

On The Longest Chain Rule and Programmed Self-Destruction of Crypto Currencies

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Abstract. In this paper we revisit some major orthodoxies which lie at the heart of the bitcoin crypto currency and its numerous clones. In particular we look at *The Longest Chain Rule*, the monetary supply policies and the exact mechanisms which implement them. We claim that these built-in properties are not as brilliant as they are sometimes claimed. A closer examination reveals that they are closer to being... engineering mistakes which other crypto currencies have copied rather blindly. More precisely we show that the capacity of current crypto currencies to resist double spending attacks is poor and most current crypto currencies are highly vulnerable. Satoshi did not implement a timestamp for bitcoin transactions and the bitcoin software does not attempt to monitor double spending events. As a result major attacks involving hundreds of millions of dollars can occur and would not even be recorded, cf. [10]. Hundreds of millions dollars have been invested to pay for ASIC hashing infrastructure yet insufficient attention was paid to insure that the protection layer it promises is effective and cannot be abused.

In this paper we develop a theory of *Programmed Self-Destruction* of crypto currencies. We observe that most crypto currencies have mandated abrupt and sudden transitions. These affect their hash rate and therefore their protection against double spending attacks which we do not limit the to the notion of 51 % attacks which is highly misleading. In addition we show that smaller bitcoin competitors are substantially more vulnerable. In addition to small hash rate, many bitcoin competitors mandate incredibly important adjustments in miner reward. We exhibit examples of ‘alt-coins’ which validate our theory and for which the process of programmed decline and rapid self-destruction has clearly already started.

Keywords: electronic payment, crypto currencies, bitcoin, alt-coins, Litecoin, Dogecoin, Unobtanium, double-spending, monetary policy, mining profitability

1 Bitcoin and Bitcoin Clones

Bitcoin is a collaborative virtual currency and payment system. It has been launched in 2009 [14] based on earlier crypto currency ideas [1, 7]. Bitcoin implements a certain type of peer-to-peer financial cooperative without trusted entities such as traditional financial institutions. Initially bitcoin was a sort of social experiment, however bitcoins have been traded for real money for several years now and their price have known a spectacular growth.

Bitcoin challenges our traditional ideas about money and payment. Ever since Bitcoin was launched [14, 15] in 2009 it has been clear that it as an experimental rather than mature electronic currency ecosystem . A paper at Financial Cryptography 2012 conference explains that Bitcoin is a system which *uses no fancy cryptography, and is by no means perfect* [2]. In one sense it is still a play currency in early stages of development. The situation is even worse for bitcoin competitors. Their authors and promoters typically just copy features of bitcoin without any deeper insight into their consequences.

In this paper we are going to see that the exact same rules which might after all work relatively well (at least for some time) for a large dominating crypto currency such as bitcoin, is rather disastrous for smaller crypto currencies.

On the picture below we explain the organization of this paper.

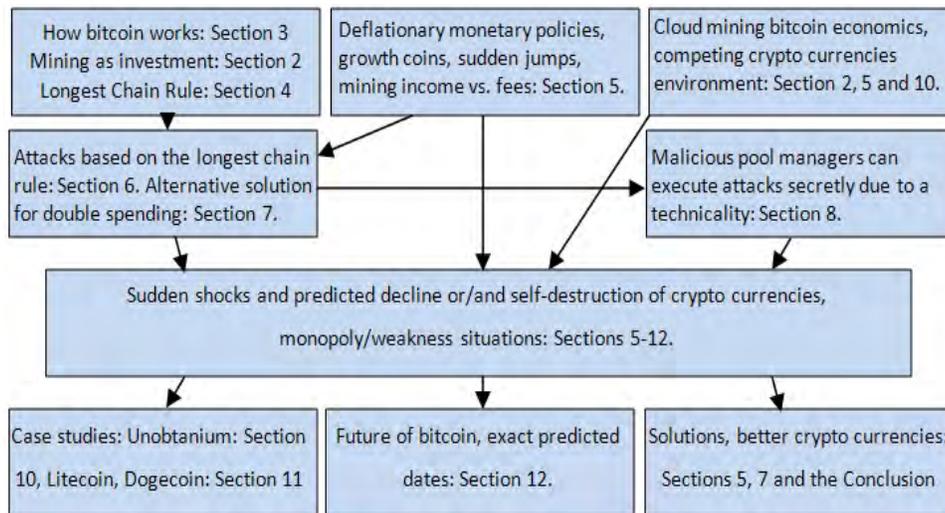


Fig. 1. Our roadmap: risks and dangers of bitcoin and other digital currencies.

2 Bitcoin As A Distributed Business: Its Key Infrastructure and Investor Economics

Bitcoin digital currency [14] is an electronic payment system based on cryptography and a self-governing open-source financial co-operative. Initially it was just a social experiment and concerned only some enthusiasts. However eventually a number of companies have started trading bitcoins for real money. One year ago, in April 2013, the leading financial magazine The Economist have recognized bitcoin as a major disruptive technology for finance and famously called bitcoin “digital gold”. We can consider that the history of bitcoin as a mainstream financial instrument starts at this moment.

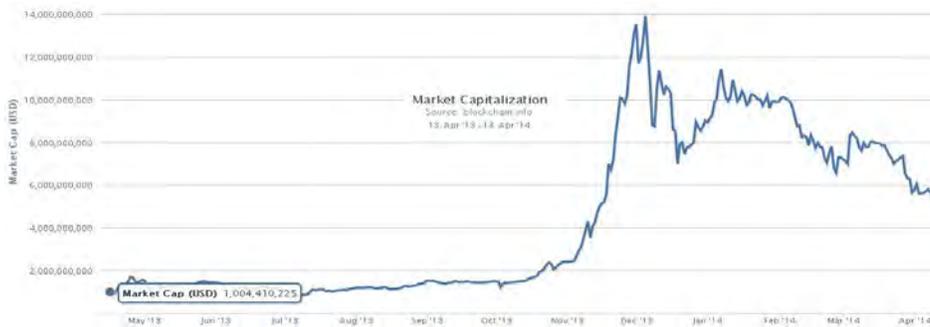


Fig. 2. The bitcoin market capitalization in the last 12 months.

Our starting point of April 2013 coincides more or less with bitcoin achieving prices of 50 USD (and above), the market capitalization exceeding 1 billion dollars, and an important shift in the nature of the ownership of the bitcoin infrastructure. In a great simplification, before April 2013, one bitcoin was rarely worth more than 5-50 dollars, and new bitcoins were produced by amateurs on their PCs. Then bitcoin rapidly switched to the phase where new bitcoins are produced by a smaller group of some 100,000 for-profit ‘bitcoin miners’ which people have invested money to purchase specialized equipment, the only purpose of which is to produce new bitcoins. A new sort of high-tech industry has emerged: the production of machines able to produce bitcoins. Such machines are called miners and are increasingly sophisticated [5].

These last 12 months of bitcoin history, April 2013-April 2014, have seen an uninterrupted explosion of **investment** in bitcoin infrastructure. Surprisingly large sums of money have been spent on purchasing new mining equipment. All this investment has been subject to excessively rapidly decreasing returns: bitcoin mining is a race against other miners in order to be able to earn a fairly limited fraction of newly created bitcoins. We examine these questions in detail.

2.1 Investment in Hashing Power and Incredible 1000x Increase

The combined power of bitcoin mining machines have been multiplied by 1000 in the last 12 months cf. Fig. 3. However due to built-in excessively conservative monetary policy cf. [5], during the last 12 months, miners have been competing for a modest fraction of bitcoins yet to be generated. The number of bitcoins in circulation has increased only by 15 %, from 11 million to 12.6 million.

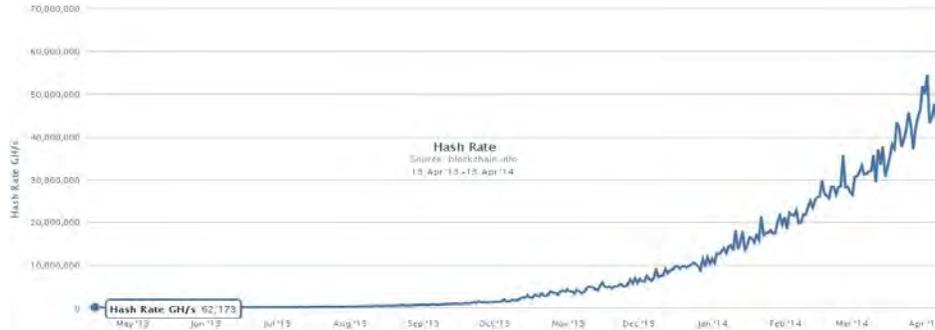


Fig. 3. The combined computing power in the collectively owned bitcoin ‘hashing infrastructure’ has nearly **doubled each month** and overall it has increased 1000 times in the last 12 months while the monetary supply has increased only by 1 % each month. The mining profitability has also been eroded accordingly. The income from any existing miner was divided by half nearly every month, cf Section 2.2.

A 1000-fold increase in hash power is a very disturbing fact. We lack precise date in order to see how much of this increase was due to improved technology (important increase in the speed of bitcoin mining machines, cf. [5]), and how much was due to a surge in investment: more customers and more orders. It is however certain that **a monumental amount of money** has been invested in these bitcoin ASIC miner machines. It is not easy to estimate it accurately. If we consider that the current hash rate is composed primarily of KNC Neptune 28 nm miners shipped in December 2013 which for the unit price of 6000 USD can deliver some 0.5 TH/s, we obtain that miners have spent in the last 4 months maybe 600 millions of dollars on some 120,000 ASIC machines which are already in operation ¹. In addition knowing that miners are typically ordered a few months in advance, it is quite plausible to assume that miners have spent already more than 1 billion dollars on ASIC miners.

As we have already explained, we don’t know exactly how this investment has evolved with time. However the near-doubling of the hash rate every month does certainly mean one thing: **excessively rapid decline in mining revenue** for every existing ASIC machine.

¹ If we consider that more recent miners with capacities between 1-3TH/s for the same price were already available to some privileged buyers many months before officially sold on the retail market, the total cost could be less than our 600M USD estimation.

2.2 Investors Facing Incredibly Fast Erosion of Profitability

This is due to the fact all miners are in competition for a fixed number of bitcoins which can be mined in one month. the rule of thumb is that exactly 25 bitcoins are produced every 10 minutes. Doubling the hash rate means dividing the income by 2 each month. It means that investors can only hope for fast short-term gains, and that their income tends to zero very quickly.

Let us develop this argument further. Imagine that a miner invests 5,000 USD and that the income from mining in the first month was 2,000 USD. Is this investment going to be profitable? Most investors will instinctively believe it will be. However in actual bitcoin it isn't. In the recent 12 months the hash power has been decreasing approximately twice each month. We need to look at the following sum:

$$1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \dots = 2$$

We see that the total income is only **twice the income for the first month**. This is not a lot. In our example the investor will earn only 4,000 USD and has spent 5,000 USD. The investor does not make money, he makes a loss.

2.3 Dividend From Hashing

It is easy to know exactly how much money was already earned by miners in freshly minted bitcoins multiplied by their present market price.

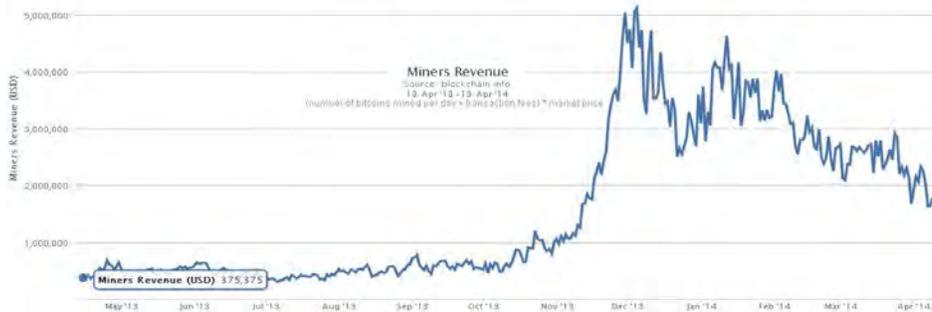


Fig. 4. The daily market price of freshly created bitcoin coins in the last 12 months.

