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An Overview of Ethereum & Its Comparison with Bitcoin

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Abstract— *Satoshi Nakamoto's development of Bitcoin in 2009 has often been hailed as a radical development in money and currency, being the first example of a digital asset which simultaneously has no backing or "intrinsic value" and no centralized issuer or controller. However, another - arguably more important - part of the Bitcoin experiment is the underlying blockchain technology as a tool of distributed consensus, and attention is rapidly starting to shift to this other aspect of Bitcoin. Commonly cited alternative applications of blockchain technology include using on-blockchain digital assets to represent custom currencies and financial instruments ("colored coins"), the ownership of an underlying physical device ("smart property"), non-fungible assets such as domain names ("Namecoin"), as well as more complex applications involving having digital assets being directly controlled by a piece of code implementing arbitrary rules ("smart contracts") or even blockchain-based "decentralized autonomous organizations" (DAOs). What Ethereum intends to provide is a blockchain with a built-in fully fledged Turing-complete programming language that can be used to create "contracts" that can be used to encode arbitrary state transition functions, allowing users to create any of the systems described above, as well as many others that we have not yet imagined, simply by writing up the logic in a few lines of code.*

Index Terms— *Blockchain; Bitcoin vs Ether; Decentralized File Storage; Decentralized Autonomous Organizations; Ethereum; Ethereum State Transition Function; Token Systems; Financial derivatives and Stable-Value Currencies; Identity and Reputation Systems.*

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1 What is Ethereum

Ethereum is a peer-to-peer network of virtual machines that any developer can use to run distributed applications (Dapps). These computer programs could be anything, but the network is optimized to carry out rules that mechanically execute when certain conditions are met, like a contract. Ethereum uses its own decentralized public blockchain to cryptographically store, execute, and protect these contracts. Each computer on their network downloads a small virtual machine to sync with the Ethereum blockchain and remains available to execute contracts. This distributed network of computers conveniently provides the security, reliability, and computing power necessary for carrying out designed arrangements. Of course, this consensus network isn't free or private, so developers only use it for consensus on outcomes and when their data can be public. The Ethereum blockchain is publicly searchable.

The intent of Ethereum is to create an alternative protocol for building decentralized applications, providing a different set of tradeoffs that we believe will be very useful for a large class of decentralized applications, with particular emphasis on situations where rapid development time, security for small and rarely used applications, and the ability of different applications to very efficiently interact, are important. Ethereum does this by building what is essentially the ultimate abstract foundational layer: a blockchain with a built-in Turing-complete programming language, allowing anyone to write smart contracts and decentralized applications where they can create their own arbitrary rules for ownership, transaction formats and state transition functions. A bare-bones version of Namecoin can be written in two lines of code, and other protocols like currencies and reputation systems can be built in under twenty. Smart contracts, cryptographic "boxes" that contain value and only unlock it if certain conditions are met, can also be built on top of the platform, with vastly more power than that offered by Bitcoin scripting because of the added powers of Turing-completeness, value-awareness, blockchain-awareness and state.

Ethereum Accounts: In Ethereum, the state is made up of objects called "accounts", with each account having a 20-byte address and state transitions being direct transfers of value and information between accounts. An Ethereum account contains four fields:

- The **nonce**, a counter used to make sure each transaction can only be processed once
- The account's current **ether balance**
- The account's **contract code**, if present
- The account's **storage** (empty by default)

"Ether" is the main internal crypto-fuel of Ethereum, and is used to pay transaction fees. In general, there are two types of accounts: **externally owned accounts**, controlled by private keys, and **contract accounts**, controlled by their contract code. An externally owned account has no code, and one can send messages from an externally owned account by creating and signing a transaction; in a contract account, every time the contract account receives a message its code activates, allowing it to read and write to internal storage and send other messages or create contracts in turn.

Note that "contracts" in Ethereum should not be seen as something that should be "fulfilled" or "complied with"; rather, they are more like "autonomous agents" that live inside of the Ethereum execution environment, always executing a specific piece of code when "poked" by a message or transaction, and having direct control over their own ether balance and their own key/value store to keep track of persistent variables.

Transaction: The term "transaction" is used in Ethereum to refer to the signed data package that stores a message to be sent from an externally owned account. Transactions contain:

- The recipient of the message
- A signature identifying the sender
- The amount of ether to transfer from the sender to the recipient
- An optional data field
- A STARTGAS value, representing the maximum number of computational steps the transaction execution is allowed to take
- A GASPRICE value, representing the fee the sender pays per computational step

The first three are standard fields expected in any cryptocurrency. The data field has no function by default, but the virtual machine has an opcode using which a contract can access the data; as an example use case, if a contract is functioning as an on-blockchain domain registration service, then it may wish to interpret the data being passed to it as containing two "fields", the first field being a domain to register and the second field being the IP address to register it to. The contract would read these values from the message data and appropriately place them in storage.

