Second Layer Network Impact on Bitcoin Mining Fees and Network Value

Abstract—**This paper analyzes the impact of the second layer networks, in particular the Lightning Network, on Bitcoin's mining fees and its broader impact on network valuation, as understood through Metcalfe's law.**

We start with an empirical study of the Bitcoin transaction data from January 2014 to November 2023, focusing on the revenue generated from transactions under USD 1000. Our analysis reveals that these transactions account for over 27% of the total mining fees collected in 2023, highlighting their significance in the Bitcoin economy. A key finding of our research is the substantial impact of the Lightning Network on the fee market, especially for smaller transactions. By facilitating faster and cheaper off-chain transactions, the Lightning Network has the potential to significantly reduce the revenue miners derive from fees, particularly from lower-value transactions. This insight is critical, considering our observation that such transactions form a substantial part of miners' fee revenue.

Next, we model Bitcoin's value over the next eight years, using Metcalfe's law, as a function of the number of Daily Active Addresses (DAA), representing the network's users. This model has been fed with estimations of the Lightning Network's adoption rates to predict Bitcoin's future price. Our results indicate that while the Lightning Network decreases fee-based revenue for miners, it will simultaneously increase Bitcoin's overall network value. This increase is based on the network's expected growth in user base and transaction volume, driven by the enhanced utility and scalability provided by the Lightning Network. Our findings reveal a significant impact on the Bitcoin fee market. While the Lightning Network diminishes transaction fees in the short-term, it has the potential to increase the network's user base drastically, and transaction volume implies a long-term benefit as per Metcalfe's law.

We argue that the Lightning Network's ability to onboard millions of users presents a potentially exponential increase in the network's value, which offsets short-term losses in mining fees. Furthermore, we delve into the future implications of the Lightning Network's widespread adoption, projecting how it could impact the Bitcoin network value proposition from a store of value to a global payment system. Using Metcalfe's law, we model an evaluation system to estimate the economic impact of the widespread adoption of the lightning network (LN). This study contributes to the broader discourse on Bitcoin scalability, the economic sustainability of mining, and the application of Metcalfe's law to digital currencies.

I. Introduction

In 2008, an anonymous entity known as Satoshi Nakamoto introduced Bitcoin [1], a peer-to-peer electronic cash system operating on a decentralized computer network. The blockchain, a public ledger that ensures the transparency and security of transactions, underpins this groundbreaking innovation. Since then, Bitcoin has grown from an esoteric experiment to a global financial asset, attracting significant attention from investors, institutions, and regulators alike.

Bitcoin and blockchain technologies operate under the pressure of solving the blockchain trilemma, a concept coined by Vitalik Buterin [2], that states it is challenging to achieve all three main attributes of a blockchain network: decentralization, scalability, and security without a trade-off in one of those aspects. While Bitcoin offers decentralization and security, its limitation in scalability has been a long-standing issue, and the network's popularity has brought a significant limitation to the forefront regarding scalability. The Bitcoin blockchain can process a finite number of transactions per block, with an upper-bound limit of 27 transactions per second (TPS) [3]. This limited throughput creates a bottleneck as transaction volume increases, leading to slower confirmation times and higher transaction fees. It is needless to say this scalability issue poses a significant challenge for Bitcoin's potential to serve as a universal, high-volume payment system.

To address the scalability issues of Bitcoin, the Lightning Network (LN) [4] was introduced as a second-layer solution to enable fast and low-cost transactions. To achieve this objective, off-chain payment channels between users are opened, allowing them to transact instantly and privately. Only when a channel is opened or closed are transactions recorded on the main Bitcoin blockchain, drastically reducing the need for on-chain confirmations. It is well-known that the Lightning Network has the potential to alleviate the existing scalability issues and substantially increase Bitcoin's transaction throughput [5], [6].

Despite the benefits that the Lightning Network offers in terms of scalability, the widespread adoption of the Lightning Network could carry unintended consequences, particularly for the miners who secure the network. Miners play a crucial role in validating transactions and adding them to new blocks on the blockchain. The miners are compensated for their efforts through block rewards and transaction fees. In particular, as Bitcoin approaches its maximum supply limit of 21 million coins, transaction fees will become the primary source of miner revenue. On the other hand, Lightning Network's off-chain transactions bypass the need for miners to validate each transaction, potentially diminishing their fee revenue. Therefore, previous work have argued that shifting transactions from the main network to second-layer networks, such as the Lightning Network, will adversely impact the miner's profit and hence pose a danger to Bitcoin as a global currency in the future [5], [6].

In this paper, we further investigate the following question concerning the impact of the Lightning Network on Bitcoin in the long run: *Will the shift of transactions to the Lightning*

Network negatively impact the fee market of the Bitcoin main network and, consequently, miner revenue?

