

The State of Lightning

October 2021





Arcane Research

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OpenNode supports settlement in major currencies and provides businesses controlled exposure to Bitcoin, removing complexity and risk.

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DISCLAIMER

This report is powered by OpenNode, a Bitcoin payments company. The report is written and compiled by Arcane Research. OpenNode has provided valuable data and feedback, but Arcane Research has had full autonomy.

Foreword by Elizabeth Stark – CEO of Lightning Labs

Arcane’s “The State of Lightning” highlights how the Lightning community has been making bitcoin more accessible to people around the world. At the end of the day, building the native transaction rails of the internet is a marathon, not a sprint. We are just hitting an inflection point, but we’re still at the very beginning of the curve. In this report, we see that Lightning is already enabling people to send money instantly via internet-native global transactions, with immense opportunities in emerging markets. We believe in solving real problems for real people and are at the cusp of bringing bitcoin to billions with Lightning. In other words, number of people go up.

Watch this space.

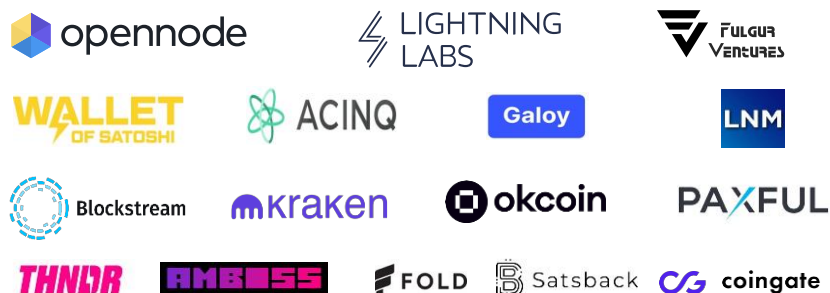


A special thanks to Lightning Labs for their help in making this report. Elizabeth and Ryan have contributed with invaluable review, feedback, and an extensive network of contacts to help us gather data. Lightning Labs develop software that powers the Lightning Network. Their open-source, secure, and scalable Lightning systems enable users to send and receive money more efficiently than ever before. They also offer a series of verifiable, non-custodial Lightning-based financial services. Lightning Labs bridge the world of open-source software and the next generation of bitcoin financial software.

Review contributor

Fulgur Ventures has been a valuable review contributor for this report. Fulgur is a VC fund investing in early-stage startups focused on Bitcoin and the Lightning Network. Since 2019 they have partnered with over 30 amazing founder teams to grow the bitcoin ecosystem together. Lightning Network projects database and useful resources from Fulgur can be found at fulgur.ventures

Another special thanks to all companies and people who have helped us get a deeper understanding of the Bitcoin Lightning Network. Joao Almeida, Afnan Rahman, Rui Gomes and Ryan Flowers (OpenNode), Ryan Gentry and Elizabeth Stark (Lightning Labs), Moritz Kaminski and Oleg Mikhalsky (Fulgur Ventures), Daniel Alexiuc (Wallet of Satoshi), Pierre-Marie Padiou (Acinq), Nicolas Burtey (Galoy), Romain Rouphael and Côme Jean Jarry (LN Markets), Christian Decker, Fernando Nikolic, and Lisa Neigut (Blockstream), Pierre Rochard (Kraken), Jason Lau (Okcoin), Kristina Bannan and Ray Youssef (Paxful), Jack Everitt (Thndr Games), Anthony Potdevin and Thomas Jestopher (Amboss), Will Reeves (Fold), Tom Chojnacki (Satsback), and Coingate.



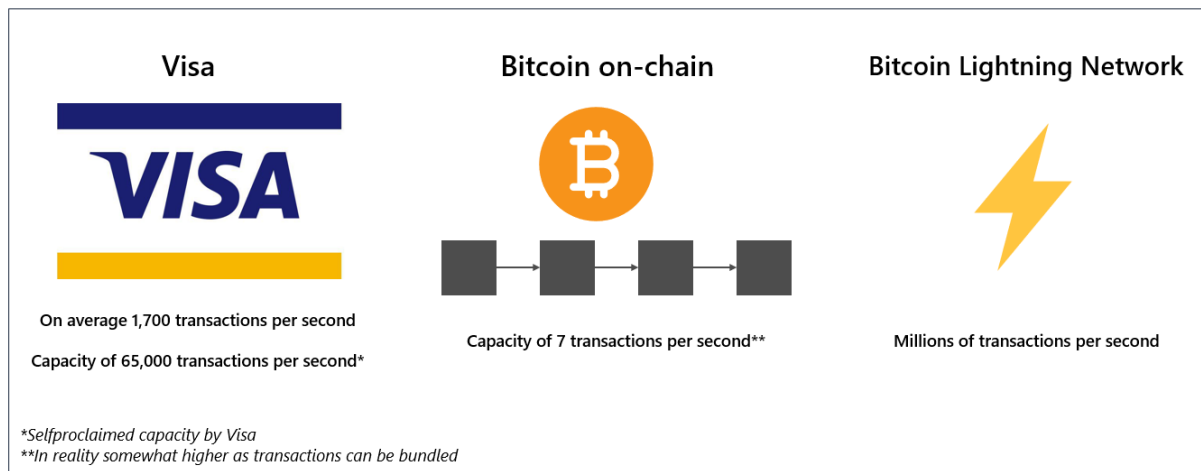
Summary: The State of Lightning

Bitcoin is a digital currency operating free of central control or oversight by any banks or governments. Instead of trusting a central bank or government to secure the value of their currency holdings, bitcoin holders can rely on the ingenious technical setup and incentive mechanisms of the Bitcoin Network to protect their value.

Critiques have labeled Bitcoin as too slow of a technology to prosper as a payment network. This is partly true, as Bitcoin’s on-chain throughput capacity peaks at 7 transaction bundles a second. For comparison, Visa handles on average 1,700 transactions a second and claims a capacity of 65,000 transactions per second. The Bitcoin Network could change its protocol to allow more payments per second, either through increasing block size or decreasing block time, but this will come at a cost. The slow validation and generation times, and the incentives for miners are fundamental to Bitcoin’s core value proposition—security.

The Lightning Network represents a solution to Bitcoin’s slow throughput without compromising the security of the Bitcoin Network. Utilizing the Lightning Network, millions of people can send fractions of a bitcoin at near-instant speed—at the same time.