The STARTGAS and GASPRICE fields are crucial for Ethereum's anti-denial of service model. In order to prevent accidental or hostile infinite loops or other computational wastage in code, each transaction is required to set a limit to how many computational steps of code execution it can use. The fundamental unit of computation is "gas"; usually, a computational step costs 1 gas, but some operations cost higher amounts of gas because they are more computationally expensive, or increase the amount of data that must be stored as part of the state. There is also a fee of 5 gas for every byte in the transaction data. The intent of the fee system is to require an attacker to pay proportionately for every resource that they consume, including computation, bandwidth and storage; hence, any transaction that leads to the network consuming a greater amount of any of these resources must have a gas fee roughly proportional to the increment.

Messages: Contracts have the ability to send "messages" to other contracts. Messages are virtual objects that are never serialized and exist only in the Ethereum execution environment. A message contains:

- The sender of the message (implicit)
- The recipient of the message
- The amount of ether to transfer alongside the message
- An optional data field
- A STARTGAS value

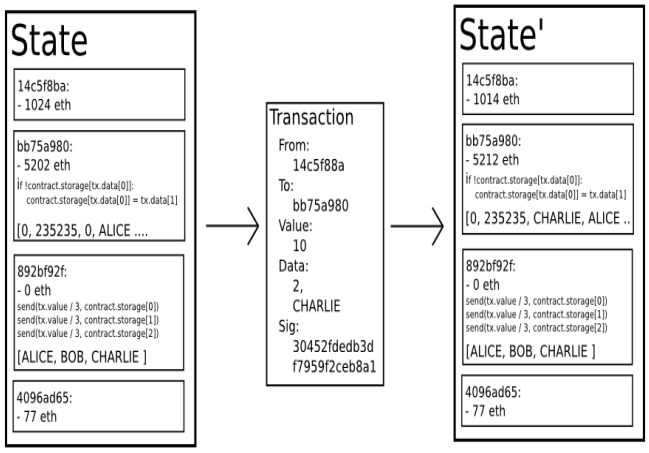
Essentially, a message is like a transaction, except it is produced by a contract and not an external actor. A message is produced when a contract currently executing code executes the CALLopcode, which produces and executes a message. Like a transaction, a message leads to the recipient account running its code. Thus, contracts can have relationships with other contracts in exactly the same way that external actors can.

Note that the gas allowance assigned by a transaction or contract applies to the total gas consumed by that transaction and all sub-executions. For example, if an external actor A sends a transaction to B with 1000 gas, and B consumes 600 gas before sending a message to C, and the internal execution of C consumes 300 gas before returning, then B can spend another 100 gas before running out of gas.

2 How Ethereum Works

The ***Ethereum State Transition Function***, APPLY(S,TX) -> S' can be defined as follows:

1. Check if the transaction is well-formed (i.e. has the right number of values), the signature is valid, and the nonce matches the nonce in the sender's account. If not, return an error.
2. Calculate the transaction fee as STARTGAS * GASPRICE, and determine the sending address from the signature. Subtract the fee from the sender's account balance and increment the sender's nonce. If there is not enough balance to spend, return an error.
3. Initialize GAS = STARTGAS, and take off a certain quantity of gas per byte to pay for the bytes in the transaction.
4. Transfer the transaction value from the sender's account to the receiving account. If the receiving account does not yet exist, create it. If the receiving account is a contract, run the contract's code either to completion or until the execution runs out of gas.
5. If the value transfer failed because the sender did not have enough money, or the code execution ran out of gas, revert all state changes except the payment of the fees, and add the fees to the miner's account.
6. Otherwise, refund the fees for all remaining gas to the sender, and send the fees paid for gas consumed to the miner.



If there was no contract at the receiving end of the transaction, then the total transaction fee would simply be equal to the provided GASPRICE multiplied by the length of the transaction in bytes, and the data sent alongside the transaction would be irrelevant.