By examining the intricate interplay between the Lightning Network solutions and the evolving economic model of Bitcoin mining, this paper seeks to provide insights into the long-term sustainability of the Bitcoin network, bringing into consideration important factors such as network growth and ordinal inscriptions.

A. Contributions

We evaluate the fee market of the Bitcoin main network from 2014 to 2023. We observe the miner's revenue if transactions below a certain threshold, e.g., 1000 USD, were carried exclusively on the Lightning Network (LN). This helps us measure the impact of removing such transactions from the main network on miners' revenue in the past. This is followed by further measuring the projected impact over the next few years as follows.

To evaluate and measure the impact of the Lightning Network on the miner's revenue in the future, we bring into consideration the positive impact of the Lightning Network (LN) in terms of the widespread adoption of the technology and integration with traditional finance entities, called *SuperHubs*, that would enable the onboarding of millions of users to the network. Analyzing historical data, we collect information concerning bitcoin value and the number of network users (Daily Active Address - DAA). We model the impact of the user adoption on the Lightning Network (LN) using Metcalfe's law [7], [8] to extrapolate the USD value for each Bitcoin as millions of users are using the Bitcoin network through LN channels.

Our experimental results confirm a potentially negative impact on the miners' nominal number of Bitcoins collected as fees with the widespread adoption of Lightning Network. Nevertheless, the projected higher Bitcoin price, as predicted by Metcalfe's law, will result in more revenue for miners in terms of USD. We conclude that the widespread use of Bitcoin, made possible through the Lightning Network, will result in higher Bitcoin value, compensating for the lower number of nominal Bitcoins collected as fees and thus, **the mining remains profitable**. In our experiments, we recognize the demand for block space from new user cases such as Ordinals inscriptions [9], which remain on the main network.

Roadmap. The rest of the paper is organized as follows. Section II presents a summary of the related work. In Section III, we introduce a preliminary analysis on the evolution of price over Halving cycles, the Evolution of the network hash rate, Metcalfe's law impact on price, the concept of SuperHubs and other components such as Ordinal and Taproot that might affect the fee market. In section IV, we present the analysis of the network and experiments we carried out on Bitcoin. In Section V, we present experimental results. Finally, in Section VI, we conclude our work with some thoughts for further exploration.

II. Related Work

Brown at all [10] used the blockchain data to infer the impact of the adoption of Segwit [11] on the fee market for block space. They found that Segwit has reduced the fee revenue for miners by about 70% and that fee revenue would be maximized with a block size of around 0.6MB. Considering Segwit adoption at the current levels and the actual blocksize, the maximum fee revenue would be 1/8 of the current average block rewards (Fee + Rewards). They concluded their research by questioning if Bitcoin can avoid double spending, only relying on transaction fees to fuel mining participants to keep the network secure.

The Lightning Network (LN) is a second-layer scaling solution designed to address the scalability limitations of the Bitcoin Network by enabling off-chain transactions. It utilizes payment channels to facilitate instant and low-cost transactions, reducing congestion on the main network and potentially influencing the fee market dynamics. Divakaruni and Zimmerman [6] studied the impact of lightning network adoption on the efficiency of Bitcoin as a means of payment. They found a strong correlation between the LN adoption and the reduction of blockchain congestion, which could not be associated with adopting SegWit or changes in transaction demand. They concluded that adopting the Lighting Network reduces the congestion on the mempool, ultimately lowering the fees.

Previous studies have investigated the impact of the Lightning Network on the Bitcoin Network fee market. Branzei et al. [5] analyzed the capacity of LN to onboard millions of users and the impact of LN on Bitcoin transaction cost, concluding that LN does allow transactions to scale to a higher number. At the same time, it does not necessarily provide higher fees to miners. A study by Decker and Wattenhofer [12] proposed a variant of the Lightning Network which is slightly different from the one introduced by Poon and Dryja [4] and analyzed its potential benefits in terms of scalability and fee reduction. They argued that allowing the two channels to operate independently could reduce the bandwidth required to reset the channel, as they do not need to renew the whole transaction structure.

Malavolta et al. [13] focused on assessing the scalability and cost-effectiveness of the Lightning Network. They evaluated the Lightning Network's performance, considering factors such as transaction confirmation times, channel capacity, and network connectivity. Their findings indicated that the Lightning Network has the potential to significantly increase the transaction capacity of the Bitcoin Network while reducing fees.

III. Components of Modern Bitcoin Network

Bitcoin is envisioned to be a decentralized, permissionless and secure payment system with a fixed supply of 21 million coins, with its issuance predetermined since its inception. To distribute the newly minted coins, a unique transaction called coinbase [14] is added at the beginning of each block, which creates new coins that the creator of the block will own.