Figure 1 – Visa Transactions per Second vs. Bitcoin on-chain Transactions per Second vs. Lightning Network

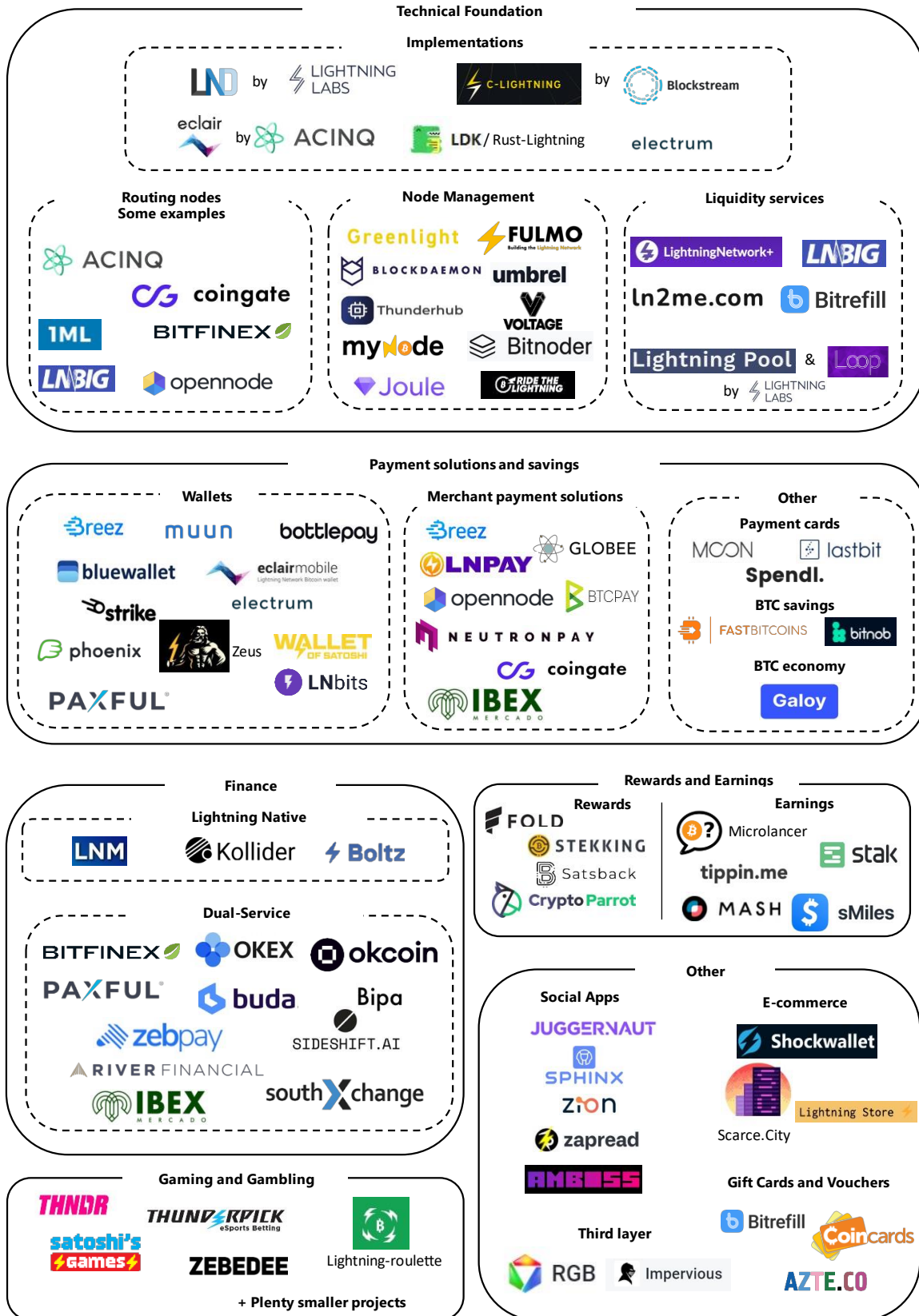


Source: Visa, Arcane Research

Lightning usage growing faster than the public metrics show

The key ideas behind the Lightning Network were first described in a [draft white paper](#) authored by Joseph Poon and Thaddeus Dryja in 2015, but it would take three years to translate the concept into a working code with the Lightning Network launching in 2018. The early years have been dominated by technical development and niche applications, and we’re still partly in this phase, but the usage growth has picked up significantly since late 2020. Making increased adoption possible is a whole ecosystem of companies and projects. Many have been working with the Lightning Network for years, while others have newly entered the scene. We have divided the current ecosystem into six subsectors, with a range of companies as an illustration.

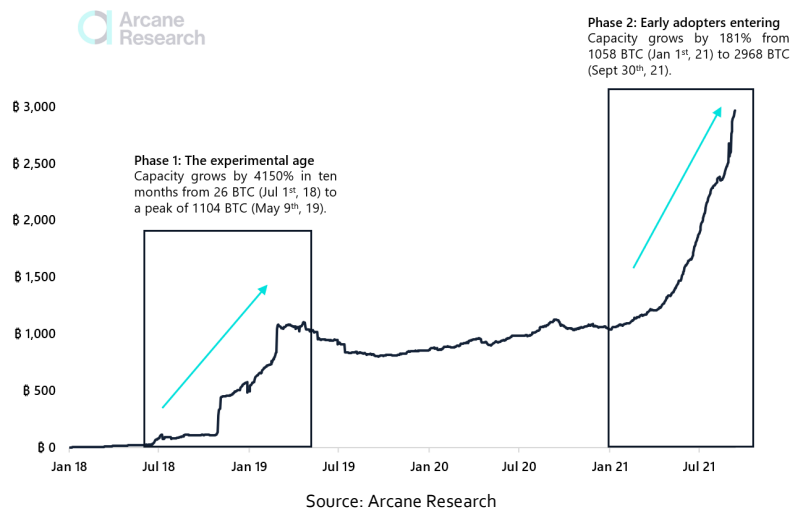
Figure 2 - Bitcoin Lightning Network: Ecosystem Overview



Source: Arcane Research

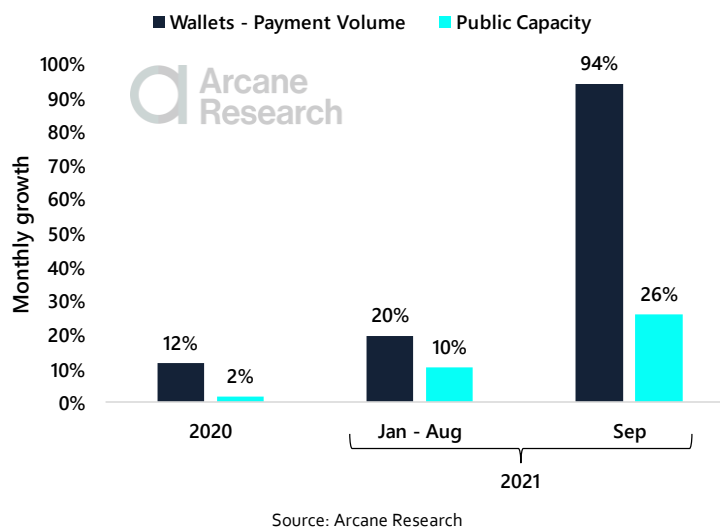
Public statistics such as total channel capacity and the number of nodes show that the Lightning Network is growing rapidly. The figure below shows the exponential growth in BTC Capacity on the Lightning Network this year.

Figure 3 – Lightning Network: Public BTC Capacity 2018 - 2021



However, public metrics do not show the true magnitude of usage growth. Due to highly detailed input data from significant actors in the Lightning ecosystem, we have been able to make detailed estimates on the historical usage of the Lightning Network. We have focused on mainstream usage through wallet providers, as we believe this is the best measuring stick of adoption. Therefore, the estimated numbers do not contain the activity from developers, channel rebalancing, most b2b transactions, etc. Wallet payment volume has increased far more than the most widely cited growth metric, total channel capacity, over the past year. Wallet payment volume grew by 20% monthly from the start of 2021 to the end of August, with the equivalent number for public channel capacity being 10%. In September, the discrepancy widened further, with payment volume almost doubling compared to a 26% increase in public channel capacity.