If we estimate the area under Fig. 4 we see that currently all miners combined make some 60 millions of dollars only per month and have been paid roughly some 400 million dollars in mining dividend most of which was earned in the last 4 months. We neglect the price of the electricity. Contrary to what is suggested by some press reports [13], this price has so far remained relatively low in bitcoin mining compared to the high prices of ASIC miners, which prices needed to be amortized over surprisingly short periods of time of not more than few months as shown in Section 2.2.

2.4 Investors' Nightmare

The market for ASIC miner machines is far from being fair and transparent. There is only a handful of ASIC companies and from their web pages it seems that they might have manufactured and sold only a few thousands units each. In fact it is believed that many manufacturers of ASIC miners have omitted to tell their customers what the actual size of their production was. It is clear that the actual production of ASIC miners have been much higher, as shown by the hash rate, cf. Fig. 3. Most manufacturers worked with pre-orders. Customers were never able to know when machines are going to be delivered and how much the hash rate would increase in the meantime. Many manufacturers have had important delays in delivery, frequently 6 months, and up to 12 months. Such delays decrease the expected income from mining by an **incredibly large factor**. We give some examples which are slightly simplified for the purpose of this paper, however they are made to be as realistic as possible, and as faithful as possible, and are based on personal experiences of ourselves and our friends:

1. If for example a miner have ordered his device from ButterflyLabs and the device is delivered 12 months later. He earns roughly 1000 times less than expected (at least with historical data, cf. Fig. 3), and even if the price of bitcoin rises 10 times during this period, he still earns maybe 100 times less than expected (!).
2. Contrary to what most people think, ButterflyLabs are not the worst. Many miners ordered devices from suppliers which do NOT even exist, and were pure criminal scams, even though they advertise on the Internet and their machines are frequently compared to legitimate ASIC manufacturers on web sites such as https://en.bitcoin.it/wiki/Mining_hardware_comparison which have NOT attempted to distinguish between criminal scams and genuine manufacturers. See Appendix of [6] and <http://bitcoinscammers.com> for specific examples.
3. In another example a miner have ordered his device from BITMINE.CH and the device was delivered with 6 months delay. He earns roughly 64 times less than expected and even if the price of bitcoin rises 4 times during this period, and even if BITMINE.CH compensates customers by increasing their hash rate by 50 % or more for late delivery, he still earns maybe 10 times less than expected (!).
4. In another example a miner have ordered his device from KNC miner or Cointerra, and the device was delivered with just one month delay compared to the predicted delivery date. Then the miner earns just half of what was expected, which is already problematic but might be OK.

Overall it is possible to see that most miners were mislead when they ordered the ASIC machines. Miners were probably confused to expect that the mining profitability was going to be much bigger than what they obtained later on, at the moment when they would eventually receive their machines and start mining. Accordingly many people **lost money** in bitcoin mining business (see also Section 2.3). In addition, many of those who made some money, have seen their bitcoins disappear in large-scale thefts, cf. [10].

2.5 Bitcoin as Medium of Exchange

It appears that bitcoin is **not used a lot** as a currency or payment instrument. The number of transactions in the bitcoin network is NOT growing, cf. Fig. 5 and it can sometimes decrease.



Fig. 5. The average number of transactions per day has remained relatively stable in the last 12 months. It remains between 40,000 and 80,000 and it can decline rather than increase during certain months of activity.

It is hard to estimate how much of bitcoin economy is a result of actual transactions (cf. Fig. 6 below) which are unrelated to the transactions very closely related to bitcoin mining (cf. yellow circles on Fig. 6).

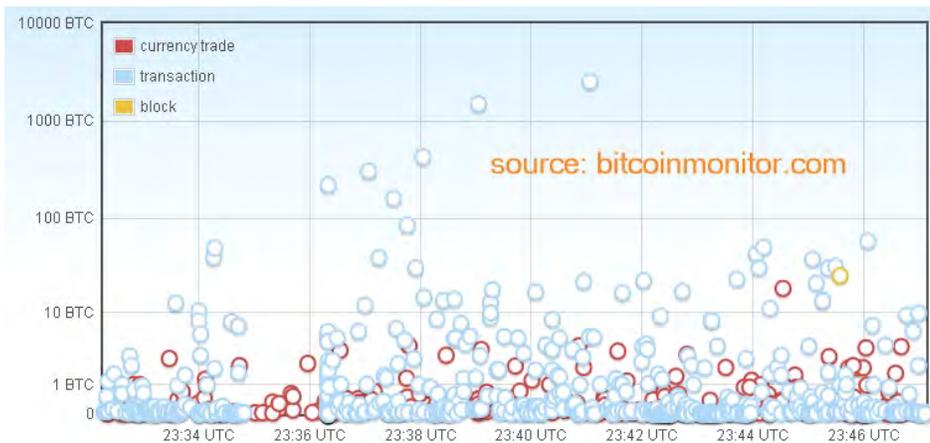


Fig. 6. Bitcoin transactions displayed in real time over a period of 15 minutes. Each circle represents a single transaction, a yellow circle is the initial 25 BTC mining event, red transactions are those which are identified as currency exchange transactions (it is probably impossible to identify all such transactions) and blue circles are all the other transactions.

On the one hand, it is easy to see that bitcoin mining events produce a stream of fresh bitcoins (cf. yellow circles on Fig. 6). However these bitcoins generate several child transactions, large and small, due to subsequent transfers, pooled mining, currency exchange and final storage operations. On the other hand various statistics about the combined output of all bitcoin transactions such as displayed by `blockchain.info` are not very meaningful because they include the amounts of money the owners of bitcoins must return to themselves in great majority of existing bitcoin transactions, and these amounts can be substantially higher than the actual amount of bitcoins spent in the actual transactions, which makes that these figures are very high and do NOT reflect at the actual bitcoin economy. Some intuitive idea about the size of the bitcoin economy can be deducted from the real-time graphs produced by <http://www.bitcoinmonitor.com/> as shown on Fig. 6.

2.6 Analysis of Bitcoin From The Point of View of Investors

We consider that until now the bitcoin business was primarily about some investors (A) spending some 1000 million dollars on mining hardware, and other investors (B) which preferred to buy or use these newly created bitcoins for 400 million dollars and holding them. This is based on the assumption that a large fraction of decisions of buying bitcoins were rather investment decisions (holding bitcoins for profit) rather than resulting from rapidly growing adoption of bitcoin in e-commerce which is not the case, cf. Fig. 5. It is not entirely clear if this assumption is reasonable to make and it requires further research.

We can now argue that the second group (B) has potentially spent MUCH more than 400 million dollars. This is due to the fact that only a small fraction of bitcoins was manufactured in the last 12 months. Investors who in the last 12 months have purchased newly created bitcoins for 400 million dollars (due to Fig. 4) have also purchased a lot more bitcoins from previous owner of bitcoins who are free riders: people who have paid/invested very little mining or purchasing some bitcoins earlier. We lack any precise data but in order to be able to pay some 400 M in to miners (A)², investors (B) must have injected into the bitcoin economy a possibly much larger sum of cash money (dollars). Let us assume that this was 2 billion dollars. This amount is hard to estimate from available data but it is probably a small multiple of 600 M and it cannot be higher than 5 billion dollars, the peak value at Fig. 2.

We can observe that the reason why so much money was made by owners of older coins was the monopoly rent: miners (A) were convinced to mine for this particular crypto currency which has influenced further investors (B) to provide additional funds also for this market. It is probably correct to assume that this is substantially more than the total amount of money invested in mining Litecoin and other crypto currencies, based on the fact that the total Market capitalization of all alternative currencies combined remains small compared to bitcoin, cf. <http://www.cryptocoincharts.info/v2/coins/info>.

² which has paid for some of their 600+ millions of dollars in hardware expenses

Both investment decisions (A,B) have been made on expectation that the bitcoin market price will rise. In fact during the last 12 months the price has been increasing (a lot) just during just one month at the end of 2013, after which we have seen a long painful correction cf. Fig. 2.

The idea that bitcoin market price in dollars will appreciate in the future is based on several premises which in our opinion are more irrational than rational:

1. Bitcoin is expected to imitate the scarcity of rare natural resources such as Gold [11] and for this purpose bitcoin has a fixed monetary supply.
2. However the scarcity of bitcoins is not natural, it is **artificial**. It is mandated by the bitcoin specification and software [14, 15]. This property is not written in stone. It is frequently criticized [5, 20] and it CAN be changed if a majority of miners agree, cf. [5].
3. Investors might be overestimating the importance of bitcoin in the economy in the future: the adoption of bitcoin as a currency or payment instrument cf. Section 2.5.
4. This expectation does not take into account the ‘alt-coins’ (competitors to bitcoin). Alt-coins clearly break the rule of fixed monetary supply of coins and can be created at will. It cannot be guaranteed that the current monopoly situation of bitcoin is going to last.

Various surveys show that about 50 % of people involved with bitcoin do very naively believe that bitcoin will be worth 10,000 USD at the end of 2014 [17].

2.7 What Does This Monumental Investment Pay For?

We have estimated that for-profit bitcoin miners (A) have invested some 1,000 M dollars in bitcoin infrastructure, while at the same time other investors (B) have invested a yet larger sum of cash money, maybe 2,000 M on buying bitcoins probably driven by a naive³ expectation that they will rise in the future.

Now the interesting question is, what these **monumental investments** pay for? Knowing that the bitcoin adoption as a medium of exchange is not expanding as suggested by Fig. 3 these investments went **mostly into building an excessive quantity of hashing power** (1000x increase). In [20] Scams writes:

”The amount of capital collectively burned hashing fixes the capital outlay required of an attacker to obtain enough hashing power to have a meaningful chance of orchestrating a successful double-spend attack on the system [...] The mitigation of this risk is valuable, [...]”

We have this expensive and powerful hashing infrastructure. We could call it (ironically) **the Great Wall of Bitcoin** which name is justified by the fact that bitcoin miners have invested roughly about 1 billion dollars to build it and it is expected to protect bitcoin against attacks. This leads to the following working hypothesis which is really about economics of information security and which we will later dispute. **Maybe** one must spend a lot of money on the bitcoin hashing infrastructure in order to achieve good security. Maybe there is a large cost associated with building a global distributed financial infrastructure totally independent from governments, large banks, the NSA, etc. Maybe one can hardly hope to spend less and security against double spending attacks has some inherent price which needs to be paid.

We claim that this sort of conclusion is **MISTAKEN** and the devil is in the details. In this paper we are going to show that the amount of money needed to commit for-profit double spending attacks remains **moderate**, it has nothing to do with the 600 M dollars spent on ASIC miners in activity. It is a fallacy to consider that money burnt in hashing could or should serve as effective protection against attacks. This is because money at risk, for example in large transactions, can be substantially larger than the cost of producing a fork in the block chain. We claim that nearly anybody can commit double spending attacks, or it will become so in the future. We claim that the current 1 billion dollar investment in bitcoin infrastructure is **neither necessary nor sufficient** to build a secure digital currency. It simply **does NOT serve as effective protection** and does not deliver the security benefits claimed. This is due to misplaced ideology such as the so called *The Longest Chain Rule*, important technicalities and lack of the most basic features in Satoshi bitcoin specification. We intend to show that it is possible to fix the double spending problem in bitcoin with cryptography and timestamping, and the cost of doing so is in general much lower than expected.

³ The bitcoin market price is rather going down ever since December 2013 cf. Fig. 2.

3 Short Description of How Bitcoin Works

We have essentially one dominant form of bitcoin software [15] and the primary “official” bitcoin protocol specification is available at [19]. However bitcoin belongs to no one and the specification is subject to change. As soon as a majority of people run a different version of it, and it is compatible with the older software, it becomes the main (dominating) version.

