Electroneum's Blockchain and Cryptonote Algorithm Technology

NOTE:

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This document is the Electroneum technical white paper. If you are looking for the Business Overview & White Paper which includes details of the history, team, market and business model of Electroneum, please download it from http://electroneum.com/overview-white-paper.pdf

The following document defines the fine, core details of the public key and blockchain technology that electroneum is based on.

CryptoNote Algorithm

The CryptoNote algorithm is released under an open source license and has been adopted and incorporated into electroneum as it forms the basis for a solid, well tested cryptocurrency core. It is the same core blockchain technology that is used by both Monero (a top 10 cryptocurrency) and Bytecoin (a top 15 cryptocurrency).

Untraceable payments

The ordinary digital signature (e.g. (EC)DSA, Schnorr, etc...) verification process involves the public key of the signer. It is a necessary condition, because the signature actually proves that the author possesses the corresponding secret key. But it is not always a sufficient condition.

Ordinary signature

Ring signature is a more sophisticated scheme, which in fact may demand several different public keys for verification. In the case of ring signature, we have a group of individuals, each with their own secret and public key. The statement proved by ring signatures is that the signer of a given message is a member of the group. The main distinction with the ordinary digital signature schemes is that the signer needs a single secret key, but a verifier cannot establish the exact identity of the signer. Therefore, if you encounter a ring signature with the public keys of Alice, Bob and Carol, you can only claim that one of these individuals was the signer but you will not be able to pinpoint him or her.

Ring signature

This concept can be used to make digital transactions sent to the network untraceable by using the public keys of other members in the ring signature one will apply to the transaction. This approach proves that the creator of the transaction is eligible to spend the amount specified in the transaction but his identity will be indistinguishable from the users whose public keys he used in his ring signatures.

Untraceable transactions

It should be noted that foreign transactions do not restrict you from spending your own money. Your public key may appear in dozens of others' ring signatures but only as a muddling factor (even if you already used the corresponding secret key for signing your own transaction). Moreover, if two users create ring signatures with the same set of public keys, the signatures will be different (unless they use the same private key).

Unlinkable transactions

Normally, when you post your public address, anyone can check all your incoming transactions even if they are hidden behind a ring signature. To avoid linking you can create hundreds of keys and send them to your payers privately, but that deprives you of the convenience of having a single public address.

Linkable transactions

Electroneum's CryptoNote solves this dilemma by an automatic creation of multiple unique one-time keys, derived from the single public key, for each p2p payment. The solution lies in a clever modification of the Diffie-Hellman exchange protocol. Originally it allows two parties to produce a common secret key derived from their public keys. In our version the sender uses the receiver's public address and his own random data to compute a one-time key for the payment.

The sender can produce only the public part of the key, whereas only the receiver can compute the private part; hence the receiver is the only one who can release the funds after the transaction is committed. He only needs to perform a single-formula check on each transactions to establish if it belongs to him. This process involves his private key, therefore no third party can perform this check and discover the link between the one-time key generated by the sender and the receiver's unique public address.

Unlinkable transactions

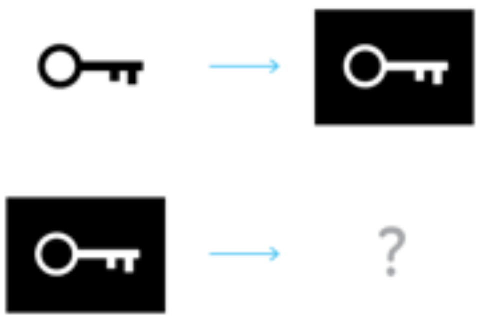
An important part of our protocol is usage of random data by the sender. It always results in a different one-time key even if the sender and the receiver both remain the same for all transactions (that is why the key is called "one-time"). Moreover, even if they are both the same person, all the one-time keys will also be absolutely unique.

Double-spending proof

Fully anonymous signatures would allow spending the same funds many times which, of course, is incompatible with any payment system's principles. The problem can be fixed as follows.