The minting of new coins through the coinbase transaction incentivizes the network's security and provides a way to distribute coins without relying on a central authority. This process is similar to gold miners expending resources to add gold to circulation. As gold is extracted from nature, more and more resources are necessary to extract the same amount over time. The same holds for Bitcoin, as there is a fixed supply of coins that will be mined and a predetermined distribution partner, namely $\sum_{i=0}^{32} 210,000 \frac{50}{(2^i)}$. This distribution partner is often called the Halving Cycle, and it is preprogrammed to occur every 210,000 blocks[1]. This process started with the Genesis block, rewarding 50 newly minted coins for each block added to the blockchain. Since then, we have passed through 3 halving cycles, bringing rewards from 50 to 6.25 coins per block.

Reducing the issuance of new coins every 210000 blocks is related to reducing its inflation rate and big swings in the market price. Gronwald et al. [15] correlate the predetermined supply reduction (new coins have been minted) with the increase in demand to the increase in the token's value. Analyzing the past 3 halving cycles see fig-1, we can quickly identify that after each halving event, the price of Bitcoin has a big swing but remains higher (on average) than the previous cycles.

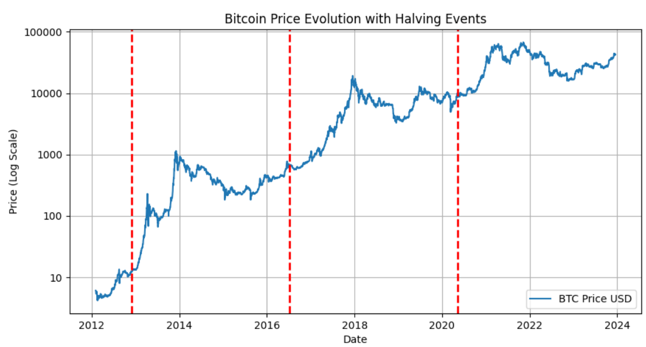


Fig. 1: Bitcoin price in USD Dollar over time with halving events highlighted

A. Lightning Network

The Lightning Network (LN) [4] was proposed to increase the throughput of the blockchain systems. This technique allows unlimited transactions to take place off-chain using the concept of *channels*, a multi-signed locked fund shared between multiple parties. A channel can be either released unilaterally (without the consent of the other parties) or through a collective agreement between parties (with the consent of all other parties). One can execute thousands of transactions instantaneously using a Lightning Network channel, with as few as two transactions processed in the main network. These two transactions are the *fund* transaction (open channel) and the *commitment* transaction (close channel). As transactions can settle off the main network, this approach offers smaller fees to allow micro-payments and instantaneous payment confirmation. Despite this advantage, the Lightning Network moves away transactions from the main network [6], reducing blockchain congestion, which ultimately can impact the fee revenue of the miners in the main network. The negative impact on revenue from fees may cause a problem in the future when the fees become the only revenue stream for the miners. The Lightning Network transactions would not compete for space in the block, contributing to decreased miner fees. As such, many miners might eventually leave the network due to decreased revenue.

Moreover, a spike in the Bitcoin fees could impose a challenge for widespread use of the LN as the eventual cost in opening and closing channels can make the use of Lightning Network too expensive to be feasible [16]. To the best of our knowledge, the only work that attempted to shed light on the impact of the Lightning Network on the Bitcoin mining fee was done by Branzei et al [5] in 2017, when the implementation of the lightning and its use was still undergoing. To conduct the study, a series of educated assumptions was made to model the market fee and the impact of lightning on the miners' revenue. As a result, they concluded that while the Lightning Network has the potential to allow micro-transactions and unblock the blockchain's true potential in terms of the throughput of transactions, it does not necessarily provide higher fees to the miners. In this paper, we will study the evolution of the bitcoin price after the halving events. The evolution of the network's hash rate over time and Metcalfe's law [17] correlation with the number of active addresses and the value of the network. In addition, We will explore the integration of Lightning Networks on centralized exchanges and other entities called SuperHubs.

B. SuperHubs

The concept of *SuperHubs* is represented by large-scale technology corporations such as banks, exchanges, startups, and technology giants such as Apple[2] and PayPal [3]. With their vast customer bases, these entities are uniquely positioned to facilitate the widespread adoption of Bitcoin and similar technologies. Their ability to integrate the Lightning Network into their services stack can onboard millions of users to the Bitcoin network.

SuperHubs have the financial and technical capacity to absorb higher operational costs, including transaction fees on the Bitcoin network. This operational efficiency is essential for maintaining the attractiveness of Bitcoin as a payment system, especially in light of fluctuating network fees. It ensures that the use of Bitcoin remains viable and cost-effective for many users. SuperHubs would work as a third layer allowing the companies and users to use Lightning Network and Bitcoin without necessarily interact with them directly. This proxies

[1] Considering the average block time of 10 minutes, the halving happens roughly every four years

[2] In 2023, Apple had 507 Million users globally

[3] In Q3 2023, PayPal had 428 Million active users

would onboard millions of users to Bitcoin network driving the appreciation of the token.