Bitcoin is a sort of distributed electronic notary system which works by consensus. We have a decentralized network of nodes with peer-to-peer connections. The main functionality of bitcoin is to allow transfer of money from one account to another. At the same time network participants create new coins and perform necessary checks on previous transactions which are meant to enforce “honest” behavior. Integrity of bitcoin transactions is guaranteed by cryptographic hash functions, digital signatures and a consensus about what is the official history of bitcoin. Below we provide a short, concise description of how bitcoin works.

1. We have a decentralized network of full bitcoin nodes which resembles a random graph. Network nodes can join and leave the network at any moment.
2. Initially, when bitcoins are created, they are attributed to any network node willing and able to spend sufficient computing power on solving a difficult cryptographic puzzle. We call these people “miners”.
3. It is a sort of lottery in which currently 25 bitcoins are attributed to one and unique “winner” every 10 minutes.
4. With time this quantity decreases which has been decided by the creator(s) of bitcoin in order to limit the monetary supply of bitcoins in the future.
5. The legitimate owner of these 25 bitcoins is simply identified by a certain public key (or several public keys).
6. A public ledger of all transactions is maintained and it is used to record all transfers of bitcoins from one account (one public key) to another.
7. Bitcoins are divisible and what is stored on the computers of the network participants are just the private keys.
8. The amount of bitcoins which belongs to a given key at a given moment is stored in the public ledger, a copy of which is stored at every full network node application and constantly kept up to date.
9. Miners repeatedly compute a double SHA-256 hash H_2 of a certain data structure called a block header which is a combination of events in the recent bitcoin history and which process is described in more detail in [5, 19].
10. This H_2 must be such that when written as an integer in binary it will have some 64 leading zeros which corresponds to the difficulty level in the bitcoin network at a given moment (cf. [5]).
11. The difficulty level can go up and down depending on how many people participate in mining at a given moment. It tends increase and it does rarely decrease ⁴.

⁴ In bitcoin it has increased at truly unbelievable speed, cf. Fig. 3. In other crypto currencies it is more likely to decrease in a substantial way as we will see in this paper

12. More precisely, in order to produce a winning block, the miner has to generate a block header such that its double SHA-256 hash H2 is smaller than a certain number called target.
13. This can be seen as essentially a repeated experiment where H2 is chosen at random. The chances of winning in the lottery are very small and proportional to one's computing power multiplied by 2^{-64} . This probability decreases with time as more miners join the network. The bitcoin network combined hash rate increases rapidly, see Fig. 3.
14. If several miners complete the winning computation only one of them will be a winner which is decided later by a consensus.
15. Existing portions of the currency are defined **either** as outputs of a block mining event (creation) **or** as outputs of past transactions (redistribution of bitcoins).
16. The ownership of any portion of the currency is achieved through chains of digital signatures.
17. Each existing quantity of bitcoin identifies its owner by specifying his public key or its hash.
18. Only the owner of the corresponding private key has the power to transfer this given quantity of bitcoins to other participants.
19. Coins are divisible and transactions are multi-input and multi-output.
20. Each transaction mixes several existing quantities of bitcoins and re-distributes the sum of these quantities of bitcoin to several recipients in an arbitrary way.
21. The difference between the sum of inputs and the sum of all outputs is the transaction fee.
22. Each transaction is approved by all the owners of each input quantity of bitcoins with a separate digital signature approving the transfer of these moneys to the new owners.
23. The correctness of these digital signatures is checked by miners.
24. Exactly one miner approves each transaction which is included in one block. However blocks form a chain and other miners will later approve this block. At this moment they should also check the past signatures, in order to prevent the miner of the current block from cheating. With time transactions are confirmed many times and it becomes increasingly hard to reverse them.
25. All this is effective only for blocks which are in the dominating branch of bitcoin history (a.k.a. the Main Chain). Until now great majority of events in the bitcoin history made it to become the part of this official history.
26. In theory every bitcoin transaction could later be invalidated. A common solution to this problem is to wait for a small multiple of 10 minutes and hope that nobody will spend additional effort just in order to invalidate one transaction. These questions are studied in more detail in Section 6.
27. Overall the network is expected to police itself. Miners not following the protocol risk that their blocks will be later rejected by the majority of other miners. Such miners would simply not get the reward for which they work.
28. There is no mechanism to insure that all transactions would be included by miners other than the financial incentive in the form of transaction fees.

29. There is no mechanism to store a complete history of events in the network other than the official (dominating) branch of the block chain. Memory about past transactions and other events in the network may be lost, cf. [10].

4 Asynchronous Operation And The Longest Chain Rule

According to the initial design by Satoshi Nakamoto [14] the initial bitcoin system is truly decentralized and can be to a large extent asynchronous. Messages are broadcast on the basis of *best effort*. Interestingly the system can support important network latency and imperfect diffusion of information. Information does not have to reach all nodes in the network in the real time and they could be synchronized later and can agree on a common history at any later moment.

The key underlying principle which allows to achieve this objective is **the Longest Chain Rule** of Satoshi Nakamoto [14]. It can be stated as follows:

1. Sometimes we can have what is called *a fork*: there are two equivalent solutions to the cryptographic puzzle.
2. Currently a fork happens less than 1 % of the time, see Table 1 in [6]. However it clearly could and would be more frequent in poor network conditions or due to certain attacks, cf. [12, 6].
3. Different nodes in the network have received one of the versions first and different miners are trying to extend one or the other branch. Both branches are legitimate and the winning branch will be decided later by a certain type of consensus mechanism, automatically without human intervention.
4. The **Longest Chain Rule** of [14] says that if at any later moment in history one chain becomes longer, all participants should switch to it automatically.

With this rule, it is possible to argue that due to the probabilistic nature of the mining process, sooner or later one branch will automatically win over the other. For example we expect that a fork of depth 2 happens with the frequency which is the square of previous frequency, i.e. about 0.01 % of the time. This is what was predicted and claimed by Satoshi Nakamoto [14]. This is precisely what makes bitcoin quite stable in practice. Forks are quite rare, and wasted branches of depth greater than one are even much less frequent, see Table 1 in [6]. All this is however theory or how the things have worked so far in recent bitcoin history. In practice it is more complicated as we will see in this paper.

4.1 Why Do We Have This Rule?

It is remarkable that in bitcoin literature this rule is taken for granted without any criticism. For example in the very highly cited recent paper [12] we read: "To resolve forks, the protocol prescribes miners to adopt and mine on the longest chain.". In this paper we are going to show that this rule is highly problematic and it leads to very serious hazards.

4.2 Genius or Engineering Mistake?

It is possible to see that this consensus mechanism in bitcoin has two distinct purposes:

1. It is needed in order to decide **which blocks** obtain a monetary reward and resolve potentially arbitrarily complex fork situations in a simple elegant and convincing way.
2. It is also used to decide **which transactions** are accepted and are part of official history, while some other transactions are rejected (and will not even be recorded, some attacks could go on without being noticed, cf. [10]).

Here is the crux of the problem. The creator of bitcoin software Satoshi Nakamoto has opted for a solution of extreme elegance and simplicity, one single (longest chain) rule which regulates both things. This is neat.

However in fact it is possible to see that this is rather a mistake. In principle there is NO REASON why the same mechanism should be used to solve both problems. On the contrary. We need to observe that the transactions are generated at every second. Blocks are generated every 10 minutes. In bitcoin the **receiver of money is kept in the state of incertitude⁵ for far too long** and this **with no apparent reason**.

The current bitcoin currency produces a situation of discomfort and dependency or peculiar sort. Miners who represent some wealthy people in the bitcoin network, are in a privileged position. Their business of making new bitcoins has negative consequences on the smooth processing of transactions. It is a source of instability which makes people wait for their transactions to be approved for far too long time⁵. We claim that it should be possible to design a better mechanism in bitcoin, which question we will study later in Section 7.1.

4.3 Consensus Building

The common history in bitcoin is agreed by a certain type of democratic consensus. In the initial period of bitcoin history people mined with CPUs and the consensus was essentially of type **one CPU one vote**. However nowadays people mine bitcoins with ASICs which are roughly ten thousand times more powerful than CPUs (more precisely they consume ten thousand times less energy, cf. [5]). Bitcoin miners need now to invest thousands of dollars to buy specialized devices and be at the mercy of the very few suppliers of such devices which tend NOT to deliver them to customers who paid them for extended periods of time, see Appendix of [6]. It appears that the democratic base of bitcoin has shrunk and the number of active miners has decreased.

Nevertheless in spite of these entry barriers the income from mining remains essentially proportional to the hashing power contributed to the network (in fact not always, see [6, 12]). This is good news: malicious network participants which

⁵ This period of incertitude is even much longer for large transactions: for example we wish to withdraw some 1 million dollars which is currently about 2200 bitcoins, we should probably wait for some 100 blocks or 10 hours. Otherwise it may be profitable to run the double spending attack which we study later on Fig. 7, page 21.

do not represent a majority of the hash power are expected to have difficult time trying to influencing the decisions of the whole bitcoin network.

In a first approximation it appears that the Longest Chain Rule works well and solves the problem of producing consensus in a very elegant way. Moreover it allows asynchronous operation: the consensus can propagate slowly in the network. In practice it is a bit different. In this paper we are going to challenge this traditional wisdom of bitcoin. In Section 6 and in later Sections 10 and 11 we are going to argument that more or less anyone can manipulate virtual currencies for profit.

In fact we are not even sure if the Longest Chain Rule is likely to be applied by miners as claimed. This is what we are going to examine first.

4.4 The Longest Chain Rule - Reality or Fiction

This rule is taken for granted and it seems to work. However. We can easily imagine that it will be otherwise. There are several reasons why the reality could be different:

1. We already have a heterogenous base of software which runs bitcoin and the protocols are on occasions updated or refined with new rules. On occasions there will be some bugs or ambiguities. This has already happened in March 2013. There were two major versions of the block chain. For 6 hours nobody was quite sure which version should be considered as correct, both were correct. The problem was solved because the majority of miners could be convinced to support one version. Apparently the only thing which could solve this crisis was human intervention and influence of a number of key people in the community, see [4].
2. Open communities tend to aggregate into clusters. These clusters could produce distinct major software distributions of bitcoin, similar to major distributions of Linux which will make some conflicting choices and will not necessarily agree on how decisions can be made. For example because they promote their brand name and some additional business interests. We already observe a tendency to set up authoritative bitcoin authorities on the Internet such as `blockchain.info`. Software developers are tempted to rely on these web services rather than work in a more “chaotic” fully distributed asynchronous way. People can decide to trust a well-established web service rather than network broadcasts which could be manipulated by an attacker.
3. This is facilitated by the fact that bitcoin community produces a lot of open source software and free community web services.
4. It is also facilitated by the fact that the great majority of miners mine in pools. Moreover they tend to “flock to the biggest pools” [6, 18]. Just one pool reportedly based in Ukraine was recently controlling some 45 % of the whole bitcoin network, see Table 2 in [6].

The pool managers and not individual miners are those who can decide which blocks are mined and which transactions will be accepted. The software run by pools is not open source and not the same as run by ordinary bitcoin users. In particular they can adopt various versions or exceptions from The

Longest Chain Rule. In Section 8.1 we will propose further new ways for pool managers to attack the bitcoin network.

5. More importantly participants could suspect or resist an attack by a powerful entity (which thing allows effectively to cancel past transactions and double spend) and they will prefer to stick to what their trusted authority says.
6. Even more importantly these sub-communities of bitcoin enthusiasts will also contain professional for-profit bitcoin miners who can be very influential because for example they will be sponsoring the community. Their interest will be that their chain wins because they simply need to pay the electricity bill for it. If another chain wins, they have lost some money.

We see that sooner or later we could have a situation in the bitcoin community such that people could agree to disagree. If one group have spent some money on electricity on one version of the chain, their interest will be to over-invest now in order to win the race. Over-investment is possible because there is always spare capacity in bitcoin mining which has been switched off because it is no longer very profitable. However the possibility to earn money also for previous blocks which money would otherwise been lost can make some operations profitable again. Such mechanisms could also be used to cancel large volumes of transactions and commit large scale financial fraud, possibly in combination with cyber attacks. This can be done in such a way that nobody is to blame and everything seems normal following the Longest Chain Rule. **Losses will be blamed on users** not being careful enough or patient enough to confirm their transactions.