Figure 4 – Growth in payment volume (USD) from wallets on the Lightning Network vs. growth in public capacity (BTC). Monthly compounded.

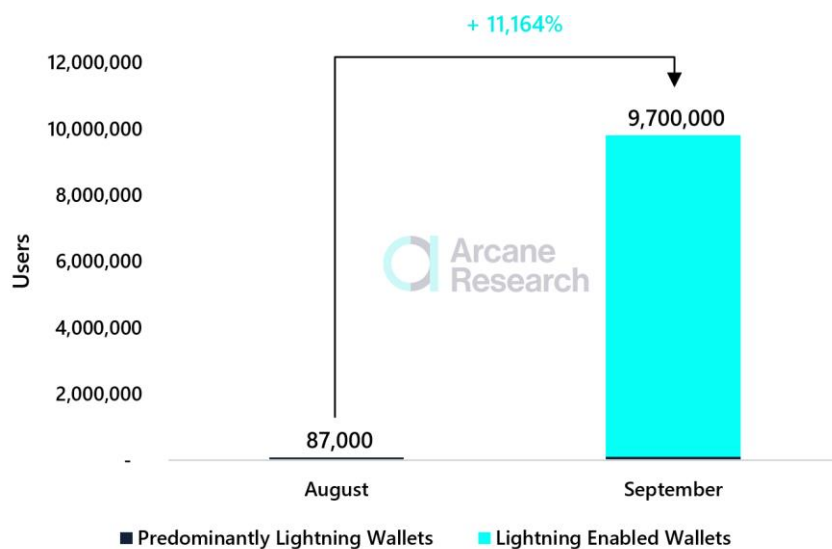


Usage on the Lightning Network has been in a steep upwards trajectory since late 2020, and in September 2021, growth went parabolic. This was driven mainly by the introduction of bitcoin as legal tender in El Salvador. As of October 1st, El Salvador President, Nayib Bukele, stated that 2.7 million Salvadorans have been onboarded to the Chivo wallet. The number of Chivo users is not directly equivalent to the same number of active Lightning users. Still, 2.7 million Salvadorans now have access to pay through the Lightning Network on their mobile phones. Other prominent players are enabling Lightning payments as well. Paxful, with a user base of 7 million, announced its Lightning Network integration on September 14th. Further, on September 23rd, Twitter launched a tipping service with Lightning integration, enabling Twitter's 186 million users to send small tips to each other by utilizing the Lightning Network.

Lightning usage is pivoting from being dominated by online services to everyday use

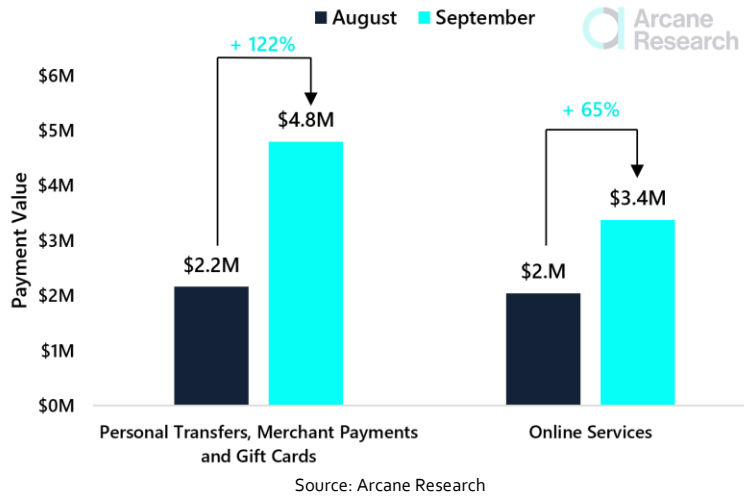
An increase in users with access to Lightning payments does not equal Lightning usage growth of the same magnitude instantly. But our Lightning wallet statistics show the above-mentioned doubling of payment volume in September and that the composition of payments is changing with new users getting access to Lightning payments. Except for transfers between Lightning wallets, payments for online services like trading and gambling have dominated payment volume. September showed that this is changing rapidly, as personal transfers and payments for more typical everyday use like merchant payments and gift cards grew by double the rate of online services.

Figure 5 – Users with access to Lightning payments.



Source: Arcane Research

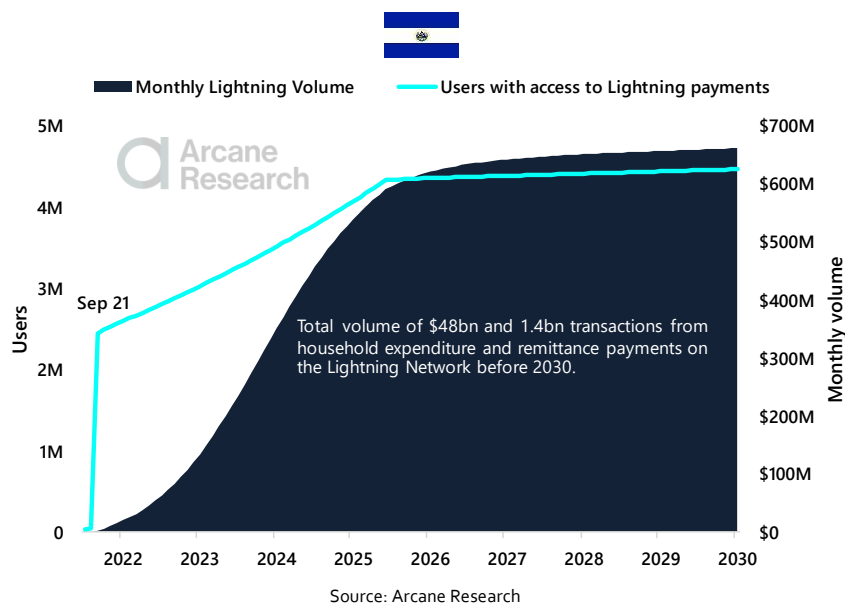
Figure 6- Lightning payments and personal transfers from wallet users.