C. Evolution of the network hashrate

The Bitcoin network was engineered to keep increasing its hash rate as adoption grows and the value of the network increases. Throughout its short history, the Bitcoin network has evolved from a single CPU miner to GPUs and, lately, to Application-specific Integrated Circuits (ASICS). Hardware specialized in executing the SHA256 faster and cheaper has been launched year by year, supporting the growing mining operation business. Companies specialized in developing mining equipment, such as Bitmain [18], have been growing rapidly, catching the attention of big tech companies such as Intel [19] and NVidia [20] that are launching its own specialized devices. Another evolution in the crypto mining business can be seen in its professionalization and growth. What was initially done by crypto enthusiasts on their equipment became a profitable business with the surge of mining pools such as Foundry [21], Antpool [22] and F2Pool [23], and openly traded companies specialized in mining operations such as Argo [24], Hive [25], Marathon [26] and others. The Bitcoin mining industry has been evolving over the last decade, overcoming big drops in token prices such as the ones in 2014, 2018 and 2022 and crackdowns on mining operations such as the one that happened in China in 2021, when around 50% of the network hash power was turned off and relocated from China to other countries. However, to support its growing rates and keep the investments in new infrastructure and power, the miners only rely on the new coins mined each block and the fees collected from the transactions processed in each block. As mentioned before, the rewards are programmed to be reduced by half for each 210.000 blocks, transitioning the source of revenue from the newly minted coins to transaction fees. A recent study from Fantazzini and Kolodin [27] investigates the correlation between Hashrate and Bitcoin price through a methodology based on exponential smoothing to model the dynamics of the Bitcoin network. The empirical evidence shows a correlation in which the causality is unidirectional, going from the Bitcoin market price to the Hashrate. As the Bitcoin price increases, more Hashrate is deployed to the network.

D. Metcalfe law impact on price

Metcalfe's law [7] concerns the impact of network parameters on asset value. Metcalfe's law suggests that the value V of a network is proportional to the square n^2 of the number n of its users, mathematically represented as $V \propto n^2$. This principle has been scrutinized in the context of Bitcoin, with studies such as [28], [29] effectively demonstrating that Bitcoin's value, in the long term, is closely related to the size and engagement level of its user network. As the number of users and transactions increases, Metcalfe's law suggest that we should see a corresponding rise in the Bitcoin network value.

The Lightning Network is a layer-2 solution that mitigates Bitcoin's scalability issues by facilitating off-chain transactions. By effectively increasing Bitcoin's transaction throughput and reducing transaction fees, the Lightning Network aims to make Bitcoin more accessible and usable. This can result in a potential broader user base and more transactions using the Bitcoin token, which, according to Metcalfe's law, would enhance the overall value of the Bitcoin network.

The wide adoption of the Lightning Network catalyzed by the integration with SuperHubs could amplify the network effects, possibly driving up Bitcoin's overall value. This increase in value could counterbalance the loss in miners' fee revenue due to the shift of transactions to the second layer, making the impact of the Lightning Network on miner profitability a complex and multi-faceted issue.

E. Ordinals Inscriptions and Taproot: Impact on Bitcoin's Block Space

Ordinals [9], a novel concept introduced in December 2022, allow individual identification of each satoshi, which, together with Taproot, pave the road for inscribing arbitrary content in individual satoshis in an economical manner. Ordinals present a unique way of utilizing the Bitcoin blockchain's capacity that was not widely utilized previously. With ordinal inscriptions, users can embed a wide range of data types onto specific satoshis, from text and images to small executable codes. This ability opens up novel use cases for the Bitcoin network, extending its utility beyond financial transactions. For instance, it allows for the creation of unique digital artifacts and collectibles, reminiscent of NFTs, as well as tokens using the BRC-20 (short for Bitcoin Request for Comment 20) [30], [31], but with the added security and immutability of the Bitcoin blockchain.

The Taproot upgrade, introduced in 2021, has been a crucial development for Bitcoin, enhancing its smart contract capabilities and efficiency. This upgrade, which incorporates Schnorr signatures and Merkelized Abstract Syntax Trees (MAST), offers a more space-efficient way of handling transactions, particularly for complex smart contracts. However, the new capabilities also pave the way for what is informally referred to as Taproot assets – new types of transactions and digital assets leveraging the improved scripting abilities. These Taproot assets could increase the overall volume of transactions on the network as they enable a broader range of applications and use cases, potentially leading to an increased demand for block space. While Taproot makes individual transactions more efficient, the cumulative effect of these new applications might necessitate further considerations for the network's scalability solutions. Finally, these enhanced functionalities mark a significant evolution in how the Bitcoin blockchain can be used; it also brings congestion to the network, increasing the fees and indirectly miner revenue [32].