Note that messages work equivalently to transactions in terms of reverts: if a message execution runs out of gas, then that message's execution, and all other executions triggered by that execution, revert, but parent executions do not need to revert. This means that it is "safe" for a contract to call another contract, as if A calls B with G gas then A's execution is guaranteed to lose at most G gas. Finally, note that there is an opcode, CREATE, that creates a contract; its execution mechanics are generally similar to CALL, with the exception that the output of the execution determines the code of a newly created contract.

Code Execution: The code in Ethereum contracts is written in a low-level, stack-based bytecode language, referred to as "Ethereum virtual machine code" or "EVM code". The code consists of a series of bytes, where each byte represents an operation. In general, code execution is an infinite loop that consists of repeatedly carrying out the operation at the current program counter (which begins at zero) and then incrementing the program counter by one, until the end of the code is reached or an error or STOP or RETURN instruction is detected. The operations have access to three types of space in which to store data:

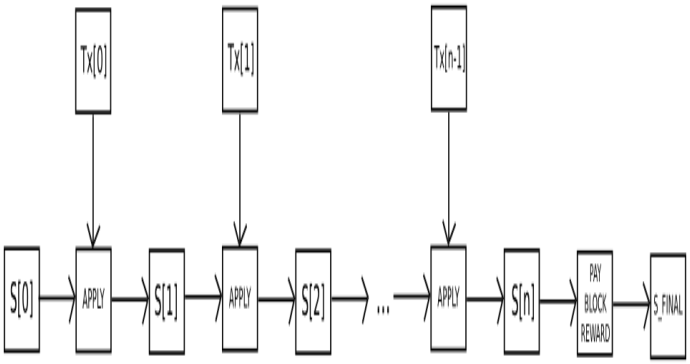
- The **stack**, a last-in-first-out container to which values can be pushed and popped
- **Memory**, an infinitely expandable byte array
- The contract's long-term **storage**, a key/value store. Unlike stack and memory, which reset after computation ends, storage persists for the long term.

The code can also access the value, sender and data of the incoming message, as well as block header data, and the code can also return a byte array of data as an output.

The formal execution model of EVM code is surprisingly simple. While the Ethereum virtual machine is running, its full computational state can be defined by the tuple (block_state, transaction, message, code, memory, stack, pc, gas), where block_state is the

global state containing all accounts and includes balances and storage. At the start of every round of execution, the current instruction is found by taking the pcth byte of code (or 0 if pc >= len(code)), and each instruction has its own definition in terms of how it affects the tuple. For example, ADD pops two items off the stack and pushes their sum, reduces gas by 1 and increments pc by 1, and SSTORE pops the top two items off the stack and inserts the second item into the contract's storage at the index specified by the first item. Although there are many ways to optimize Ethereum virtual machine execution via just-in-time compilation, a basic implementation of Ethereum can be done in a few hundred lines of code.

Blockchain & Mining:



The Ethereum blockchain is in many ways similar to the Bitcoin blockchain, although it does have some differences. The main difference between Ethereum and Bitcoin with regard to the blockchain architecture is that, unlike Bitcoin, Ethereum blocks contain a copy of both the transaction list and the most recent state. Aside from that, two other values, the block number and the difficulty, are also stored in the block. The basic block validation algorithm in Ethereum is as follows:

1. Check if the previous block referenced exists and is valid.
2. Check that the timestamp of the block is greater than that of the referenced previous block and less than 15 minutes into the future
3. Check that the block number, difficulty, transaction root, uncle root and gas limit (various low-level Ethereum-specific concepts) are valid.
4. Check that the proof of work on the block is valid.
5. Let S[0] be the state at the end of the previous block.
6. Let TX be the block's transaction list, with n transactions. For all i in 0...n-1, set S[i+1] = APPLY(S[i],TX[i]). If any applications returns an error, or if the total gas consumed in the block up until this point exceeds the GASLIMIT, return an error.
7. Let S_FINAL be S[n], but adding the block reward paid to the miner.
8. Check if the Merkle tree root of the state S_FINAL is equal to the final state root provided in the block header. If it is, the block is valid; otherwise, it is not valid.

The approach may seem highly inefficient at first glance, because it needs to store the entire state with each block, but in reality efficiency should be comparable to that of Bitcoin. The reason is that the state is stored in the tree structure, and after every block only a small part of the tree needs to be changed. Thus, in general, between two adjacent blocks the vast majority of the tree should be the same, and therefore the data can be stored once and referenced twice using pointers (ie. hashes of subtrees). A special kind of tree known as a "Patricia tree" is used to accomplish this, including a modification to the Merkle tree concept that allows for nodes to be inserted and deleted, and not just changed, efficiently. Additionally, because all of the state information is part of the last block, there is no need to store the entire blockchain history - a strategy which, if it could be applied to Bitcoin, can be calculated to provide 5-20x savings in space.