What we’ve seen so far is only the beginning

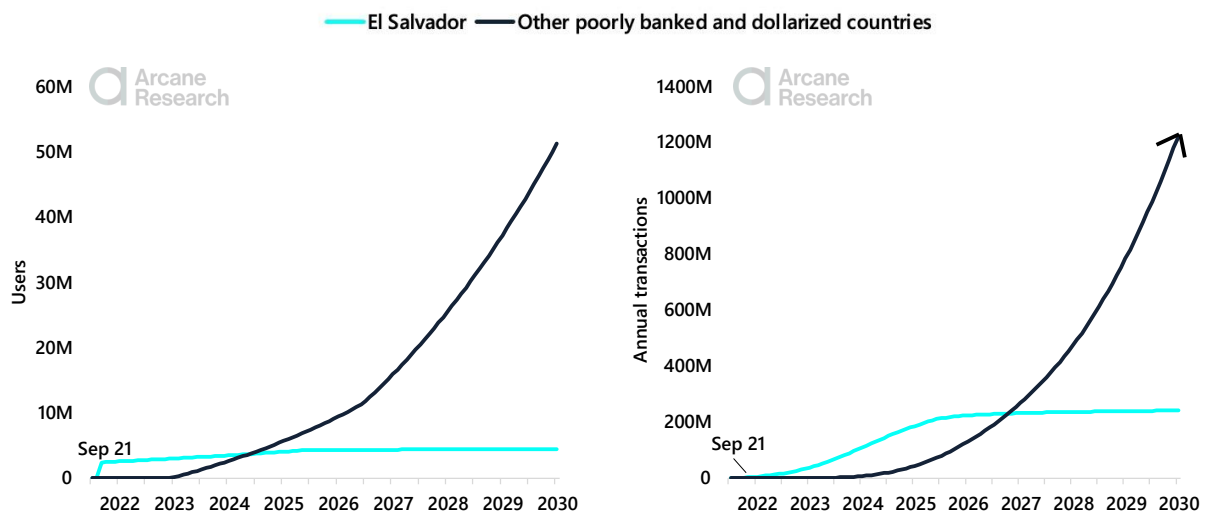
Bitcoin and the Lightning Network can provide access to a well-functioning monetary system for billions of unbanked and easier access for millions of already banked. We have scoped the potential impact on activity on the Lightning Network from the adoption wave now started with El Salvador. Based on a set of assumptions rooted in population statistics such as the number of unbanked people, people with internet access, growth in internet adoption, etc., we have made projections for the usage of the Lightning Network. We focus exclusively on Lightning transactions for household expenditure and remittance payments. Broad Lightning adoption will probably take some time, but usage growth will likely be exponential when bitcoin gets a foothold. In a potential scenario for Lightning adoption in El Salvador, close to 90% of the grown population will have access to Lightning payments by 2026. With an S-shaped adoption curve for usage, the monthly volume of household expenditure and remittance payments on the Lightning Network will grow to around \$650 million and 20 million transactions each month.

Figure 7 – A potential scenario for Lightning usage from household expenditure and remittance payments in El Salvador until 2030.



If successful, other countries will try to emulate El Salvador’s approach. The first to follow will likely be other countries with poor banking access and inflated or eradicated national currencies. We have made a “hot list” of potential followers among poorly banked countries with high reliance on remittances and a strong dependence on the US dollar. These countries have a combined population of 850 million, with 650 of those currently unbanked. In a scenario where countries equivalent to 10% of that population adopt bitcoin before 2030, we look at another 50 million Lightning users by the end of the 2020s. By 2030, these users will be behind \$17 billion in annualized Lightning payment volume and more than 1.2 billion Lightning transactions through household expenditure and remittance payments. And these numbers will increase in the 2030s through increased usage adoption alone, not to think of more countries catching on.

Figure 8 – A possible scenario for Lightning usage from household expenditure and remittance payments in other poorly banked and dollarized countries until 2030.

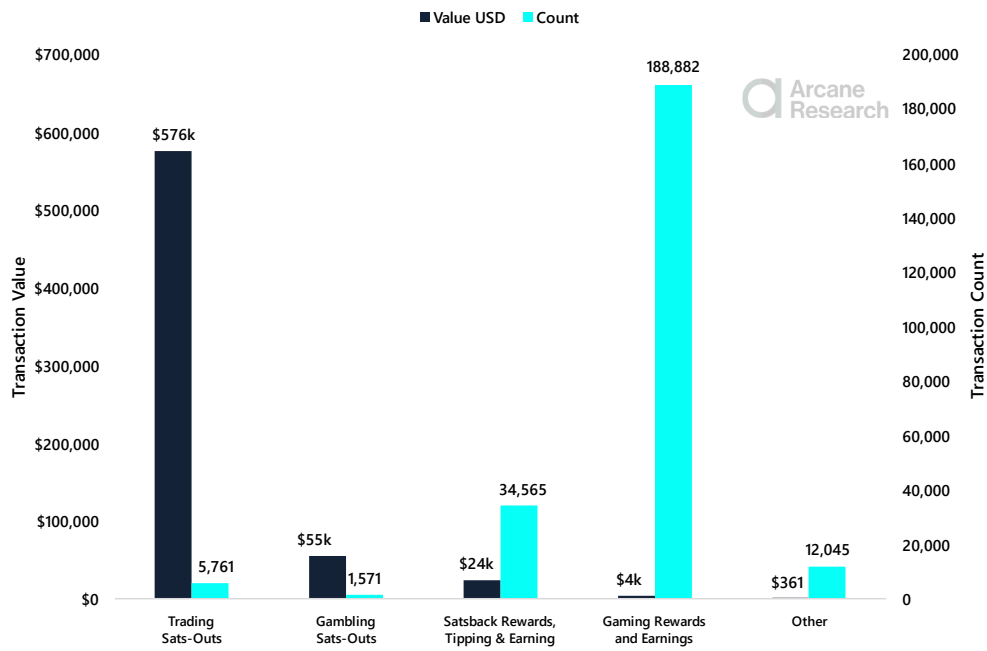


Source: Arcane Research

The Lightning Network can disrupt how services are offered

The Lightning Network’s scope of adoption does not stop with being a medium of exchange in poorly banked countries. Incoming transactions to wallets likely tell a story of what’s to come. In Figure 9 below, we show incoming transaction volume and transaction count for different types of transfers, excluding personal transfers. In terms of volume, withdrawals stemming from earlier deposits to trading and gambling services dominate. However, it’s further to the right in the figure below that we find proof of the uniqueness of the Lightning Network. Gaming rewards and earnings only accounted for an estimated \$4,000 of incoming transaction volume but did this on a whopping 189,000 transactions, implying an average transaction size of 2 cents. These transactions clearly demonstrate the possibility of making minuscule payments on the Lightning Network, potentially allowing users and companies to settle almost instantly and thereby mitigate counterparty risk.

Figure 9 – Lightning Wallet Statistics – Distribution of Incoming Transactions (August 2021)
Excluded wallet-to-wallet



The Lightning Network, and the possibility to perform micropayments instantaneously, will most likely change how we pay for certain services. We already see the first steps, but the alternative to *stream money* will revolutionize many popular services in the future.

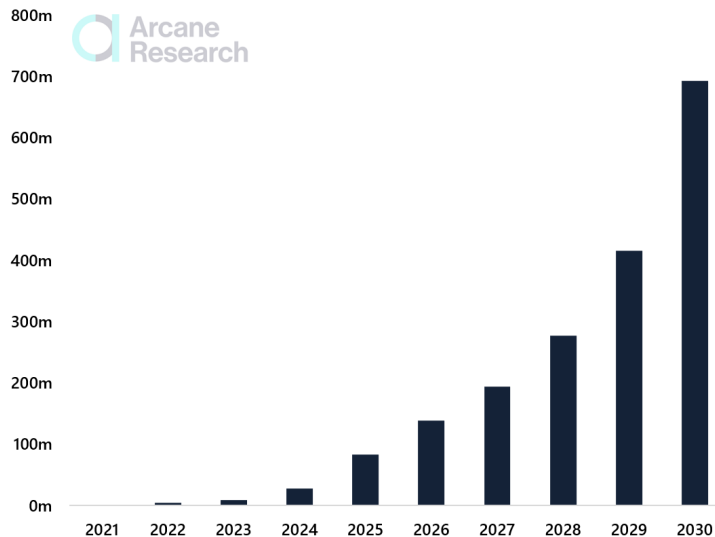
The possibility of streaming money can disrupt the business models we know today. Why shouldn't you be able to pay per minute you listen to songs on Spotify or per second you watch of a movie on Netflix? Why should you give away your credit card details to a content service if you could pay directly from your Lightning wallet without giving away any information about yourself?