IV. Network Analyses

A. Data Collection

This section reviews the setup used to obtain the Bitcoin data and how we establish a safe selection strategy for the transactions we considered relevant for the experiment.

For our work, we collect the transaction data from Google BigQuery public Data, dataset *crypto_bitcoin* provided and maintained by Google [33]. We use the Bitcoin transaction data from the blockchain data platform Dune Analytics [34] to get the data for ordinal-inscription transactions. Both datasets have a reliable ETL (Extract, Transform, Load) data pipeline from a public blockchain to a relational database, which allows us to query specific information about the transactions using Structured Query Language (SQL). We also use the Bitcoin daily price dataset from Investing.com [35].

To visualize the fees paid to miners generated by small transactions, we queried Google BigQuery public Data for transactions on the Bitcoin Blockchain from 01/01/2014 to 30/11/2023 excluding coinbase transactions. The following information are extracted:

- Block_timestamp: the timestamp that the transaction was recorded;
- Input_value: the value in satoshis of all the UTXOs used as input of the transaction;
- Fee: the fee value in satoshis paid to the miner that included it in the blockchain.

We obtained the Bitcoin price from Investing.com [35]; we have used the following information from this dataset:

- Date: Representing the date for the data point;
- Low: The lower the price went within that day in USD;
- High: The higher the price went within that day in USD.

B. Potential Impact on Fees with Lightning Adoption

Based on the assumption that small transactions would be better suited to be carried through Lightning Network, we created a series of thresholds, namely 100, 500, and 1000 USD, to compute the fees such transactions have paid on the Bitcoin Blockchain since 2014.

We computed this impact using the following steps:

- We converted the input values from satoshis to Bitcoin using the following equation (based on the definition of satoshis) as
$$\frac{InputValue}{10^8}$$
- The input value in bitcoin was then converted to USD by multiplying the bitcoin amount with the average of the lowest and highest USD exchange rate for the given day.
$$InputValue \cdot (\frac{USD(Low) + USD(High)}{2})$$
- We calculated the total fees collected for each year from 2014 to November 2023, accounting for the fees generated from transactions below each threshold. Fig.2 depicts the potential impact on fees collected if all those transactions were carried out using LN.

In order to model the price of Bitcoin using Metcalfe's law, we query all the addresses that have a balance above Dust [36] on any given day to compute the "Daily Active Address" (DAA) data point. We also compute the commutative number of Bitcoin in circulation for the study period based on coinbase transactions [14].

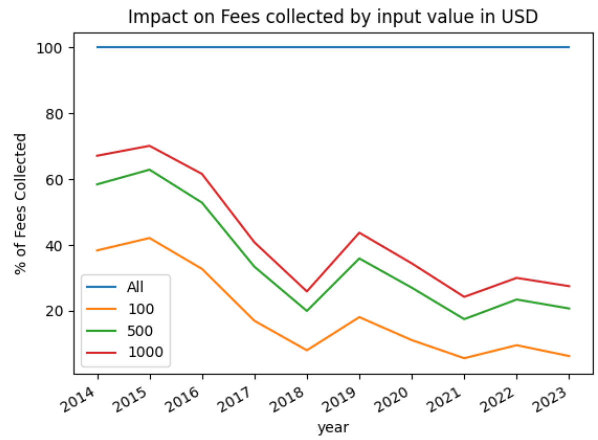


Fig. 2: Impact on yearly fees collected by removing transactions that fit on thresholds 100, 500, and 1000 USD when processed.

C. Bitcoin price model using MetCalfe's law

We model the price of a Bitcoin (in USD) based on the Metcalfe law valuation of a network. Similar methodology has been adopted in [29], [37]. We used the Bitcoin on-chain transactions dataset provided by Google in the BigQuery [38], and the Bitcoin daily closing price from Investing.com [35]. We queried the transaction dataset to compute the number of Daily Active Addresses (DAA), which is a count of distinct addresses that were involved in any transaction happening on a given day.