3 APPLICATIONS OF ETHEREUM

In general, there are three types of applications on top of Ethereum. The first category is financial applications, providing users with more powerful ways of managing and entering into contracts using their money. This includes sub-currencies, financial derivatives, hedging contracts, savings wallets, wills, and ultimately even some classes of full-scale employment contracts. The second category is semi-financial applica-

tions, where money is involved but there is also a heavy non-monetary side to what is being done; a perfect example is self-enforcing bounties for solutions to computational problems. Finally, there are applications such as online voting and decentralized governance that are not financial at all.

- **Token Systems**: On-blockchain token systems have many applications ranging from subcurrencies representing assets such as USD or gold to company stocks, individual tokens representing smart property, secure unforgeable coupons, and even token systems with no ties to conventional value at all, used as point systems for incentivization. Token systems are surprisingly easy to implement in Ethereum. The key point to understand is that all a currency, or token system, fundamentally is a database with one operation: subtract X units from A and give X units to B, with the proviso that (1) A had at least X units before the transaction and (2) the transaction is approved by A. All that it takes to implement a token system is to implement this logic into a contract.
- **Financial derivatives and Stable-Value Currencies**: Financial derivatives are the most common application of a "smart contract", and one of the simplest to implement in code. The main challenge in implementing financial contracts is that the majority of them require reference to an external price ticker; for example, a very desirable application is a smart contract that hedges against the volatility of ether (or another cryptocurrency) with respect to the US dollar, but doing this requires the contract to know what the value of ETH/USD is. The simplest way to do this is through a "data feed" contract maintained by a specific party (eg. NASDAQ) designed so that that party has the ability to update the contract as needed, and providing an interface that allows other contracts to send a message to that contract and get back a response that provides the price.
- **Identity and Reputation Systems:** The earliest alternative cryptocurrency of all, Namecoin, attempted to use a Bitcoin-like blockchain to provide a name registration system, where users can register their names in a public database alongside other data. The major cited use case is for a DNS system, mapping domain names like "bitcoin.org" (or, in Namecoin's case, "bitcoin.bit") to an IP address. Other use cases include email authentication and potentially more advanced reputation systems. The contract is very simple; all it is is a database inside the Ethereum network that can be added to, but not modified or removed from. Anyone can register a name with some value, and that registration then sticks forever. A more sophisticated name registration contract will also have a "function clause" allowing other contracts to query it, as well as a mechanism for the "owner" (i.e. the first registerer) of a name to change the data or transfer ownership. One can even add reputation and web-of-trust functionality on top.
- **Decentralized File Storage:** Ethereum contracts can allow for the development of a decentralized file storage ecosystem, where individual users can earn small quantities of money by renting out their own hard drives and unused space can be used to further drive down the costs of file storage. The key underpinning piece of such a device would be what we have termed the "decentralized Dropbox contract". This contract works as follows. First, one splits the desired data up into blocks, encrypting each block for privacy, and builds a Merkle tree out of it. One then makes a contract with the rule that, every N blocks, the contract would pick a random index in the Merkle tree (using the previous block hash, accessible from contract code, as a source of randomness), and give X ether to the first entity to supply a transaction with a simplified payment verification-like proof of ownership of the block at that particular index in the tree. When a user wants to re-download their file, they can use a micropayment channel protocol (eg. pay 1 szabo per 32 kilobytes) to recover the file; the most fee-efficient approach is for the payer not to publish the transaction until the end, instead

replacing the transaction with a slightly more lucrative one with the same nonce after every 32 kilobytes.

- **Decentralized Autonomous Organizations:** The general concept of a "decentralized autonomous organization" is that of a virtual entity that has a certain set of members or shareholders which, perhaps with a 67% majority, have the right to spend the entity's funds and modify its code. The members would collectively decide on how the organization should allocate its funds. Methods for allocating a DAO's funds could range from bounties, salaries to even more exotic mechanisms such as an internal currency to reward work. This essentially replicates the legal trappings of a traditional company or nonprofit but using only cryptographic blockchain technology for enforcement. So far much of the talk around DAOs has been around the "capitalist" model of a "decentralized autonomous corporation" (DAC) with dividend-receiving shareholders and tradable shares; an alternative, perhaps described as a "decentralized autonomous community", would have all members have an equal share in the decision making and require 67% of existing members to agree to add or remove a member. The requirement that one person can only have one membership would then need to be enforced collectively by the group**.** The simplest design is simply a piece of self-modifying code that changes if two thirds of members agree on a change. Although code is theoretically immutable, one can easily get around this and have de-facto mutability by having chunks of the code in separate contracts, and having the address of which contracts to call stored in the modifiable storage.