A ring signature is actually a class of crypto-algorithms with different features. The one electroneum's CryptoNote uses is the modified version of the "Traceable ring signature". In fact we transformed traceability into linkability. This property restricts a signer's anonymity as follows: if he creates more than one ring signature using the same private key (the set of foreign public keys is irrelevant), these signatures will be linked together which indicates a double-spending attempt.

To support linkability, electroneum's CryptoNote introduced a special marker being created by a user while signing, which we called a key image. It is the value of a cryptographic one-way function of the secret key, so in math terms it is actually an image of this key. One-wayness means that given only the key image it is impossible to recover the private key. On the other hand, it is computationally impossible to find a collision (two different private keys, which have the same image). Using any formula, except for the specified one, will result in an unverifiable signature. All things considered, the key image is unavoidable, unambiguous and yet an anonymous marker of the private key.



Key image via one-way function

All users keep the list of the used key images (compared with the history of all valid transactions it requires an insignificant amount of storage) and immediately reject any new ring signature with a duplicate key image. It will not identify the misbehaving user, but it does prevent any double-spending attempts, caused by malicious intentions or software errors.

Double-spending check

Blockchain analysis resistance

There are many academic papers dedicated to the analysis of the Bitcoin's blockchain. Their authors trace the money flow, identify the owners of coins, determine wallet balances and so on. The ability to make such analysis is due to the fact that all the transfers between addresses are transparent: every input in a transaction refers to a unique output. Moreover, users often re-use their old addresses, receiving and sending coins from them many times, which simplifies the analyst's work. It happens unintentionally: if you have a public address (for example, for donations), you are sure to use this address in many inputs and transactions.

Electroneum's CryptoNote is designed to mitigate the risks associated with key re-usage and one-input-to-one-output tracing. Every address for a payment is a unique one-time key, derived from both the sender's and the recipient's data. It can appear twice with a probability of a 256-bit hash collision. As soon as you use a ring signature in your input, it entails the uncertainty: which output has just been spent?

Trying to draw a graph with addresses in the vertices and transactions on the edges, one will get a tree: a graph without any cycles (because no key/address was used twice). Moreover, there are billions of possible graphs, since every ring signature produces ambiguity. Thus, you can't be certain from which possible sender the transaction-edge comes to the address-vertice. Depending on the size of the ring you will guess from "one out of two" to "one out of a thousand". Every next transaction increases the entropy and creates additional obstacles for an analyst.

Blockchain analysis ambiguity

Standard CryptoNote transaction

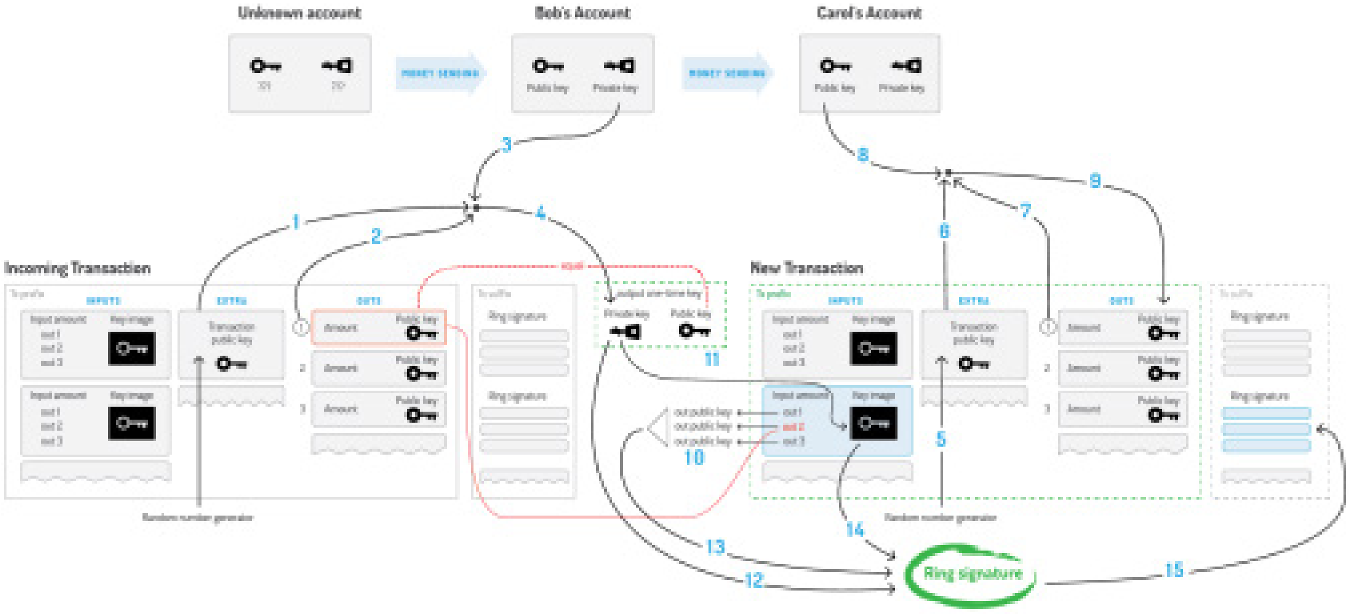
A standard electroneum CryptoNote transaction is generated by the following sequence covered in the white paper.