4.5 Summary: Operation in Normal Networks

We have seen that bitcoin has been designed to operate in **extreme** network conditions. Most probably bitcoin could operate in North Korea or in Syria torn by war operations, or in countries in which the government is trying to ban bitcoin or is very heavily limiting the access of the citizens to fast computer networks such as the Internet.

In contrast in the real life, the propagation in the global network of bitcoin client applications is quite fast: the median time until a node receives a block is 6.5 seconds whereas the average time is 12.6 seconds, see [8, 9]. The main claim in this paper is that in normal networks the Longest Chain Rule is not only not very useful, but in fact it is sort of **toxic** and leads to increased risks of attacks or just unnecessary instability and overall slower financial transactions.

Before we consider how to reform or replace the Longest Chain Rule, we look at the questions of monetary policy in bitcoin. Later we will discover that both questions are related, because deflationary policies erode the income of honest miners which increases the risk of for-profit block chain manipulation attacks, cf. Sections 10, 11 and 12.

5 Deflationary Coins vs. Growth Coins

It is possible to classify crypto currencies in two families:

1. **Deflationary Currencies** in which the monetary supply is fixed⁶. For example in bitcoin and Litecoin.
2. **Growth Currencies** in which the monetary supply is allowed to grow at a steady pace, for example in Dogecoin.

Bitcoin belongs to the first family. This is quite unfortunate. In [20] we read:

”This limited-supply issue is the most common argument against the viability of the new currency. You read it so often on the web. It comes up time and again”.

In the following three subsections we look at the main arguments why a fixed monetary supply in bitcoin is heavily criticized. We need to examine the following four questions:

1. comparison to gold, other currencies and commodities
2. volatility
3. miner reward vs. fees
4. competition with other cryptocurrencies.

5.1 Comparison to Gold Other Currencies and Commodities

Bitcoin is frequently compared to gold and The Economist called it “Digital Gold” in April 2013, cf. [11]. However actually gold belongs to the second category: the worldwide supply of gold grows every year due to gold mining, with a yearly increase of the quantity of gold by some 0.5 - 1 %. In fact when bitcoin mandates a fixed monetary supply, ignoring the growth of the bitcoin economy, arguably we enter an area of misplaced ideology and monetary non-sense. If the economy grows substantially, the monetary supply should probably follow or the currency is not going to be able to make a correct connection between the past and the future. It is widely believed that business does not like instability. It is well known in traditional economics that deflation discourages spending, creates an expectation that prices would further decrease with no apparent limit.

To the best of our knowledge, no currency and no commodity has ever had in the human history a totally fixed quantity in circulation. This is clearly an artificial property which makes that bitcoin is like no other currency and like no other commodity. This is expected to have very serious consequences and could be potentially fatal to bitcoin in the long run.

⁶ These are also called Log Coins in [20] which is not quite correct because the monetary supply in bitcoin does not grow logarithmically.

5.2 The Question of Volatility

Here the argument is that basically deflationary currencies are expected to have **higher volatility** due to the existence of people holding large balances for speculation. In [16] Robert Scams claims that deflationary currencies lead to a “toxic amount of exchange rate volatility” providing yet another reason for users to “run away” from using these currencies as a medium of exchange.

5.3 Miner Reward

We need to recognize the role of miners in digital currencies. In [20] Scams writes:

”The amount of capital collectively burned hashing fixes the capital outlay required of an attacker to obtain enough hashing power to have a meaningful chance of orchestrating a successful double-spend attack on the system [...] The mitigation of this risk is valuable, [...]”

Now the deflationary currencies do with time decrease the reward for miners. This is highly problematic. In [20] citing J. Kroll from Princeton university we read: ”If you take this away, there will be no incentive for people to keep contributing processing power to the system [...] ”If the miner reward goes to zero, people will stop investing in miners,”. Then the hash rate is likely to decrease and bitcoin will no longer benefit from a protection against double spending attacks, cf. Section 6.

Moreover Kroll explicitly says that the problem is NOT solved by transaction fees and says: [...] You have to enforce some sort of standard payment to the miners, [...] change the system so that it keeps creating bitcoins.

5.4 The Increasing Fees Argument

The question of why fees are not enough to support miners has been brilliantly explained by Robert Scams in [16].

The argument is that basically sooner or later “deflationary currencies” and “growth currencies” will be in competition. Then all the other things being more or less in equilibrium, in deflationary currencies most of the profit from appreciation will be received by holders of current coins through their appreciation. Therefore less profit will be made by miners in these currencies. However miners control the network and they will impose higher fees. In contrast in growth coins, there will be comparatively more seignorage profit and it will be spent on hashing. Miners will make good profits and transaction fees will be lower. Thus year after year people will prefer growth currencies due to lower transaction fees.

Overall we see that this is crucial question of how the cost of the infrastructure necessary for the maintain a digital currency is split between new adopters (which pay for it through appreciation) and users (which pay through transaction fees. It is obvious that there exists an optimal equilibrium between these two sources of income, and that there is no reason why the creator of bitcoin would get it right, some adjustments will be necessary in the future.

5.5 The Appreciation Argument

There is yet another argument: it is possible to believe that bitcoin will appreciate so much that halving the reward every 4 years will be absorbed by an increase in bitcoin price. This means an extreme amount of deflation (double every 4 years) making it tempting to hoard bitcoins, which further decreases the amount of bitcoins in actual usage and makes people hoard bitcoins even more.

We claim that this is very unlikely. This is mainly because the digital economy does not double every 4 years and does NOT grow by sudden jumps at the boundaries of the intervals arbitrarily decided by the creator of bitcoin. We refer to Part 3 of [5], Sections 10, 11 and 12 for further discussion and concrete examples of predicted and actual devastating effects of sudden jumps in the miner reward.

6 Is The Longest Chain Rule Helping The Criminals?

This section is the central section in this paper. We are going to show a simple attack which allows double spending. The attack is not very complicated and we do not claim it is entirely new.

Our attack could be called a 51 % attack however we avoid this name because it is very highly misleading. There are many different things which can be done with 51 % of computing power, (for example to run a mining cartel [6] or/and cancel/undo any chosen subset of past transactions) and many very different attacks have been called a 51 % attack. We are in general under the impression that a 51 % attack is about holding more than 50 % of the hash power kind of permanently or for a longer period of time, while our attacks are rapid short-term attacks cf. Fig. 7 page 21.

The main reasons why this attack has not been properly understood and studied before in bitcoin literature are probably as follows:

1. There is some sort of intuitive understanding in the bitcoin community that the Longest Chain Rule solves all problems in this space, and there is simply no problem of this sort, and if there is, people naively believe that it is not very serious. In other terms nobody wants to admit that the creators of bitcoin could have created a system which has this sort of problem.
2. People have wrongly assumed that bitcoin achieves very substantial computing power which no one can match, which is still the case today however it is highly problematic to see if this will hold in the future.
3. Great majority of people who discuss bitcoin make an implicit wrong assumption about a static nature of threats and attacks about bitcoin. We hear about 51 % attack etc and it seems that nobody except maybe the NSA could execute such an attack.

In reality the notion of a 51 % attack takes a very different meaning in a cloud computing world: the attacker does not need to own a lot of computing power, he can rent it for a short time, and then 51 % attack can have a surprisingly low cost.

4. The notion of 51 % attacks is also very highly misleading because presenting the hash power as a percentage figure does NOT make sense because the hash rate is measured at two different moments. Therefore the proportion of hash power used in attack is NOT a number between 0 and 100 %. It can easily be larger than 100 %.

In fact the hash power at one moment can be 10 times bigger than a few minutes later, see Fig. 14 on page 37 for an actual historical example.

5. It was also wrongly assumed that the bitcoin adopters are more or less the same as miners, they own the devices and the computing power cannot change hands very quickly.
6. Many bitcoin adopters did not anticipate that in the future bitcoin will have to compete with other crypto currencies and that hash power could instantly be moved from one crypto currency to another.

- Many people did not predict that an increasing fraction of all available computing power is going to exist in the form of rented cloud miners. This is due to several factors. Investing in wholly owned mining equipment has been excessively risky. This is both due to the impossibility to know if and when miners will effectively be delivered (cf. Appendix of [6] and Section 2.4) and due to the price volatility. In contrast investing in rented capacity is nearly risk-free. Another reason is that some large investors may have over-invested in large bitcoin mining farms consuming many Megawatts of electricity (we know from the press that such facilities have been built in Sweden, Hong Kong, USA, etc..) and now they want to rent some parts of it in order to get immediate cashflow and return on their investment.

Later we are going to see that this attack also gets worse with time due to the build-in monetary policy in bitcoin and that there will be sudden transitions because the monetary policy mandates sudden jumps in the miner reward (cf. also Part 3 in [5]).

Our basic attack is self-explanatory, some attacker produces a fork in order to cancel some transaction[s] by producing a longer chain in a fixed interval of time, see Fig. 7 below. The attack clearly can be profitable. The question of actual feasibility of this attack is a complex one, it depends on many factors and we will amply study this and related questions later throughout in this paper.

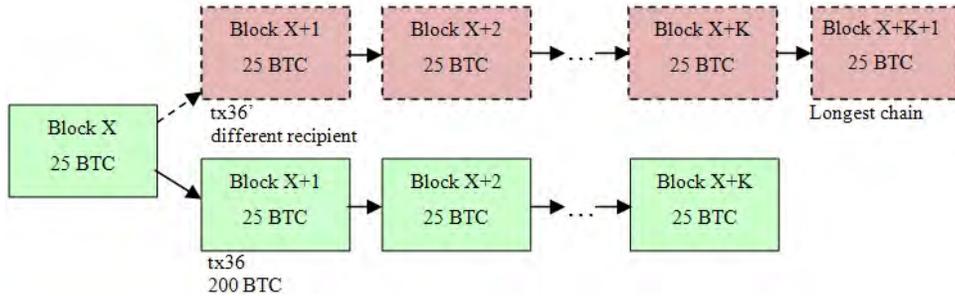


Fig. 7. A simple method to commit double spending. The attacker tries to produce the second chain of blocks in order to modify the recipient of some large transaction(s) he has generated himself. Arguably under the right conditions, this is easy to achieve and clearly profitable. The only problem is the timing: to produce these blocks on time requires one to temporarily acquire very substantial computing power such as more than 51 % at the expense of other miners or other crypto currencies.

In the following sections we are going to analyse the risks which result from this and similar attacks.

6.1 Discussion

Important Remark 1. The attack does NOT limit to defraud people who would accept a single large payment in exchange of goods or another quantity of a virtual currency (mixing services, exchanges, some sorts of shares). The attacker can in the same way issue a large number of small transactions and cancel all of them simultaneously in the same way.

Important Remark 2. The most shocking discovery is that **anyone** can commit such fraud and steal money. They just need to rent some hashing power from a cloud hashing provider. Bitcoin software does not know a notion of a double spending attack and if it occurs possibly nobody would notice: only transactions in the official dominating branch of the blockchain are recorded in the current bitcoin network, cf. [10]. It may also be difficult to claim that something wrong happened: one may consider that this is how bitcoin works and the attacker has not done anything wrong.

In a competitive market they do not need to pay a lot for this. Not much more than 25 BTC per block (this is because miners do not mine at a loss, the inherent cost of mining per block should be less than 25 BTC). The attacker just needs to temporarily displace the hashing power from other crypto currencies for a very short period of time which is easy to achieve by paying a small premium over the market price.

There is another very serious possibility, that the spare hash power could also be obtained from older miner devices which have been switched off because they are no longer profitable (or a combination of old and new devices). However they may be profitable for criminals able to generate an additional income from attacks. Given the fact that the hash rate increases steadily, cf. Fig. 3, it is quite possible to imagine that the hash power which has been switched off is very substantial and comparable in size to the active hash power.