Metcalfe's law is a core idea in network economics, that states that value of any network connecting users is proportional to the number of possible pairs of users in the network (say P). For Bitcoin payment network, we compute the transaction pairs P from Daily Active Addresses DAA (say D) as

$$P = \frac{D(D-1)}{2}. \quad (1)$$

We also query the blocks generated on each day which are used to compute the cumulative bitcoins generated in the network till a given day (say N), which is used to model the value decay factor in Metcalfe's modelling of Bitcoin network. A Bitcoin address is considered active on a given day if it was part of at least one transaction. We also take into account the saturation in growth of network value as more users become part of it, by factoring in a decay parameter (G) modelled as Gompertz sigmoid function [4], described by equation below.

$$G = N \cdot \ln(21000000/N) \quad (2)$$

Here, 21000000 represents the total number of Bitcoins to be mined. To assess the impact of network value on Bitcoin's

[4]Function used to model a time series, where growth is slowest at the start and end of a time period.

price, we introduce the Metcalfe input M:

$$M = \ln(P/G) \tag{3}$$

We fit a linear regression model using Metcalfe input described above as the independent variable and the price of 1 BTC denominated in USD as the dependent variable. We use a 30 Day moving average transformation of the Metcalfe prediction to remove noise and only capture the trends. The model is trained on data from 2014 to 2023 and results can be seen in Fig.3 which depicts a close relation between value of Bitcoin and its predicted value from Metcalfe's model.

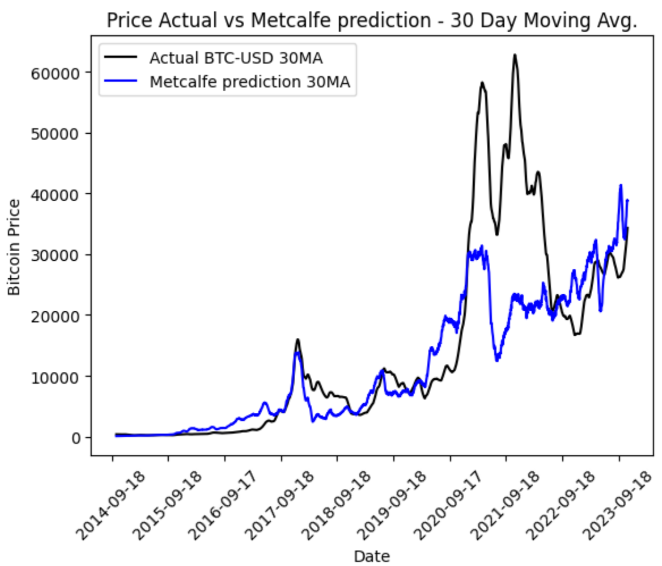


Fig. 3: BTC price vs Metcalfe's law prediction on a 30 day moving average

V. Experimental Results

We experimentally simulate the impact on mining fees, considering that Bitcoin network users would rationally settle transactions of a value smaller than our chosen thresholds in USD terms (100, 500, 1000) in the Lightning Network. To simulate three chosen thresholds, we choose the transactions in which the UTXOs used as inputs are smaller than the given threshold. We know that centralized exchanges and seasoned Bitcoin users might batch transactions to reduce the cost of fees. Thus, in our simulation, we still have fees paid to miners that eventually would be moved to the Lightning Network but are not captured on the current heuristic. We also evaluate the transactions that fit in the thresholds but are not usual payment transactions or transference of Bitcoins, such as Ordinal inscriptions [9], that are used to write arbitrary data into the blockchain; the majority of ordinal transactions have a small input value and would not move to LN as the core goal of this type of transactions is to write data into the main network.

The percentage of fees collected that would fit each threshold excluding the ordinal transactions by year can be see in Fig.2. Transactions suitable to LN can represent a considerable amount of fees miners collect in 2023. The higher threshold transaction with a USD value below 1000 dollars (highest of the three thresholds) represents more than 27% of the total fees miners accrued in 2023. As these transactions have a small value, they are more suitable to be carried on a second-layer network, such as LN, as it would be cheaper and faster to process. Considering the rapid shift of the incentives from rewards (new coins created on each minted block) to fees collected from transactions. The potential to have over 27% of the revenue moved away from the main network might be a risk for the network's security, as miners might move their computation power to other networks with better incentives.