The potential impact on the activity on the Lightning Network can be enormous, bringing millions of users, if not billions, onboard. Below, we have listed the number of global users for some services where Lightning payments can become an alternative way to pay for these services. There's no reason for adoption to stop with these services. However, the high number of users among these three groups serves the purpose of illustrating the extreme impact these types of services can have on Lightning activity.



The chart below illustrates the potential impact on the Lightning Network, showing the growth in users who pay for their gaming, video, and audio services through Lightning.

Figure 10 – Users of Gaming, Video, and Audio Services Paying with Lightning.



Source: Arcane Research

To estimate the potential number of users on the Lightning Network from gaming, video, and audio, we apply a set of assumptions explained in detail in the report. We then end up with an estimated 700 million users paying for gaming, video, and audio through the Lightning Network by 2030.

Another estimate that will likely blow your mind is the number of potential Lightning transactions this could equal. Based on a conservative estimate of 1 hour used per day on these services and an average of 25% of this time spent consuming services with Lightning payments, our estimate equals no less than 364 trillion Lightning transactions per year by 2030.

While this is nothing but an estimate, it's hard to grasp the potential impact the Lightning Network can have on the services we use today. New, innovative companies and services will emerge if the power is switched from provider to user by switching out old business models with streaming of payments. Over 700 million people using these services with Lightning by 2030 is not unlikely. Still, the question is, will they use Steam, Netflix, and Spotify, or a completely new service that has built its service around the Lightning Network?

All these estimates might seem farfetched and ridiculous. However, we must not forget the innovation and extreme growth that we have seen on many fronts over the last decades. What the Internet did to information sharing worldwide was impossible to predict. Many were skeptical of the Internet and how it could be used to transfer files, emails, audio, and other content. These technical challenges were solved quicker than many expected. Today, 5 billion people use the Internet, we send more than 60 billion WhatsApp messages per day, and it's estimated that we will send 376 billion emails per day by 2025. Bitcoin and the Lightning Network are also based on open-source protocols and software, in the same way as the Internet, making another Internet story much more likely, with innovation and contribution from all parts of the world.

What the Internet has done for information, Bitcoin and the Lightning Network will do for money.

- Elizabeth Stark, CEO Lightning Labs



The new standard for Bitcoin payments

OpenNode provides Bitcoin-powered payment acceptance and payout solutions for businesses everywhere.



Instant global payments

The Lightning Network enables borderless payments, with instant and final settlement at scale.



Simple integration

One powerful Bitcoin Payment API for custom implementation of payments and payouts.



No price volatility

Accept Bitcoin payments, receive Bitcoin or preferred local currency.

The State of Lightning

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1 What is the Bitcoin lightning network?

Critiques have labeled Bitcoin as too slow of a technology to prosper as a payment network. However, the slow throughput of Bitcoin is fundamental to Bitcoin’s core value proposition – its state-of-the-art security. The Lightning Network represents a solution to Bitcoin’s slow throughput, functioning as an extension of the Bitcoin blockchain as a second layer alternative, enabling rapid, cheap, and vast amounts of transactions.

1.1 The problem with the Bitcoin on-chain network

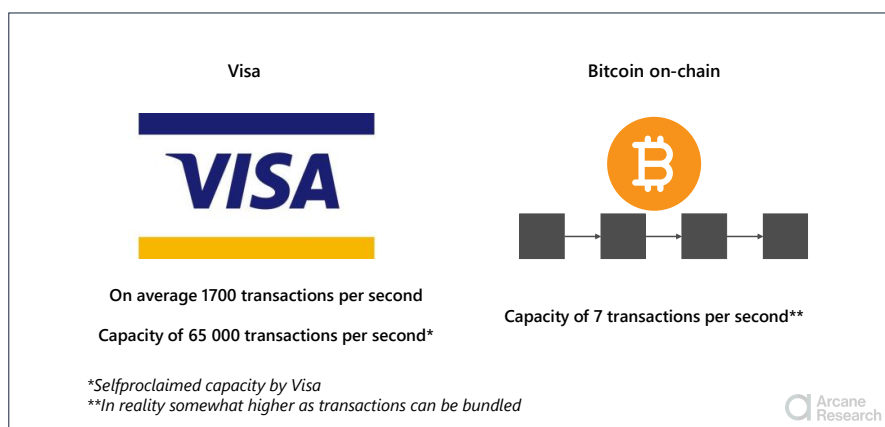
Bitcoin is a digital currency operating free of central control or oversight by any banks or governments. Instead of trusting a central bank or government to secure the value of their currency holdings, bitcoin holders can rely on the ingenious technical setup and incentive mechanisms of The Bitcoin Network to protect their bitcoins’ value. As part of this setup, The Bitcoin Network uses a blockchain to store the network’s information.

In a nutshell, the blockchain is a public ledger where all transactions are recorded. Each block contains specific information, such as the time, amount, and counterparties of each transaction. It also includes an answer to a complex mathematical puzzle, which is unique to each block.

Despite this, Bitcoin's technology has its drawbacks. As a peer-to-peer electronic cash system, two limitations stand out. The first is throughput capacity, which is measured by the size of the transaction blocks. Initially, this was not explicitly restricted but rather implicitly limited by the 32 MB maximum size of the P2P protocol message in any given block. Then, in September 2010, Satoshi Nakamoto added a block size limit of 1 MB to the protocol. The goal was initially to prevent server attacks, as the number of transactions was far from reaching the limit at this point.

Later, in August 2017, an upgrade to the Bitcoin protocol known as Segregated Witness (SegWit) was implemented, which drastically changed how blocks are measured by introducing the concept of weight. The block size limit was replaced by a block weight of 4 million units, which corresponds to increasing the maximum block size to roughly 4MB under full SegWit adoption. Although intended as a solution to the scalability problem that had manifested with the rising popularity of Bitcoin, the ability to scale ultimately reaches a ceiling before it can handle the millions of small transactions humans make daily.

Figure 11 – Bitcoin on-chain Transactions per Second vs. Visa Transactions per Second



Source: Visa, Arcane Research

The second limitation is high transaction fees. Before a bitcoin transaction is included in a block, it goes into the mempool while awaiting validation from miners. Because there is a backlog of transactions awaiting validation, miners are incentivized to validate transactions with higher fee rates first. In other words, transaction fees are relative to confirmation times and increase as network volume rises.