Important Remark 3. There is yet another way to execute such attacks: to offer a large number of miners a small incentive (as a premium over the market price) to go mine for another crypto currency, **before** the attack begins. This can lead to massive displacement of hash power before the attack starts. Then at the moment when block $X+1$ is mined following the notations of Fig. 7, the double spending attack costs less. Further advanced attacks scenarios with malicious pool managers an which can easily be combined with this preliminary displacement of hash power are proposed and studied in Section 8.2.

Important Remark 4. It is very important to understand that what we present on Fig. 7 **is not an attack (yet)** if (as it is currently the case) bitcoin is a dominating crypto currency. However **it becomes an attack** when bitcoin ceases to be a dominant crypto currency. It already is an attack on many existing crypto currencies cf. for example Section 10 and 11.

The **ONLY** thing which makes that this attack is not feasible in practice on bitcoin itself at the moment of writing, is that bitcoin remains the dominating crypto currency and commands more hash power than all other currencies combined. It appears that bitcoin could claim to be a sort of natural monopoly: it is able to monopolize the market and its competitors find it hard to compete.

Important Remark 5. Things are expected to considerably change in the future for bitcoin. We do not expect bitcoin to remain dominant forever. Here is why! Unhappily due to the cost of adopting bitcoin as a currency (the necessity to purchase bitcoins which have already been mined at a high price) one cannot prevent users from creating their own crypto currency. Gold does not give people and major countries any choice: some countries have gold mines or gold reserves, others don't. Digital currencies put all the countries and all the people at an equal footing. There will be always a large percentage of the population which will not be happy about the distribution of wealth and will try to promote a new crypto currency which gives (new) investors a better chance than having to buy coins already mined by other people.

The fact that bitcoin is expected to lose its dominant position is also due to another factor, built-in decreasing returns for miners and the predicted consequences of this fact, see Section 5.

Summary. Overall we get a **combination of factors** which are expected to lead to a rapid transition: from bitcoin being secure to bitcoin becoming vulnerable. For many crypto currencies all these things are already happening, see Section 10 and 11. The question whether it can also happen to bitcoin and what might be further consequences of it is further studied in Section 12.

7 An Alternative Solution For Double Spending

In this paper we heavily criticize the longest chain rule of Satoshi Nakamoto. A single rule which offers apparent elegance and simplicity and regulates two things at one time. It is responsible for deciding which freshly mined blocks are “accepted” and obtain monetary reward and at the same for deciding which transactions are finally accepted and are part of the official common history of bitcoin. However as we have explained before, it is problematic to solve both problems with one single “blunt” rule, **there is NO REASON why the same mechanism should govern both areas**. It should be possible to design a better mechanism in bitcoin.

7.1 Desired Characteristics

Let us examine what kind of solution would be desirable.

1. Earlier transactions should be preferred and as time goes by it should be increasingly difficult to commit double spending.
2. Instead of instability and all or nothing behavior where large number of transactions could be put into question, we should get stability and convergence.
3. Relying parties should get increasing probabilistic certitude that the transaction is final as times goes by, second after second.
4. Unique transactions which spend some quantity[ies] of money in bitcoin should be always accepted with very large probability.
5. Double spending transactions should simply be resolved on the basis of earlier transaction, if one transaction is much earlier than the other.
6. Only in rare cases where competing transactions are emitted within a certain time frame there could be an ambiguity about which transaction will be accepted.

We should also ask the question that maybe no transaction should be accepted in this case, as it would show in a short time that either the payer is trying to cheat or his private key has been compromised.

7. In particular though it is possible and does not cost a lot to rewrite bitcoin history in terms of which blocks get the reward, it should be somewhat STRICTLY HARDER and/or cost more (the exact criteria to be determined) to rewrite bitcoin history in terms of who is the recipient of moneys.
8. Even though miners can produce competing blocks and no one can decide which block obtains the reward later, all blocks are likely to include the same transactions.
9. There should also be some protection against spam or DOS attacks: it should be difficult to jam the P2P network with too many transactions.
10. People who deliberately execute attacks on the bitcoin network should possibly be punished rather than be rewarded or get away with it.

How exactly this can be done is not totally obvious, however it appears that bitcoin does not really provide an optimal solution and we need to propose something better. We are not going to claim to provide the ultimate solution. This is expected to be a solution better than status quo, subject to further improvement and detailed tuning to adapt it to the realities of bitcoin.

7.2 Proposed Solution

It surprising to discover that **Satoshi did NOT introduce a transaction timestamp** in bitcoin software. It is NOT known WHY neither the original creator of bitcoin nor later bitcoin developers did not mandate one. This could be seen as an expression of **misplaced ideology**. Giving an impression showing that maybe the Longest Chain Rule does solve the problems in an appropriate way. Unhappily it doesn't.

Currently an approximate timing of transactions is known in the bitcoin network, it comes from the number of block in which a given transaction is included: this gives a precision of approx. 10 minutes. Transactions without a fee could be much older than the block. However all blocks are broadcast on the network and it is very easy for the bitcoin software to obtain more precise timing of transactions with a precision of 1 second, maybe better. A number of web sites such as `blockchain.info` are already doing this: they publish timestamps for all bitcoin transactions which correspond to the earliest moment at which these transactions have been seen.

A preliminary remark is that in the current bitcoin system, each quantity of bitcoins such as created or attributed to a certain public key by some previous transaction, can be used only once. There should be at most one digital signature which transfers this quantity to another set of public keys (there can be multiple recipients for each transaction). Two distinct signatures indicate double spending⁷.

Then the solution is quite simple:

1. In case of double spending if the second event is older than say 20 seconds after the first transaction, the first transaction will simply be considered as valid and the second as invalid. This based on the earliest timestamp in existence which proves that one transaction was in existence earlier.

This seems reasonable knowing that the median time until a node receives a block is 6.5 seconds cf. [8,9].

The implementation of such a mechanism is not obvious and will be discussed separately below. However it seems that it could be left to the free market: several mechanisms could function simultaneously. For example one can immediately use timestamps published by `blockchain.info` and simultaneously use timestamps from other sources.

For solutions which would prevent various bitcoin web servers from manipulating these time stamps we will need to propose additional mechanisms, such as secure bitstamps or additional distributed consensus mechanisms. We will develop these questions in another paper.

2. In case of double spending if both events come within at most 20 seconds of each other, miners should NOT include any of these transactions in block they mine. Some miners can nevertheless accept a transaction because they have only received one of the two transactions, or because they are trying to

⁷ Things get more complicated with transactions which contain multiple signatures, cf. also transaction malleability attacks [10]

cheat. Then their block could simply be invalidated because they have not been careful enough about collecting all the transactions which have been around. For honest miners this would occur with small probability.

Yet it makes sense to make miners responsible for policing this: this is because miners are fewer than ordinary network nodes and mine in pools which are expected to help them to do it right.

In other terms a mined block could be considered as invalid if it only includes one transaction while two were already in existence say 20 seconds before it was produced AND if these transactions were close in time. If one was much earlier, it could be included. Again this decision on whether to include or not a given transaction could be decentralized.

All this requires some form of timestamping and some security against manipulation of these timestamps to be implemented than in the current software, either by consensus or secure timestamps.

An alternative to timestamps could be a pure consensus mechanism by which numerous network nodes would certify that that they have seen one transaction earlier than another transaction. This can be very easy done: we can re-use shares which are already computed by miners in vast quantities or select only certain shares with a sufficient number of zeros. We could mandate that if transactions are hashed in a certain order in a Merkle hash tree, it means that this miner have seen certain transactions earlier or another similar mechanism assuming that the majority of miners are honest.

Discussion: This is NOT yet a full solution. It requires further work to specify and analyse if it does the job reasonably well and if it does not lead to new attacks.

Remark: This solution is not an urgent need for larger crypto currencies which enjoy a dominant position and command a lot of hash power. They can probably survive for years without it. It is however **vital** for all small crypto currencies which are subject to risk of very rapid self-destruction if it is not applied, as shown in this paper.

Enhancements: Probably we need to require more than a timestamp for all bitcoin transactions. We could also require timestamps for all individual signatures. A digital signature gives security guarantees which answer two questions: Who? (signs) and What? (is signed). A digital signature which includes a timestamp which also answers the question When? (the transaction was authorized).

Limitations: A major factor which is expected to affect the development and adoption of solutions to our problem is the size of the blockchain in bitcoin which is stored at every full network node and takes about 14 gigabytes.

8 Hidden Attacks: How To Abuse Miners

8.1 A Small But Important Technicality

We examine the process of double hashing which is used in bitcoin mining according to [5].

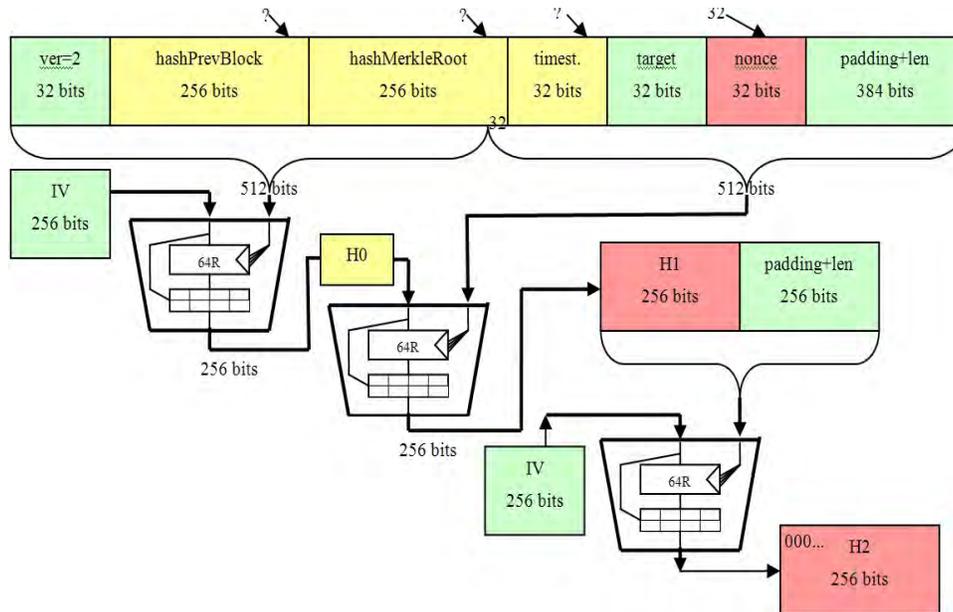


Fig. 8. The process of bitcoin mining according to [5].

One thing jumps to our attention [we thank Lear Bahack for observing this fact independently, though we have observed that many months earlier]. The miners do NOT need to know on which block they are mining: they do NOT need to know the value of **hashPrevBlock** which computation is amortized over many has operations and the value of **H0** changes very slowly. They only need to know the value **H0** which will be computed for them by the pool manager for them. Miners can be made to **mine without any precise knowledge about which block they are mining for**.

Only an excessively small number of miners, will actually manage to find a winning block: only a very small proportion of about 2^{-32} of all shares found by miners are winning shares. Only these miners can know on which block they have mined and they will know it from the public data in the blockchain.

Thus pool managers CAN implement arbitrary subversive strategies, for example accept certain transactions only to overthrow them within less than one

hour and accept another transaction with another recipient. **Nobody will notice:** miners will never know that they have been involved in some major attacks against bitcoin such as producing two different versions of the blockchain in order to double spend some large amount of money.

Remark 1. Moreover even those miners who have produced winning blocks and therefore will be made aware of the previous block on which they have been mining, still cannot claim they have participated in some sort of attack. Fork events do happen in the bitcoin network. Only overall higher frequency of fork events mined by one large pool could suggest that some attacks have been executed by that pool, however the pools can execute such attacks just within the limits of the standard deviation ⁸ and never attract any attention.