Bob decides to spend an output, which was sent to the one-time public key. He needs Extra (1), TxOutNumber (2), and his Account private key (3) to recover his one-time private key (4).

When sending a transaction to Carol, Bob generates its Extra value by random (5). He uses Extra (6), TxOutNumber (7) and Carol's Account public key (8) to get her Output public key (9).

In the input Bob hides the link to his output among the foreign keys (10). To prevent double-spending he also packs the Key image, derived from his One-time private key (11).

Finally, Bob signs the transaction, using his One-time private key (12), all the public keys (13) and Key Image (14). He appends the resulting Ring Signature to the end of the transaction (15).



A standard electroneum CryptoNote transaction

Adaptive limits

A decentralized payment system must not depend on a single person's decisions, even if this person is a core developer. Hard constants and magic numbers in the code deter the system's evolution and therefore should be eliminated (or at least be cut down to the minimum). Every crucial limit (like max block size or min fee amount) should be re-calculated based on the system's previous state. Therefore, it always changes adaptively and independently, allowing the network to develop on it's own.

Electroneum's CryptoNote has the following parameters which adjust automatically for each new block:

1. Difficulty. The general idea of our algorithm is to sum all the work that nodes have performed during the last 720 blocks and divide it by the time they have spent to accomplish it. The measure of the work is the corresponding difficulty value for each of the blocks. The time is calculated as follows: sort all the 720 timestamps and cut-off 20% of the outliers. The range of the rest 600 values is the time which was spent for 80% of the corresponding blocks.
2. Max block size. Let MN be the median value of the last N blocks sizes. Then the "hard-limit" for the size of accepting blocks is 2*MN. It averts blockchain bloating but still allows the limit to slowly grow with the time if necessary. Transaction size does not need to be limited explicitly. It is bounded by the size of the block.

Smooth emission

The upper bound for the overall amount of all digital coins is also digital:

MSupply = 264 − 1 atomic units

This is a natural restriction based only on the implementation limits, not on intuition like "N coins ought to be enough for everybody". To make the emission process smoother electroneum's CryptoNote uses the following formula for block rewards:

BaseReward = (MSupply − A) >> 18

Where A is amount of previously generated coins. It gives a predictable growth of the money supply without any breakpoints.

Mobile Mining Experience

The mobile mining experience is the only part of Electroneum that is a centralized system and not a decentralized one.

We've taken the view that whilst the Electroneum blockchain is a decentralized system, it is only fully decentralized in all other aspects outside the mobile app and mobile mining experience. We've taken the view that the positive benefits to be gained from a centralized app and mobile mining algorithm outweigh any negative aspects.