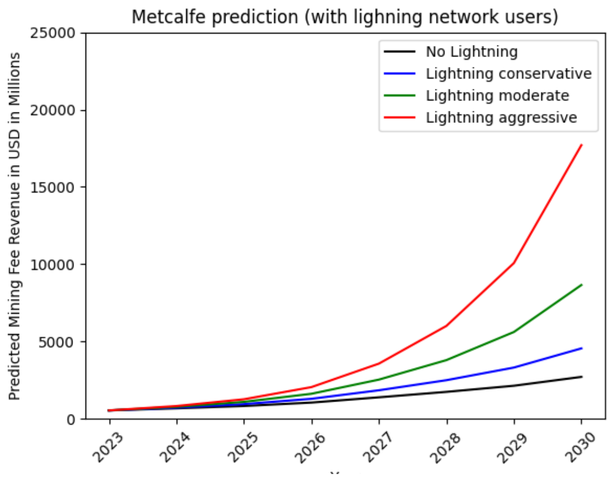
Our hypothesis is that any such reduction in fee collected would be compensated by the increase in value of a single Bitcoin due to the increase in user base enabled by LN and SuperHubs. We use the Metcalfe's model described in section III-D. The predictions of the trained Metcalfe's model compared to actual Bitcoin prices for the period of study are plotted in Fig.3. We use this trained model to get the price in next 8 years based on the projected number of Daily Active Addresses (DAA). We first estimate the number of DAA on the Bitcoin main network by doing a linear extrapolation of the average yearly DAA from 2018 to 2023. This count is further augmented by the active Lightning Network users, which is based on a research report by River Financial [39] estimating between 279,000 to 1,116,000 monthly active users. We take the lower end of the estimated users from this report (279,000 active lightning users in October 2023), and then for future years, we assume yearly growth based on the following three scenarios - conservative (10 % growth), moderate (20 % growth), and aggressive (30 % growth), with a decay factor year over year of 2%, 3% and 4% respectively. The DAA for 2024 - 2030 is calculated based on these yearly growth rates plus the linear extrapolation of users from the Bitcoin network. The Metcalfe input is computed on these hypothetical future users using the equation **??**. We also compute the new bitcoins minted for these future years based on the reward mechanism in Bitcoin protocol. The BTC price prediction for years 2023 - 2030 based on the conservative growth of the Lightning Network user base is shown in Fig.5.

Considering the hypothetical situation of all the transactions under the thresholds (100, 500, 1000 USD) moving to LN, we apply the impact (say I) on the amount of fees generated to miners (say F) and keep it constant throughout the following year. The total fee collected over a year (say TF) is computed as follows:

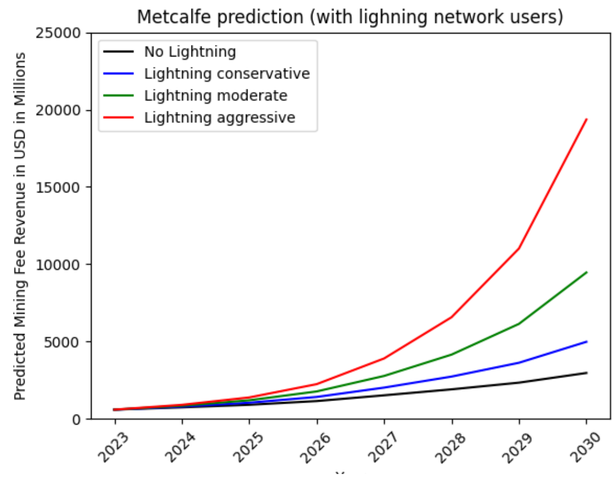
$$TF = I \cdot F \tag{4}$$

The total amount of USD collected as fees from miners is computed by multiplying Metcalfe's prediction by the Total fee collected (TF). These years are shown in Fig.4.

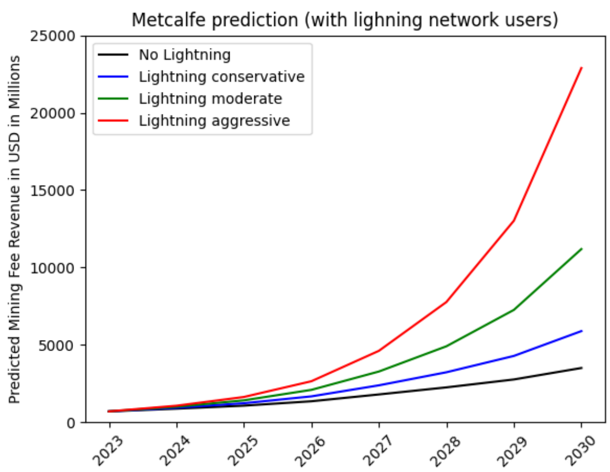
The worst-case scenario represented by Fig.4a in which the fee collected by miners is reduced by 27.48% due to transactions with values smaller than 1000USD moving to



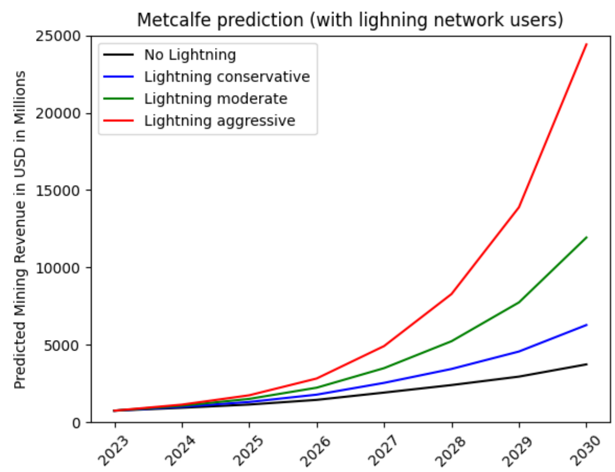
(a) Annual Miner's Fee Revenue stream assuming that the amount of fees paid by transactions below 1000 USD move entire to LN