Remark 2. It is also possible to see that even with the knowledge of all recent transactions from the network and with the knowledge of H0, it is not possible to guess how exactly the Merkle root hash is composed. We are talking about preimage (inversion) attacks starting from H0 aiming at guessing which hashPrevBlock was used to produce this H0. This is because the number of combinations is too large. For example the number of ways to permute the order of 100 transactions is already more than 2^{500} .

8.2 Miner Hidden Abuse Attack Across Currencies

The same attack works **across digital currencies**. Some miners think that they mine bitcoin, while in fact they are made to mine Unobtanium, and vice versa. All this is the discretionary power of the pool manager, this is due to the fact that one can mine only knowing H0 and most of the time no other information is disclosed to miners. In rare cases miners could discover that they found a block for another crypto currency which they have never mined. In practice miners do NOT store vast quantities of H0 values with which they have mined. Miner devices do NOT have enough memory to store them.

8.3 Further Manipulation Scenario With Deflected Responsibility

Our attack can also be made to work in the scenario in which it is not possible for the attacker to corrupt pool managers. It can be run in a different way in which pool managers are going to corrupt themselves and there will be no reason to accuse them of acting with any sort of malicious or criminal intention.

Basically it is possible for an attacker to manipulate the price of a small crypto currency such as Unobtanium to be 10 % MORE profitable than bitcoin mining (typically such currencies are in a sort of equilibrium situation in which the profitability is similar as for bitcoin). Then we can hope that the pool managers themselves are going to implement code to switch to this crypto currency for a short time (real-time switching mechanism mining for the most profitable currency at the moment). If not, the attackers can themselves release open-source code of this sort in order to encourage the adoption of this sort

⁸ Standard deviation is excessively large mining events which are quite rare, cf. [6].

of gain optimization techniques among pool managers. Pool manager can now re-direct 100 % of the hashing power they command to another entity. They are NOT going to tell this to miners and simply pocket the difference, and they will still pay miners in bitcoins. Again, there is in principle no way in which miners could see the difference.

9 Towards A Theory of Programmed Self-Destruction

In this section we are going to try to combine all the elements which we have studied so far in order to see what is the overall landscape. We can now formulate a certain theory or set of claims about the predicted future of crypto currencies. based on what we learned.

Our main claim is that the combination of three things:

1. the longest chain rule,
2. deflationary monetary policies which heavily limit the production of new coins (with or without sudden jumps in miner reward),
3. and a competitive environment where hash power can shift rapidly from one coin to another,

is a **fatal** combination. It leads to predicted destruction of crypto coins.

On Fig. 9 we summarize again the main premises in our theory and also try to show some additional influencers.

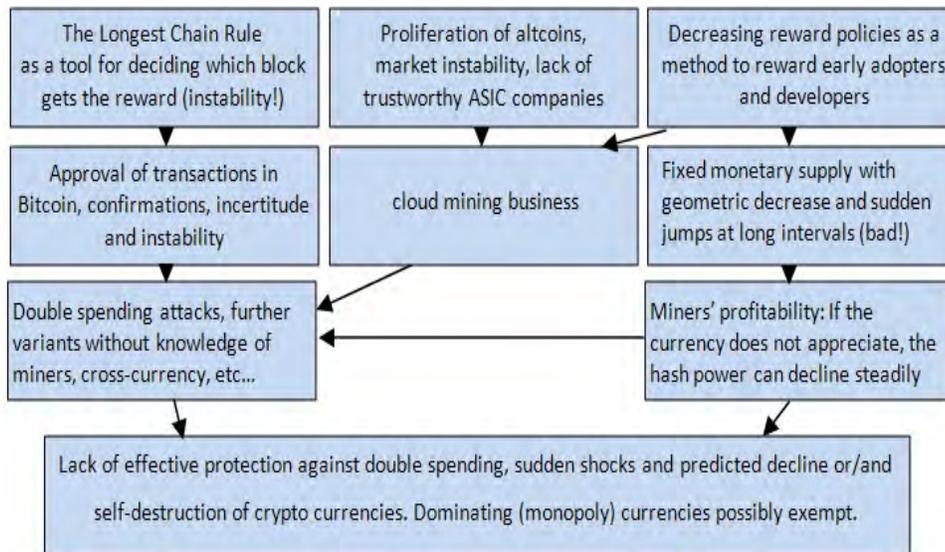


Fig. 9. Theory of programmed self-destruction of crypto currencies: major factors and influencers which are also the main premises of our theory.

The remaining part of the paper will be a study of particular use cases. Does our theory work? Does it allow us to understand the past and and somewhat predict future of various crypto currencies?

10 Case Study: Unobtanium

Unobtanium is a clone of bitcoin which is in operation since October 2013 (cf. unobtanium.io). Unobtanium uses SHA256 and can reuse bitcoin ASICs for mining, and it has a non-negligible value. In March 2014 it was worth some 0.01 BTC which at the current hash speed made Unobtanium mining roughly as profitable as standard bitcoin mining. (note: later in April 2014 the profitability of UNO mining has declined). It is traded at several exchanges. Transactions are substantially faster than bitcoin: blocks are generated and transactions are confirmed once per 1.24 minutes instead of every 10 minutes for bitcoin (it is 1.24 minutes and not 3 minutes as reported incorrectly by many sources). At the first sight this currency seems therefore a quite promising clone of bitcoin and the current market value of all Unobtanium in circulation is roughly about 0.5 million dollars. On the official web page unobtanium.io we read that Unobtanium is expected to be “the cryptocurrency for serious traders” and that “Unobtanium is safe”. At the first sight we see no problem with this currency whatsoever apart from the fact that there are very few actual transactions in the blockchain.

Unobtanium is quite rare: only 250,000 will be ever made, and the production of new currency is halving every 2.88 months which is **incredibly fast**. There are only a few halving periods however, and in September 2014 the miner reward settles forever at a surprisingly small value.

Table 1. The Unobtanium Reward

blocks	approx. dates	UNO/block
1 – 102K	18 Oct 2013-	1
102K – 204K	15 Dec 2013-	0.5
204K – 300K	12 Feb 2014-	0.25
300K – 408K	4 April 2014-	0.125
322,050	-today-	0.125
408K – 510K	5 Jun 2014-	0.0625
510K – 612K	1 Aug 2014-	0.03125
612K –	after 29 Sep 2014	0.0001

In fact this crypto currency smells **programmed self-destruction**.

At the moment of writing some 2/3 of all coins were already made. In March 2014 the current price of Unobtanium (UNO) was about 6 USD and we again Unobtanium mining was roughly as profitable as standard bitcoin mining. However because Unobtanium uses **the same SHA256 ASICs** as in bitcoin mining, the computing power (hash power) can shift in both directions instantly. In particular the computing power in Unobtanium currency is NOT growing, it is rather declining.

10.1 Double or Die

When the next rewards block halving comes in April, the price of UNO needs to be at 12 USD in order to keep mining equally profitable (cf. later Theorem 11.1 page 35). Then in June it would need to become 24 USD, then in August it

would need to become 48 USD. Such rapid appreciation at an exponential rate is unlikely to happen and the hash rate must decline accordingly, until mining becomes profitable.

10.2 The Self-Destruction of Unobtanium

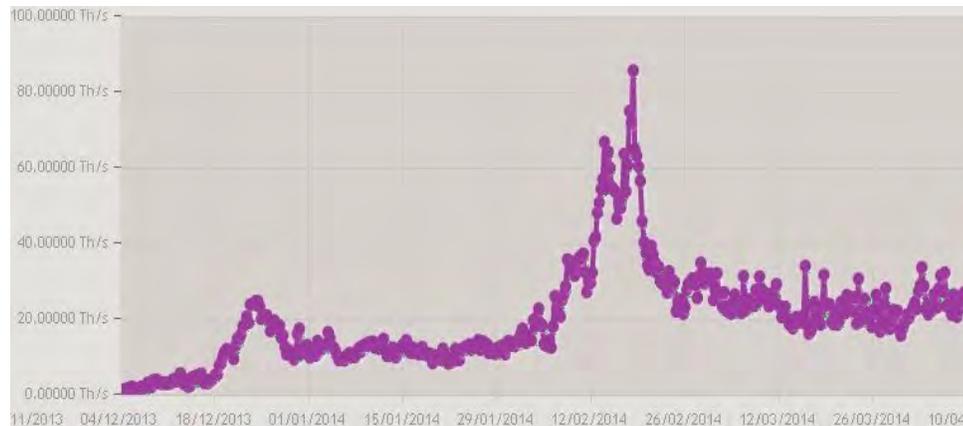


Fig. 10. The growth and decline of UNOBTANIUM hash power in the last few months. We observe sudden (speculative?) jumps and periods of intensive mining followed by steady decline in days following each block halving date (15 Dec and 12 Feb) in the hash power

On Fig. 10 we see that miners are already running away from this crypto currency. This happens in sudden slumps as predicted. There is an important decline in the hash rate which occurs some few days after block halving dates after some sort of short period of instability. We see that the process of rapid self-destruction has already started for this crypto currency⁹.

Unobtanium is a crypto currency which is already destroying itself. It is bound to always have very small market cap, which implies small anonymity and small adoption. In bitcoin the decline in mining profitability could be compensated by massive adoption and fees, and miners do not have a better crypto currency to escape to. Here the adoption as a payment instrument is close to zero, fees are zero and miners have very good alternatives to switch to.

10.3 A Kill Switch

There is much worse than that. After 29 September 2014 the miner reward is going to be **divided by 312.5 overnight**. Then if we want the mining profitability to be the same as today and the hash rate not to decline, the price

⁹ We claim that similar periods of decline in hash power are also likely to happen for bitcoin, though not before 2015/2016 see Section 12, and more quickly for Dogecoin, at several moments during 2014, see Section 11.

of UNO would need to be 15,000 USD each to compensate for that again (or mining will not be profitable and hash power protection will go elsewhere). This would make UNO achieve a market capitalization of about 4 billion dollars from 0.5 million today. Unbelievable 8000x growth in a few months.

Of course it obvious that this is not going to happen. We expect rather that there will be a very fast outflow of hash power at each reward halving (cf. Fig. 10) until we reach again an equilibrium situation where again mining Unobtanium will be as profitable as mining bitcoin. Overall on and before 29 September 2014 we predict very rapid spectacular collapse in Unobtanium hash power.

Of course at the same time there can be some appreciation of Unobtanium due to their increasing rarity and increased popularity, however this appreciation is unlikely to happen by sudden jumps, and it is obvious that it cannot achieve 100% appreciation every 3 months and 30,000 % appreciation (300 times increase) on one single day in September.

10.4 Further Decline?

Our prediction is that the hash power in Unobtanium will **decline to a ridiculously small value** (for example 1000x smaller than today). If we assume (being VERY conservative and optimistic) that Unobtanium miners mine at the same profitability threshold as bitcoin miners, and if UNO pays less miners would switch to bitcoin, following Table 1 in September 2014 the hash rate is going to be at most 1250 times lower than the peak of 80,000 TH/s of February 2014. This is at most 70 TH/s. In September 2014 anybody should be able to execute a 51 % attack on Unobtanium. For example we can estimate that in order to execute the attack of Section 11.5 based essentially on Fig. 7 which is expected to last only about 5 minutes, the attacker needs to rent 35 TH/s of SHA-256 for about 5 minutes. It is easy to see that this will cost only a few dollars.

A decline in hash power will inevitably lead to several major problems:

- It will become easy to double spend older coins, there will be permanent for-profit criminal activity (cf. also Section 11.5).
Yes in September 2014 it will cost only a few dollars to execute a 51 % attack on Unobtanium.
- It will become easy to run a “mining cartel attack” only accept blocks mined by members of a certain group, cf. [6].
- A sudden collapse of this crypto currency will probably occur much earlier, as soon as any of these two starts happening, totally destroying confidence of investors and users in this crypto currency.

Remark. It is clear that Unobtanium is in trouble, and later in April 2014 we observed that the profitability of UNO mining has declined and apparently some miners are artificially sustaining it and accept to mine with lower profitability, probably in a bid to avoid total collapse of this currency. We also observed on 28 April that the official web site for Unobtanium is not even displaying the current hash rate anymore for the second half of April.