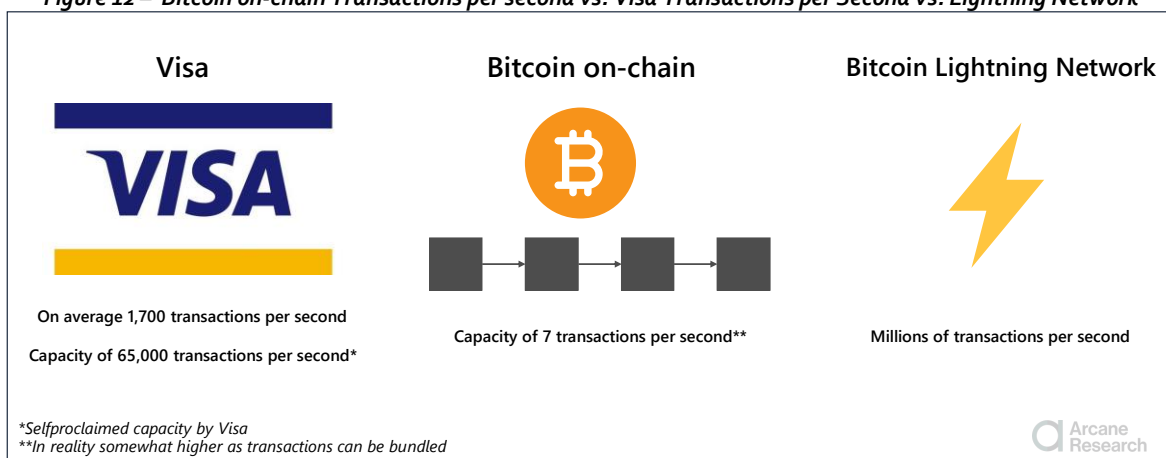
However, these limitations are not weaknesses in themselves. The slow validation and generation times and the incentives for miners are fundamental to Bitcoin’s core value proposition—security. Bitcoin is the most secure blockchain by orders of magnitude. Therefore, it is essential to understand that changing parameters in the blockchain, such as increasing the block size or decreasing the block time, would come at the cost of security. That is the genius of the Lightning Network: transactions are not recorded on the blockchain and therefore do not require mining, making Lightning payments instant and extremely low cost. All while still using bitcoin.

1.2 The Lightning Network fixes the Bitcoin problem – and opens a new set of possibilities

The difference between Bitcoin and Lightning is that Bitcoin broadcasts each transaction to the chain, whereas Lightning verifies a channel status against the chain. Because on-chain transactions require a significant amount of data to be transmitted, the Bitcoin blockchain can handle a limited number of transactions per second. In contrast, credit card providers claim to handle up to 65,000 payment transactions per second. Because Lightning is built on top of Bitcoin, while drastically increasing transaction capacity and lowering costs, it represents a competitive alternative to traditional payment providers and a true peer-to-peer electronic cash system.

Theoretically, the Lightning Network is capable of millions of transactions per second, far surpassing global payment providers such as Visa and MasterCard. Moreover, Lightning transactions are extremely low cost without the block size limit acting as a bottleneck on the supply side. Together, the speed and cost benefits of the Lightning Network have the potential to disrupt entire industries.

Figure 12 – Bitcoin on-chain Transactions per second vs. Visa Transactions per Second vs. Lightning Network



Source: Visa, Arcane Research

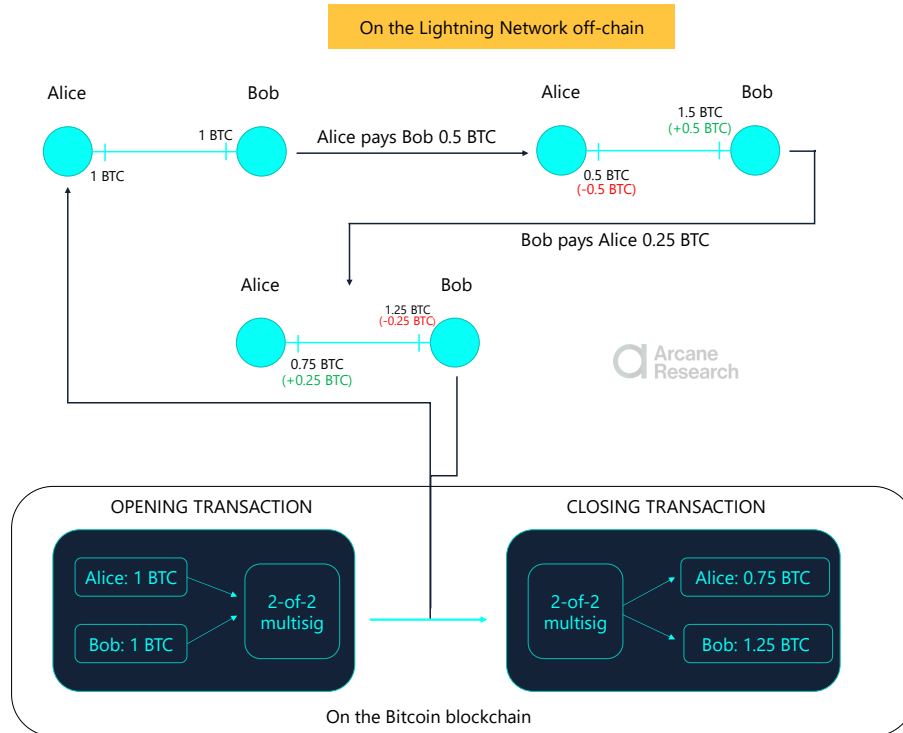
1.3 How does the Lightning Network function?

The Lightning Network utilizes a network of payment channels powered by smart contracts to send transactions between peers. A payment channel is a connection between two counterparties on the Lightning Network called nodes. Each counterparty has committed a certain amount of bitcoin that can be sent to the other counterparty's side of the channel. Figure 13 below illustrates how such a channel is opened, how the nodes relay bitcoin to each other on the Lightning Network, and eventually how debts are settled through the closing of a channel.

Two counterparts can decide to open a payment channel by creating a multi-signed transaction on the blockchain, allowing them to transfer funds between themselves without broadcasting their transactions on the blockchain. Eventually, a transaction corresponding to the final balance between the two parties will be broadcasted to the blockchain when either or both parties decide that the channel is no longer needed.

The Lightning Network is a layer 2 solution on the Bitcoin Network, meaning it builds upon Bitcoin. We can see this clearly by examining the opening of a channel on the Lightning Network. When two counterparties (nodes) decide to open a channel on the Lightning Network, they need to fund the channel by a transaction on the Bitcoin blockchain. In the opening transaction, each node commits an amount of bitcoin stored on the blockchain that funds their side of the channel. In the illustration below, Alice and Bob each commit 1 bitcoin to their side of the channel in the opening transaction. They do this by both signing a multisignature UTXO (Unspent transaction output) on the blockchain where they commit 1 bitcoin each. In simplistic terms, they have now locked up 1 bitcoin each on the blockchain that can only be moved by a new input from the channel on the Lightning Network. In terms of our illustration below, we have moved from the on-chain opening transaction in the lower left of the figure to the newly opened channel between Alice and Bob in the upper left corner of the figure.

Figure 13 – Illustration of Payment Channels on the Lightning Network



Source: Arcane Research

Once the channel is opened, Alice and Bob can start sending payments to each other. First, Alice pays Bob 0.5 BTC. The figure shows how this works by moving from our newly opened channel in the top left to the top right after Alice has sent Bob 0.5 BTC. 0.5 BTC is then subtracted from Alice's side of the channel and added to Bob's side of the channel. After this transaction, Alice has 0.5 bitcoin on her side while Bob has 1.5 bitcoin on his side. Now, Bob wants to send Alice 0.25 bitcoin. Bob has sufficient funds in his side of the channel and can therefore send Alice 0.25 bitcoin. After this transaction, Alice now has 0.75 bitcoin on her side and Bob 1.25 bitcoin on his side of the channel.