(b) Annual Miner's Fee Revenue stream assuming that the amount of fees paid by transactions below 500 USD move entirely to LN



(c) Annual Miner's Fee Revenue stream assuming that the amount of fees paid by transactions below 100 USD move entire to LN



(d) Annual Miner's Fee Revenue stream considering that the amount of fees paid to Miner stays flat

Fig. 4: Miner Fee revenue using MetCalfe's law price prediction on different assumptions for LN impact on Mainnet Fee Market and Different growth for Lightning active daily users.

the Lightning Network. Even considering that this demand for block space, and hence transactions fees, would not come back to miners by other use cases such as ordinals, this scenario, considering the increase in adoption that lightning can provide with the SuperHubs, will impact the Bitcoin price so that the mining revenue is still growing superlinear.

The best-case scenario is represented by Fig.4d where the fee collected by the miners is not reduced, due to new demands such as Ordinals and Taproot assets as discussed in III. In this case, the miners revenue tend to increase substantially, as they still collecting the same amount of Bitcoins from fees but leveraged by the increase in price due to the increase adoption promoted by LN and SuperHubs.

The exploration of the Bitcoin network value, particularly through the lens of Metcalfe's law and user adoption through the use of the Lightning Network on the SuperHubs, reveals a complex yet compelling interaction between a possible reduction in fee collected and an increase in network value. Our analysis also shows that in 2023, ordinal inscriptions have already begun to significantly influence the network's fee market, accounting for a notable 20.6%[5] of miners' fees. Furthermore, transactions under $1000, comprising over a quarter of miners' fees, underscore the demand for retail and micro-transactions within the Bitcoin ecosystem. In a scenario in which ordinal inscriptions are developed in a mature market, the demand for block space tends to increase, which will positively impact the fees collected by miners. Considering that other types of transactions can replace the small transactions in value moving to LN, in Fig.4d, we show

[5]Value computed considering transactions processed from Jan to Nov 2023

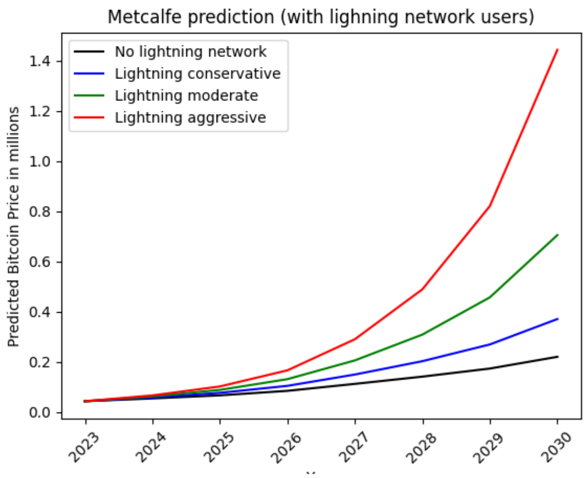


Fig. 5: Bitcoin price in millions of USD computed from price prediction based on Metcalfe model and simulated growth of Lightning Network activity (Conservative, Moderate and Aggressive)

the projection of miner revenue when the amount of Bitcoins collected as fee stays flat even.

In summary, our model of Metcalfe's law to predict Bitcoin's value, incorporating various adoption scenarios for the Lightning Network, offers an optimistic view of the network's growth and valuation over the next eight years. The models predict a robust expansion in network value, driven by increasing user engagement and transaction volumes. This growth trajectory suggests that while the Lightning Network might initially impact miners' fees, the long-term effect could be a substantial increase in the overall economic activity on the network.

VI. Conclusions and Future Work

This study's findings highlight a shift in Bitcoin's operational dynamics. As we move forward, the network is consolidating the transition from a mining-reward-based economy to an increasingly transaction-oriented one. This shift has challenges, particularly regarding scalability, accessibility and network efficiency. However, the potential for growth and innovation within the Bitcoin network remains immense. As the network grows in number of users and its applications, the demand for the token will raise the price, contributing positively to the amount of hash power deployed to the network.

As Bitcoin continues to evolve, the increasing integration of technologies like the Lightning Network and the introduction of other user cases for blockchain immutability and security, like Ordinals applications, is set to redefine the landscape of Bitcoin. These advancements enhance Bitcoin's utility and applications, which can usher in a new era of digital finance.

In conclusion, our study shows that the Bitcoin network is evolving, and the demand for block space trends will increase even though the Lightning Network moves transactions away from the main network. For future work, The decisions and paths taken in the near future will significantly shape the network's trajectory, potentially influencing the broader digital economy. Continuous observation, analysis, and adaptation will be key to navigating this ever-evolving domain.

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