11 Another Case Study: Dogecoin vs. Litecoin

In this section we we look at two currencies Litecoin (long time established) and Dogecoin (started end of 2013) which are quite comparable ¹⁰. Both currencies use the same hash function (SCRYPT) and they have historically known comparable hashrates. The hash power can move freely and it is possible to see that throughout most of the recent history of Dogecoin **EACH currency could be used to attack each other with a 51 % attack**. We are going now to show that this “symmetric” situation is changing very rapidly, and we will attempt to predict the future of these currencies.

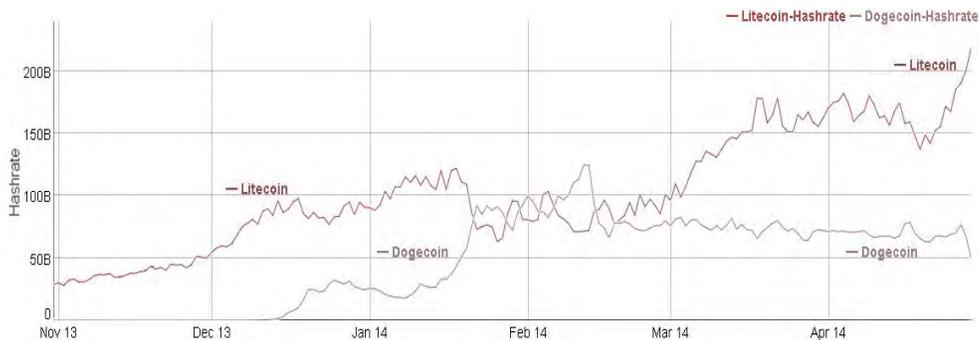


Fig. 11. DOGE hashrate compared to LTC hashrate in the last 6 months

Dogecoin is a newcomer which has challenged the incumbent Litecoin very seriously in terms of achieving a higher hash rate at moments. However the market capitalization of Litecoin remains at least 8 times bigger (300 M USD vs. 37 M USD at the moment of writing). This is because Litecoin has been mined for longer and more people hold some balances in Litecoins.

11.1 Block Halving and Programmed Self-Destruction of Dogecoin

In Litecoin no block halving is planned until 30 August 2015, then the reward is halved, and then the reward remains stable until 2019. Then it has countless block halving events programmed over a period of some 100 years.

In Dogecoin block reward halving events are only very few but they are all planned to occur very soon at the very early stage of existence of Dogecoin in the coming months of 2014. Important events are unfolding before our eyes.

In excessively short time after its creation, Dogecoin has been able to achieve a comparable and even higher hash rate than Litecoin. This has lasted until

¹⁰ There was a very strong asymmetry between bitcoin and Unobtanium, bitcoin was always many thousands of times larger and it was never able to challenge bitcoin in any way

March 2014 cf. Fig. 11. On this figure we also observe very strong negative correlation between the two hash rates. When one goes up, the other goes down, the sum is nearly constant at times. We take it as a strong evidence that the hash power has already been shifting in both directions between these two currencies.

Then on 17 March 2014 the reward was halved cf. Fig. 12. At this moment the hashrate in Litecoin has immediately adjusted and switched to another curve, very precisely in days following 17 March 2014, cf. Fig. 11. This ratio has then been quite stable with the hash rate of Dogecoin remaining at or below half of the hash rate of Litecoin.

In this paper we claim that this is strict mathematics. When the reward halves, miners will either see the value of Dogecoin double or a fraction of miners will switch and mine for a competing crypto currency. More precisely miners will be leaving this crypto currency until a new equilibrium is reached: less miners will be there to share the new (decreased) reward and therefore the profitability of their mining operations will be restored. We have the following result:

Theorem 11.1 (Law Of Decreasing Hash Rates). *If the miner reward of crypto currency is decreased 2 times and the market price remains the same the hash rate will be divided by 2 approximately.*

Dogecoin has failed to appreciate 2x in value, therefore the hash rate must decrease 2x.¹¹ We will see this happen again on Fig. 13.

Block numbers	Per-block reward	First block	Expected coins produced (approx)	Expected total circulation (approx)
1-100,000	0-1,000,000 (random)	8 December 2013	50,000,000,000	50,000,000,000
100,001-144,999	0-500,000 (random)	14 February 2014	11,250,000,000	61,250,000,000
145,000-200,000	250,000 (fixed)	17 March 2014	13,750,000,000	75,000,000,000
200,001-300,000	125,000 (fixed)	28 April 2014 (estimated)	12,500,000,000	87,500,000,000
300,001-400,000	62,500 (fixed)	2 July 2014 (estimated)	6,250,000,000	93,750,000,000
400,001-500,000	31,250 (fixed)	9 September 2014 (estimated)	3,125,000,000	96,875,000,000
500,001-600,000	15,625 (fixed)	18 November 2014 (estimated)	1,562,000,000	98,437,500,000
600,001+	10,000 (fixed)	26 January 2015 (estimated)	5,200,000,000 per year	No limit

Fig. 12. Programmed sudden jumps in DOGE block reward

A few more successive block halving events in Dogecoin are programmed every 69 days leading to rapid decline in hashing power. This is again **unbelievably fast speed** for a financial asset, not less crazy than with Unobtanium cf. Section 10.1.

¹¹ The same phenomenon of rapid decline in hash rate at moments of block halving, was also observed with Unobtanium currency, cf. Fig. 10 in Section 10.1.

11.2 How Vulnerable Is DogeCoin?

In this paper we show that Dogecoin is threatened by the 51 % attack in more than one way. For example because in April 2014 it was reported that one single pool in Dogecoin was controlling 50.3 % of the network hashrate http://www.reddit.com/r/dogecoin/comments/22j0rq/wafflepool_currently_controls_503_of_the_network/ . Moreover the pool managers can execute attacks without the knowledge of miners, see Section 8.1. However bigger threats come from the fact that the hash power in Dogecoin is declining and the hash power available outside Dogecoin is becoming many times larger than the whole of Dogecoin, knowing that the hash power used to mine for one currency can be reused (with or without the knowledge of the miner) to mine for another currency, cf. Section 8.2.

11.3 Latest News: Decline Under Our Eyes

The latest Dogecoin halving event has occurred on 28 April 2014 at 14:32. Our theory predicts that at this moment either Dogecoin market price goes up abruptly (not very likely) or the hash power should be then divided by 2 in a short time. At this moment Dogecoin capability to be protected against double spending attacks will be seriously affected.

In order to verify if our theory is exact, we have observed the hash rate of Dogecoin at dogechain.info in the hours following the block halving on 28 April 2014. We have observed exactly what we expect: a decline to achieve roughly half of the previous hash rate. We were in fact surprised by the rapidity of this decline.



Fig. 13. Rapid decline in DOGE hash rate in hours after block halving.

In a few hours the Dogecoin hash rate has declined below 50 Gh/s while AT THE SAME time one single miner had 21.70 GH/s <http://wafflepool.com/>

miner/14t8yB3PDGfZT3VppxMY4J9xiBaXUcZvKp, which data are updated every 15 minutes.

11.4 Is Dogecoin Under Attack?

At one moment at 15h44 we have actually observed that the hash rate went down to 40 GH/s for a short moment and conditions for a 51% attack have been met. **One single miner had 51 %** for a short while.

At another moment we have observed that the hash rate has increased 10 times in a very short time, see Fig. , and went back to normal few minutes later. We do not know if this was an attack on Dogecoin of the precise sort we study in this paper, and we do not know how much the data reported by `dogecoin.info` are reliable. The peak hash rate of 548 TH/s shown at this moment seems too large to be true and would exceed the hash rate of Litecoin.



Fig. 14. A rapid increase in DOGE hash rate observed in hours after block halving.

11.5 Near Future - Is There A Criminal Business Case?

It is easy to show that Dogecoin can hardly survive in the current form.

After April 2014 there will be a few more periods in which the block reward will be halved after 69 days, cf. Fig. 12, and accordingly the hash rate is also expected to decline twice at each moment. Overall we expect that at the end of 2014, the hash rate of Dogecoin will be already some 32 times smaller than what it was in February 2014, when it was equal to that of Litecoin. We expect that very soon Dogecoin will become **a perfect target for criminal activity where money can be made easily**. Let us discuss if this is really plausible. We restrict to the question if double-spending attacks will be feasible.

It has already happened on April 28 that ONE SINGLE MINER had enough hash power in order to execute a double spending attack. The worst is however yet to come. We claim that in the coming months it will be possible for criminals

to execute double spending attacks with much lower investment. Here is one possible way for an attacker to proceed:

- The attacker needs an initial amount of say 10 times the amount of money mined in one block, currently about 10x120 USD, he needs about 1200 USD.
- He sends 600 USD to some recipient and keeps 600 USD for the cost of doing the blockchain manipulation.
- He executes the attack as on Fig. 7 page 21 and spends 600 USD on mining.
- The attack will be feasible as soon as a certain fraction of hash power in Litecoin is available in hosted cloud mining. It should be at least 51 % of Dogecoin hash rate which is going to become very easy in the coming months due to very rapid decline in the hash rate predicted due to Table 12. There is also another even more subversive scenario in which pools automatically provide computing power to the attacker, without the knowledge of miners and without the knowledge of pool managers, see Section 8.3.
- He is then able to spend his 600 USD again as on Fig. 7.
- The net profit in this attack is 600 USD and it takes about 5 minutes.

11.6 Better Prospects For Dogecoin in 2015?

Let us assume that Dogecoin survives until 2015, and it is not destroyed by massive outflows of capital, double-spending attacks and serious for-profit blockchain manipulation or a mining cartel attack, which will be very surprising.

The the situation is expected to stabilize in 2015. After January 2015: there will be no more reward halving in Dogecoin. There will be a steady production of new coins and progressive but infinite growth of monetary supply.

- 98 billion coins will be released by January 2015.
- Then some 5.2 billion more coins will be produced each year.

It is like a 5 % increase in the monetary supply in the first year, slightly less in the coming years.

Unhappily at this moment the hash rate of Dogecoin will be maybe 50 times lower than in Litecoin, which is what we expect from Table 12. It will be difficult for Dogecoin to compete with Litecoin. It is expected to remain permanently weaker, and if the specification is not changed, it will become a permanent target for profitable criminal activity, as shown above. However the Dogecoin developers can apply some fixes such as proposed in Section 7.2 and their currency will be able to function correctly in spite of having a low hash rate.

11.7 The Improbable Revenge of Dogecoin in the Long Run

Ironically it is possible to see that in the long run, like after 10, 20 or 30 years, Dogecoin hash rate should again exceed that of Litecoin, this is if they are still in existence at that moment and their miner reward policies are not reformed. This is because the monetary supply of Litecoin is fixed, and the monetary supply of Dogecoin is unlimited. In the long run, Litecoin will see the profitability of

mining halved many times, while it is expected to remain relatively stable in Dogecoin. Accordingly we expect that the hash rate of Litecoin will in turn decrease at certain moments (every 4 years, next halving expected in August 2015). This process is expected to take a lot of time, probably many decades because Litecoin is more popular than Dogecoin, and some of the decreased income for miners could be compensated by the slow appreciation of Litecoin and higher amount of transaction fees collected in Litecoin.

12 Future of Bitcoin: Is Bitcoin Strong Enough to Avoid Programmed Decline?

Now we are going to speculate about privileged moments in time at which bitcoin could see a decline in its hash rate. The next block reward halving in bitcoin is predicted to happen on **22 August 2016** according¹² to bitcoinclock.com.

We predict that a major crisis of bitcoin digital currency could occur at this moment. In fact however it does not have to be so. we predict that bitcoin will be in trouble **only if** some preliminary conditions¹³ are also met at this date:

1. If bitcoin mining has sufficient competition by that time,
2. If miners are willing and able to reprogram their ASIC machines to mine for other competing crypto-currencies,
3. If overall mining market outside of bitcoin will be large enough to provide a better mining income in a sustainable way: even if there is a massive transfer of hash power from bitcoin to these alternative crypto currencies.
4. If bitcoin specification is not changed (cf. changes proposed in Section 7.2).