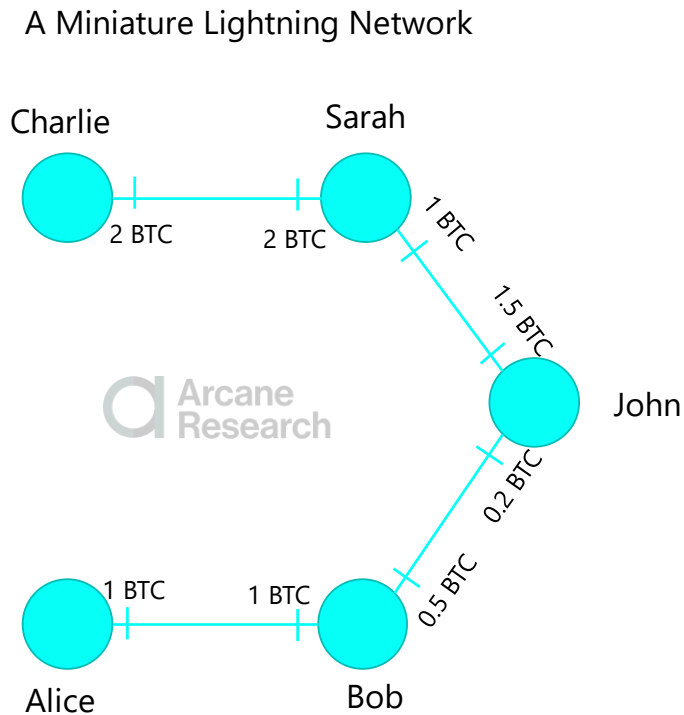
Alice and Bob could now go on forever, sending bitcoin back and forth to each other on the Lightning Network. In our case, however, Alice decides she no longer needs a payment channel with Bob. She, therefore, decides to shut down the channel. Bob can't stop Alice from doing so, but he can prevent her from sending false information to the blockchain. If Alice tries to send a final ledger with more than 0.75 bitcoin on her side of the channel, Bob can dispute this with his evidence that Alice only had 0.75 after the last transaction between the two. To prevent people from trying to steal bitcoin through false closing statements, the Lightning Network has a punishment protocol in place. If Alice sends incorrect information, and Bob proves this information to be false, all the funds in the channel will be transferred to Bob's side of the channel. In other words, Alice would lose 0.75 bitcoin by trying to fool Bob.

Alice, though, has no intention to steal from Bob, and Bob also agrees that the channel should be closed. They, therefore, close the channel in cooperation. They do this by both signing off on a closing statement that confirms Alice has 0.75 bitcoin on her side and Bob 1.25 bitcoin on his. The closing transaction can now take part on the blockchain. Remember Alice and Bob and both committed 1 bitcoin each in the opening transaction. In the closing transaction, this amount gets redistributed as told by the closing announcement from the Lightning Network, meaning Bob now has increased his on-chain holdings to 1.25 bitcoin while Alice has reduced her on-chain holdings to 0.75 bitcoin.

The above is an example of a bi-directional channel, which is limited to two parties transacting. However, globally viable payment networks are not built on bi-directional payments channels. Instead of establishing a direct payment channel to every other person and company on the network, a technique called Hash Time-Locked Contracts (HTLCs) allows payments to be sent through a path of payment channels. To illustrate how this works, we have sketched a miniature Lightning Network in Figure 14 on the next page.

The Lightning Network is a network of payment channels, which means that every node is connected to another node¹. In our miniature Lightning Network, we have made the network of channels very simplistic for illustration purposes. Alice and Bob have yet again opened a channel with 1 bitcoin on each side. Bob has, in addition, opened a channel with John, John, in turn, has opened a channel with Sarah, and Sarah has also opened a channel with Charlie.

Figure 14 – A Miniature Lightning Network for Illustrative Purposes.



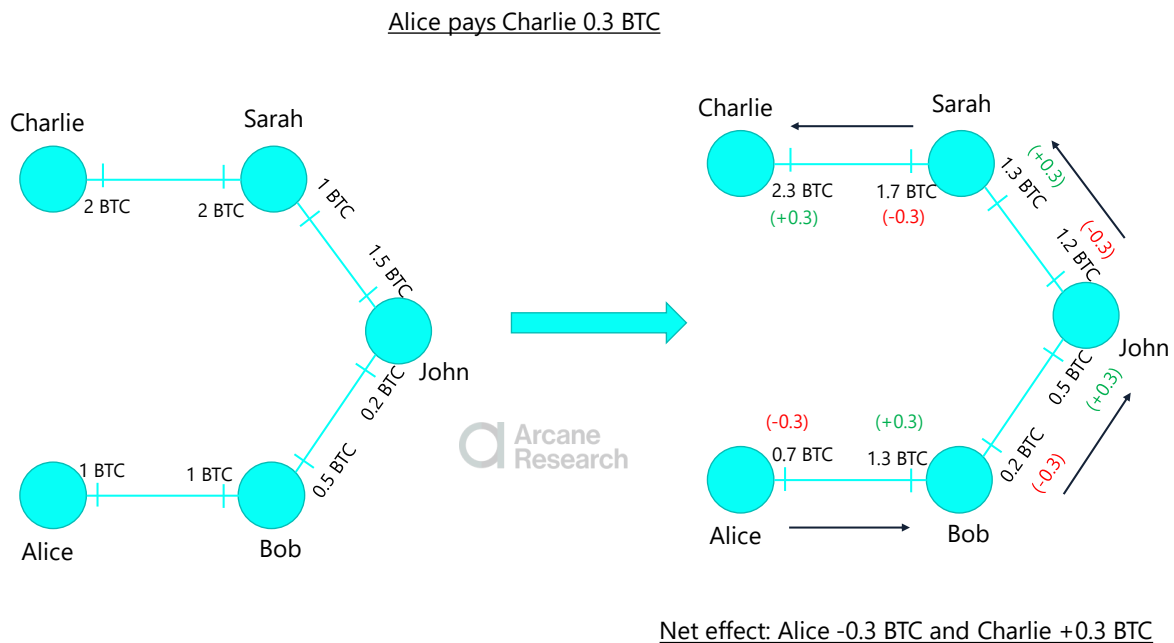
Alice now wants to send Charlie 0.3 bitcoin. Alice and Charlie have no direct channel, as we can see in our sketch of the miniature Lightning Network. However, we can find a way to Charlie by moving through the connected channels. Alice can reach Bob, who can reach John, who can reach Sarah, who can reach Charlie. Alice has 1 bitcoin on her side and should therefore be able to give Bob 0.3 bitcoin, who can give it to John, who can give it to Sarah, who again can deliver it to Charlie, right? This is only partially true. Due to how payment channels are constructed, funds cannot be transferred from one channel to another. The transfer, therefore, must be done by rebalancing all the channels along the route from Alice to Charlie.