- **Others:** Savings wallets, Crop insurance**,** a decentralized data feed, Smart multisignature escrow**,** Cloud computing, Peer-to-peer gambling, Prediction markets, & On-chain decentralized marketplaces**.**

4 ETHER VS BITCOIN

Parameter	***Ether***	***Bitcoin***
What is it?	A token	A currency
Supply Style	Inflationary (much like fiat currency, where more tokens can be made over time)	Deflationary (a finite # of bitcoin will be made)
Utility	Used for making dApps (decentralized apps) on the Ethereum blockchain.	Used for purchasing goods and services, as well as storing value (much like how we currently use gold).
Price	Around $800 at the moment	Around $17,500 at the moment
New token issuance time	Every 10 to 20 seconds	Every 10 minutes approximately
Purpose	A token capable of facilitating Smart Contracts (For example: a lawyer's contract, an exchange of ownership of property, and voting)	A new currency created to compete against the gold standard and fiat currencies
Supply Cap	18 million every year	21 million in total
Smallest Unit	1 Wei = 0.000000000000000001 ETH	1 Satoshi = 0.00000001 BTC
Debut	July 2015	January 2009
Amount of new token at issuance	5 per every new block	12.5 at the moment. Half at every 210,000 blocks
Inventor	Vitalik Buterin; Other co-founders include Gavin Wood and Joseph Lubin	Satoshi Nakamoto

5 CONCLUSION

The Ethereum protocol was originally conceived as an upgraded version of a cryptocurrency, providing advanced features such as on-blockchain escrow, withdrawal limits, financial contracts, gambling markets and the like via a highly generalized programming language. The Ethereum protocol would not "support" any of the applications directly, but the existence of a Turing-complete programming language means that arbitrary contracts can theoretically be created for any transaction type or application. What is

more interesting about Ethereum, however, is that the Ethereum protocol moves far beyond just currency. Protocols around decentralized file storage, decentralized computation and decentralized prediction markets, among dozens of other such concepts, have the potential to substantially increase the efficiency of the computational industry, and provide a massive boost to other peer-to-peer protocols by adding for the first time an economic layer. Finally, there is also a substantial array of applications that have nothing to do with money at all.

The concept of an arbitrary state transition function as implemented by the Ethereum protocol provides for a platform with unique potential; rather than being a closed-ended, single-purpose protocol intended for a specific array of applications in data storage, gambling or finance, Ethereum is open-ended by design, and we believe that it is extremely well-suited to serving as a foundational layer for a very large number of both financial and non-financial protocols in the years to come.

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REFERENCES

[1] V. P. D. K. Sanjana Panicker, "An Overview of Blockchain Architecture and it's Applications," *International Journal of Innovative Research in S cience, Engineering and Technology , Vol. 5, Issue 11,* pp. 1111-1125, November 2016.

[2] A. L. Anastasia Mavridou, "Designing Secure Ethereum Smart Contracts: A Finite State Machine Based Approach," in *22nd International Conference on Financial Cryptography and Data Security (FC 2018)*, February 2017.

[3] S. Jani, "Scope for Bitcoins in India," December 2017. [Online]. Available: www.researchgate.net/publication/321780780_Scope_for_Bitcoins_in_India.

[4] S. B. I. E. E. Adem Efe Gencer, "Decentralization in Bitcoin and Ethereum Networks," in *nitiative for Cryptocurrencies and Contracts (IC3)*, January 2018.

[5] M. B. M. B. M. S. Sidney Amani, "Towards verifying ethereum smart contract bytecode in Isabelle/HOL," in *Conference: the 7th ACM SIGPLAN International Conference*, January 2018.

[6] E. Sixt, Bitcoins und andere dezentrale Transaktionssysteme, 2017.

[7] S. Madani, "Cryptocurrency: Is Ether the new Bitcoin?," Zonebourse, June 2017.

[8] A. Hertig, "How Ethereum Works," Coindesk, February 2018. [Online].
[9]Available: https://www.coindesk.com/information/how-ethereum-works/.

[10] C. Jagers, "What is Ethereum?," Investopedia, July 2017. [Online]. Available: https://www.investopedia.com/articles/investing/022516/what-ethereum.asp.