Then we predict that at this next bitcoin block reward halving (in or before August 2016), the hash power will massively shift to other crypto currencies. This could possibly destroy the reputation of bitcoin as it might suddenly become vulnerable to 51 %-like attacks such as described on Fig. 7 page 21. We stress that such transition could happen nearly overnight, on some day in 2016.

12.1 Possible Consequences

At a certain moment in the future we predict a rapid transition to occur and bitcoin becoming vulnerable attacks. We expect that such a transition can lead to a rapid decline of bitcoin as people can switch to other competing crypto currencies very quickly as soon as double spending suddenly becomes feasible to execute in bitcoin. More importantly, merchants would probably **all of the sudden stop accepting any bitcoin payments whatsoever** (the tipping point). This would be as soon as it becomes profitable to commit double spending attacks and therefore it will become very risky to accept any bitcoin payments (as they can be reversed later).

12.2 Counter Arguments

It is very difficult to predict the future. **How can we claim** that a 50 % reduction in mining income will make miners massively quit bitcoin mining? This seems to be in contradiction with recent bitcoin history. In fact the actual reward

¹² However this is subject to some known irregularities and imperfections in the automatic difficulty adjustment mechanism of bitcoin. It is known that the bitcoin clock have been accelerating. Some authors claim the block 420,000 and the block reward halving will happen at up to 1 year earlier, maybe in May 2016, maybe as early as September 2015, see <https://bitcointalk.org/index.php?topic=279460.0>.

¹³ See also Fig. 9 page 30.

for every existing bitcoin mining machines **HAVE BEEN divided by two** countless times already. For example it was divided by two **NEARLY EVERY MONTH** in the last 12 months, see Fig. 3. Yet people **did NOT** go to mine for other crypto currencies at a massive scale. There was no important displacement of hash power, though certainly there was some (which works in both directions, many miners people also switched from other currencies back to bitcoin mining, see Fig. 10). Overall the majority of people kept mining bitcoins as usual.

The reason why miners did not stop mining bitcoins is that miners had no choice so far. No plausible alternative to switch to.

12.3 Decline or Persistent Domination?

We observe that until now there was not a sufficiently strong SHA256-based bitcoin competitor to switch to (LiteCoin does not apply). As long as bitcoin remains a **dominant** monopolist crypto currency, our predictions about decline of bitcoin simply do NOT work.

Now we anticipate that sooner or later competition to bitcoin will be there. One or several SHA256-based crypto currencies will be able to provide higher returns for miners contributing raw hash power.

Remark. This is more than just an opinion. We believe that in the future one should be able to develop a sort of economic theory which shows that this is very likely to happen as already explained in Section 5 as a predictable consequence of several contributing factors: current monetary and reward policies which erode the miners' income¹⁴ with important and sudden jumps¹⁵, competitive markets¹⁶ and other factors¹⁷ including precisely their yet lower level of protection for some currencies¹⁸.

¹⁴ One argument for this (due to J. Kroll) was that bitcoin reward policy is NOT generous enough and does NOT reward miners well enough in the long run, see Section 5.3.

¹⁵ Such sudden jumps have no justification whatsoever, they can only be harmful. They are NOT justified even if we keep the premises of fixed monetary supply, see Part 3 of [5].

¹⁶ When mining becomes less profitable miners are going to increase transaction fees which is going to seriously affect the adoption of bitcoin as a medium of exchange, see Section 5.4.

¹⁷ We can also argue that one of the reasons why bitcoin has attracted such a growth was the expectation it will raise a lot, which is due to built-in unreasonable deflationary monetary policy. Then once bitcoin have achieves the peak of possible appreciation, possibly already in 2014, other crypto currencies with "more reasonable" policies and settings in the sense of Section 5, are likely to emerge as obvious challengers and drive bitcoin out of business.

¹⁸ Additional important shifts in hash power could occur because several criminals might simultaneously be trying to exploit all other SHA256-based crypto currencies in which double spending attacks will be easier to execute by displacing hash power rapidly in both directions, also possibly playing with automatic difficulty adjustments in these currencies at the same time.

13 Summary and Conclusion

Bitcoin has a number of features and properties which are sometimes presented as very interesting and positive. In fact they are highly problematic and there are rather engineering mistakes and early sins of bitcoin digital currency. More importantly, these features have been copied by other currencies, so called alt-coins. We are presented with software systems which are claimed to be payment systems and currencies. Therefore people expect that they will be relatively stable and that they are protected against attacks. In reality serious problems are programmed right there in the DNA of these currencies. Sudden jumps and rapid phase transitions **are programmed at fixed dates in time** and are likely to ruin the life of these currencies. In this paper we show that most crypto currencies simply **do NOT have ANY protection** against double spending. More precisely the current protection is flawed or/and ineffective in all crypto currencies which have copied the mechanisms in place in bitcoin. Overall, many crypto currencies make such attacks too easy. They becomes possible and profitable at particular moments in time known in advance. We do **not know** a single crypto currency which in our view would have been correctly designed and engineered in order to protect our money. On the contrary.

13.1 What's Wrong?

We discovered that **neither Satoshi nor bitcoin developers have EVER mandated any sort of transaction timestamp** in bitcoin software. This can be seen as an expression of some sort of strange **ideology**: giving an impression that maybe the *Longest Chain Rule* does solve the problems in an appropriate way. However clearly this rule is inadequate, it has definite perverse effects and it is in fact simply dangerous and encourages criminal activity. Double spending events are not only facilitated by this exact rule as we show in this paper but they are not even recorded in the current bitcoin network, cf. [10].

The *Longest Chain Rule* is not exactly dead. It is probably OK for deciding for which blocks miners will be attributed a monetary reward (though more stable mechanisms could be proposed). However there is no reason why **the same exact slow and unstable mechanism would also be used to decide which transactions are valid. This is NOT a feature, it is a bug.** An engineering mistake on behalf of Satoshi Nakamoto, the founder of bitcoin. It affects not only the security of bitcoin but also its usability: it makes transactions unnecessarily slow, especially for larger transactions which require more confirmations.

13.2 A Vulnerability Which is Programmed To Get Worse

In this paper we initiate something which could be called a *Theory of Programmed Self-Destruction of Crypto Currencies*. We look at built-in properties in crypto currencies and we point out the combined effect of several factors. We observe that vulnerability to double spending attacks is very closely affected by build-in deflationary miner reward policies and the fact that these policies in their current implementation mandate abrupt and sudden jumps. These moments are likely to coincide with dates on which the hash power is going to

dramatically fall, most probably in August 2016 for bitcoin, and much sooner, at several moments during 2014 for Dogecoin, Unobtanium and many other existing coins. At one moment the protection cushion which is provided by the high hash rate goes away overnight. It becomes possible to execute double spending attacks. More importantly, we show that such attacks can be executed WITHOUT the knowledge of miners which participate in the attack, see Section 8.1. In Section 8.3 we describe a further realistic attack scenario in which this is done without the knowledge of pool managers.

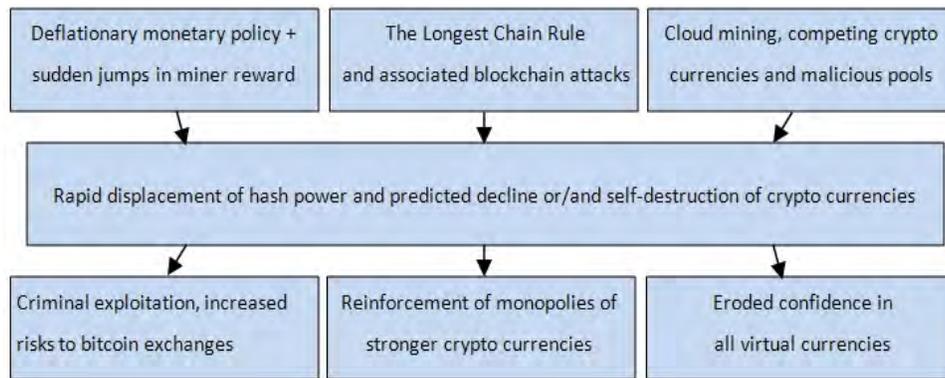


Fig. 15. The built-in risks and dangers in current digital currencies.

In this paper we have identified the DNA responsible for the epidemics of programmed self-destruction which is already affecting more than one crypto coin quite badly with rapid outflow of hash power within days/hours: cf. Section 10 and 11. We conjecture that for small coins, the Longest Chain Rule alone is sufficient to kill them. For large coins which dominate the market, it is still most probably fatal in the long run when it occurs in combination with deflationary monetary policies and in a competitive market environment.

13.3 How To Fix It

It is possible to see that the potentially harmful properties of bitcoin and other crypto currencies which we study on the present paper are not fatal. There is no doubt that the virtual currency technology could be improved or fixed in order to implement more reasonable rules. However it appears that a majority of existing crypto currencies have copied the unreasonable *Longest Chain Rule* of bitcoin and made things substantially worse by mandating substantially faster transitions in monetary policy and reward rules.

In Section 7.2 we propose a method to modify the process of deciding which transactions are valid in a crypto currency. This method is expected to solve the problem of double spending in a better way and also dramatically improve the speed of transactions in crypto currencies. More research on such solutions is needed. The bottom line is that bitcoin software MUST change and implement timestamps for transactions and use them to prevent and police double spend-

ing better than with blockchain alone. Current situation leads to attacks which should simply not exist in a crypto currency.

13.4 Discussion

We should think twice before saying that what Satoshi did was wrong or mistaken. In Section 12 we show that current bitcoin specification makes that bitcoin currency has a privileged position. Smaller bitcoin competitors which use the same hash function are rather unable to survive, cf. Section 10 and 11. Bitcoin tends to remain in a monopoly situation while smaller alt-coins are in trouble, even if they copy its mechanisms exactly. Satoshi and other early adopters may then hope that nobody will challenge bitcoin and they will be able to earn hundreds of millions of dollars selling their coins, cf. Section 2.6 and 12.3.

Remark: Litecoin which uses a different hash function escapes this rule and creates a dominating position in its own space. Here it has been recently challenged by Dogecoin which has achieved a comparable hash rate in February 2014. Unhappily as we show in this paper, the hash rate of Dogecoin is now bound to substantially deflate. It has already become highly vulnerable to double spending attacks, which can be executed by one single miner, cf. Section 11.5.

13.5 Investors and Alt-Coin Designers in Trouble

In this paper we have studied how hundreds of millions of dollars were invested in bitcoin. On one side it is a bubble, on the other side it is an investment. An investment in building secure distributed hashing infrastructure which has costed hundreds of millions dollars and consumes tens of megawatts in electricity. In this paper we show that this investment does **NOT** do the job correctly. We claim that large hash power is **neither necessary nor sufficient** in order to run a digital currency system. We contend that this expensive electronic notary infrastructure is **not** needed for bitcoin to function correctly. It is **not** justified by security against double spending. Now it may appear necessary, because bitcoin and other digital currencies have not really tried to protect themselves against double spending attacks. Current digital currencies simply do allow blockchain manipulation to affect transactions too easily (cf. Fig. 7 page 21).

The current monopoly rent situation for bitcoin (if there is one) is more accidental than deserved. It is rather due to the fact that competitors of bitcoin have not done enough in order to design reasonable crypto currencies (cf. Section 7.2). In fact it is possible to believe that they have been excessively naive and they have fallen into a specific sort of deadly trap. They have copied **those exact mechanisms in bitcoin which mandate programmed destruction of all (weaker) crypto currencies which implement them**. Moreover many alt-coins have accelerated this processus greatly by programming many consecutive very fast transitions to occur within months.

Current alt-coin crypto currencies are also ideal candidates for “pump and dump” investment strategies in which the decline is bound to happen at exact predicted moments in time.

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