Experiments in using the same algorithm that the blockchain uses for standard mining on a mobile device have been carried out by various cryptocurrencies in the past and they generally drain the battery, result in poor performance and often cause issues with the quantity of data used in downloading the blockchain. They have also been know to make devices run uncomfortably hot.

As such the algorithm for the Electroneum mobile mining experience reflects the Electroneum emission algorithm +Y / app miners / X, where Y is any additional coins left over from the token sale and X is the time period of emission which is a restriction based upon a minimum coin release for mobile mining experience and a maximum mobile mining coin release and control is also subject to the market value of Electroneum (if any). The minimum mining rate will always be a reflection of the Electroneum smooth emission algorithm and the maximum mobile mining rate is a series of failsafes and security checks to prevent whale mining and virtual app environment mining and ensure individuals taking part in the mobile mining experience are treated fairly.

The mobile mining experience does not download a copy of the blockchain or carry out intensive CPU operations to provide egalitarian proof of work, it is intended to give entry level access to a cryptocurrency by allowing the experience of mining (i.e. being issued a hash rate reflective of the CPU processing power of the device and being awarded coins for participating in the experience). The Mobile mining experience does not directly add blocks to the blockchain and thus it does not overheat the mobile device or use precious bandwidth. The CPU of the device is periodically queried to ensure the simulated hashrate is correctly balanced with the other running processes and it gives the user a very realistic mining experience, including accurately issuing Electroneum coin rewards.

The issued Electroneum coins are true Electroneum coins, the same as issued by the Windows, Mac and Linux full miner. The Windows, Mac and Linux full miner does download the full blockchain and operate in a fully decentralized manner.

The mobile mining experience has been designed to yield rapid user growth. These users will be encouraged and likely to take advantage of the significant mining speed and coin emission improvements of mining with the Windows, Mac or Linux GUI miner, which will enable Electroneum to grow to huge user numbers via the app, whilst still retaining a significant mining community running the transactional blockchain by running the intuitive Windows, Mac or Linux application.

The centralized nature of the mobile app will also allow Electroneum to perform transfers of Electroneum via the contact list in the device, rather than using lengthy public keys which are currently required by all decentralized blockchains. Those public keys still exist and can be used but a simpler, more intuitive way of using cryptocurrency is envisaged.

Egalitarian proof of work

The proof of work mechanism is actually a voting system. Users vote for the right order of the transactions, for enabling new features in the protocol and for the honest money supply distribution. Therefore, it is important that during the voting process all participant have equal voting rights. Electroneum's CryptoNote brings the equality with an egalitarian proof-of-work pricing function, which is perfectly suitable for ordinary PCs. It utilizes built-in CPU instructions, which are very hard and too expensive to implement in special purpose devices or fast memory-on-chip devices with low latency.

We propose a new memory-bound algorithm for the proof-of-work pricing function. It relies on random access to a slow memory and emphasizes latency dependence. As opposed to scrypt, every new block (64 bytes in length) depends on all the previous blocks. As a result a hypothetical "memory-saver" should increase his calculation speed exponentially.

Our algorithm requires about 2 Mb per instance for the following reasons:

1. It fits in the L3 cache (per core) of modern processors, which should become mainstream in a few years;
2. A megabyte of internal memory is an almost unacceptable size for a modern ASIC pipeline;
3. GPUs may run hundreds of concurrent instances, but they are limited in other ways: GDDR5 memory is slower than the CPU L3 cache and remarkable for its bandwidth, not random access speed.
4. Significant expansion of the scratchpad would require an increase in iterations, which in turn implies an overall time increase. “Heavy” calls in a trust-less p2p network may lead to serious vulnerabilities, because nodes are obliged to check every new block’s proof-of-work. If a node spends a considerable amount of time on each hash evaluation, it can be easily DDoSed by a flood of fake objects with arbitrary work data (nonce values).

One of the proof-of-work algorithms that is in line with our propositions is CryptoNight. It is designed to make CPU and GPU mining roughly equally efficient and restrict ASIC mining.

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