Figure 15 shows how this is done on the Lightning Network. Alice starts by transferring 0.3 bitcoin from her side of the channel between Alice and Bob to Bob's side of the channel. To forward the payment on its path to Charlie, Bob now takes 0.3 bitcoin from his side in the channel with John and transfers them to John's side. John does the same in his channel with Sarah, and Sarah then does the same in her channel with Charlie. The net effect of this routing is that Charlie's side of the channel with Sarah increases by 0.3 bitcoin, and Alice's side of the channel with Bob decreases by 0.3 bitcoin. Bob, John, and Sarah all have a net effect of zero from this transaction when you combine their

¹ Not all nodes on the Lightning Network have channels, so technically all nodes are not connected to another node. But all nodes with channels are naturally connected to at least one other node.

holdings in both their channels. Following the counterclockwise direction of the payment, the three have increased their holdings on the incoming side by 0.3 bitcoin and decreased their holdings on the outgoing side by 0.3 bitcoin.

Figure 15 – Illustration Alice Pays Charlie 0.3 BTC



Source: Arcane Research

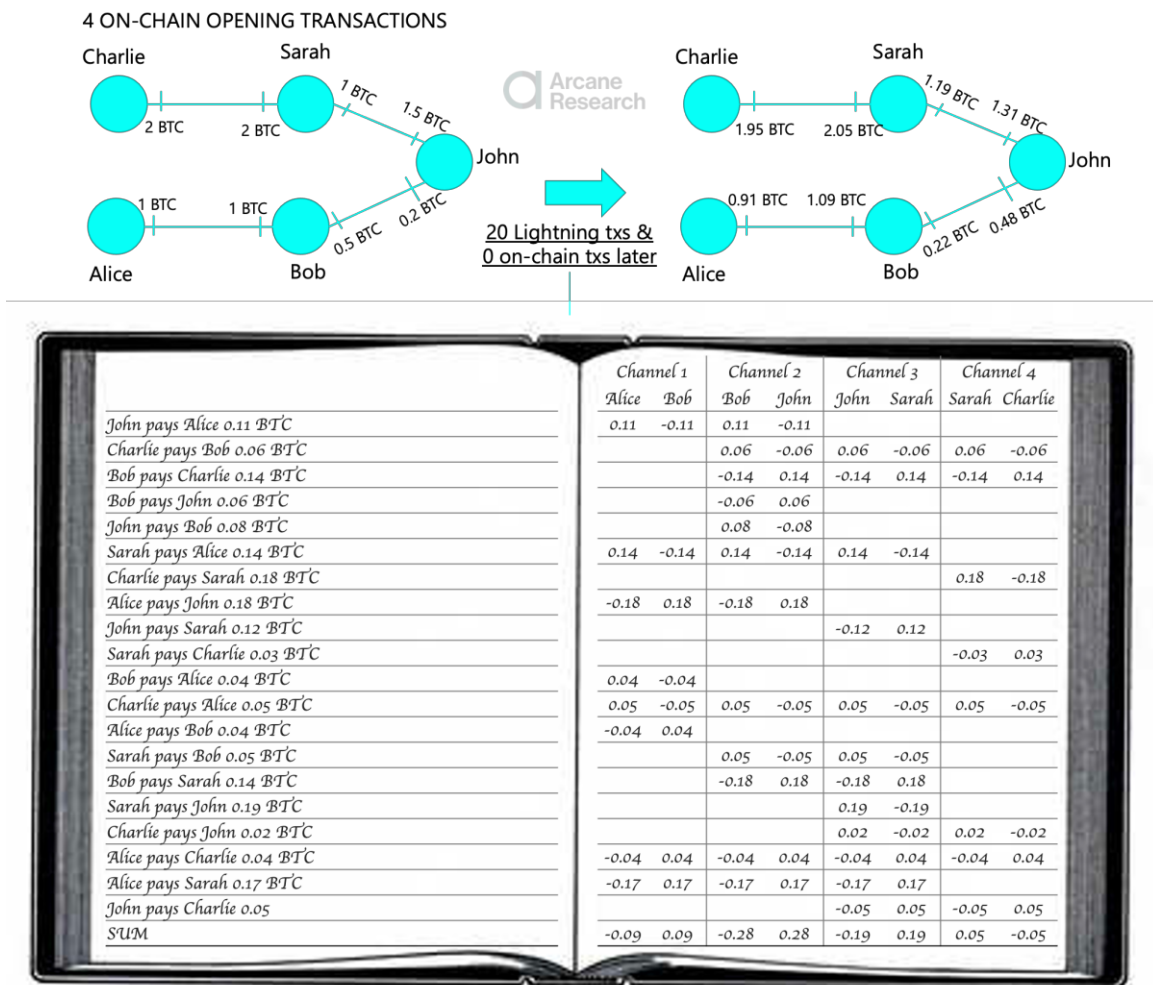
In our example, the payment from Alice to Charlie, Bob, Sarah, and John did not lose anything but did not gain anything either. Why should they then bother with doing the work on relaying Alice's payment? They might be good Samaritans, but a reliable payment network cannot be built on that assumption. To address this incentive problem, Bob, John, and Sara can claim a fee for relaying Alice's payment. How this fee is calculated must be broadcasted in advance so that Alice can decide whether she wants to send the payment. In our example, Bob, for instance, has a monopoly on relaying payments from Alice to the other three. In this instance, Bob could leverage his monopoly power to claim a high fee for relaying Alice's payments. Luckily, the actual Lightning Network looks nothing like the above example. Between nodes, multiple payment paths are preventing this type of monopoly power from arising.

Before showing how the Lightning Network increases the transaction capacity of the Bitcoin Network, we would like to address one more thing. In the above example, what stops Bob from simply keeping the 0.3 bitcoin Alice transfers to his side of the channel and not continue with Alice's payment. Remember, we earlier wrote that a technique called Hash Time-Locked Contracts (HTLCs) allows transactions to be sent through a path of payment channels, and that is still true. The Hash Time-Locked Contracts remove the possibility to intercept and keep payments. Simply put, the HTLCs use cryptography that requires the recipient, in our case Charlie, to confirm he has received the payment. If Charlie does not confirm the reception of the payment within a certain amount of time, the payment will be returned to the sender. So, If John tries to keep Alice's 0.3 bitcoin meant for Charlie, Charlie will not confirm the payment within the time limit, and the 0.3 bitcoin is returned to Alice.

So far, we have tried to explain in non-technical terms how the Lightning Network functions and not explicitly told how it solves the scaling problem of the Bitcoin on-chain Network. To do this, we provide a simple example of how our Miniature Lightning Network can send each other a multitude of payments on Lightning while not increasing the number of transactions on the Bitcoin blockchain.

In Figure 16, we start with the same network as earlier. Our Miniature Lightning Network consists of four channels connecting five nodes. Four on-chain opening transactions are needed to set up this network. Now, all five nodes (people) in the network can freely send payments to each other if each payment is within the bounds of the possible payment amount between the payer and recipient. The Miniature Lightning Network ledger records all the transactions between the people in the network. The first 20 payments are listed in chronological order on the first page of our ledger book, with the channel bookkeeping on the second page. After these 20 payments are conducted, the payment channels are rebalanced, as shown to the right in the figure. The great part is, these 20 transactions have required zero on-chain transactions. Now, the people in our network would likely keep their channels open and keep sending payments to each other. But even if they all decided to close their channels after the 20th transaction, they would still have saved space on the blockchain, with only four closing on-chain transactions needed to settle the final ledger after 20 transactions.

Figure 16 – Multiple Transactions on the Miniature Lightning Network



Source: Arcane Research

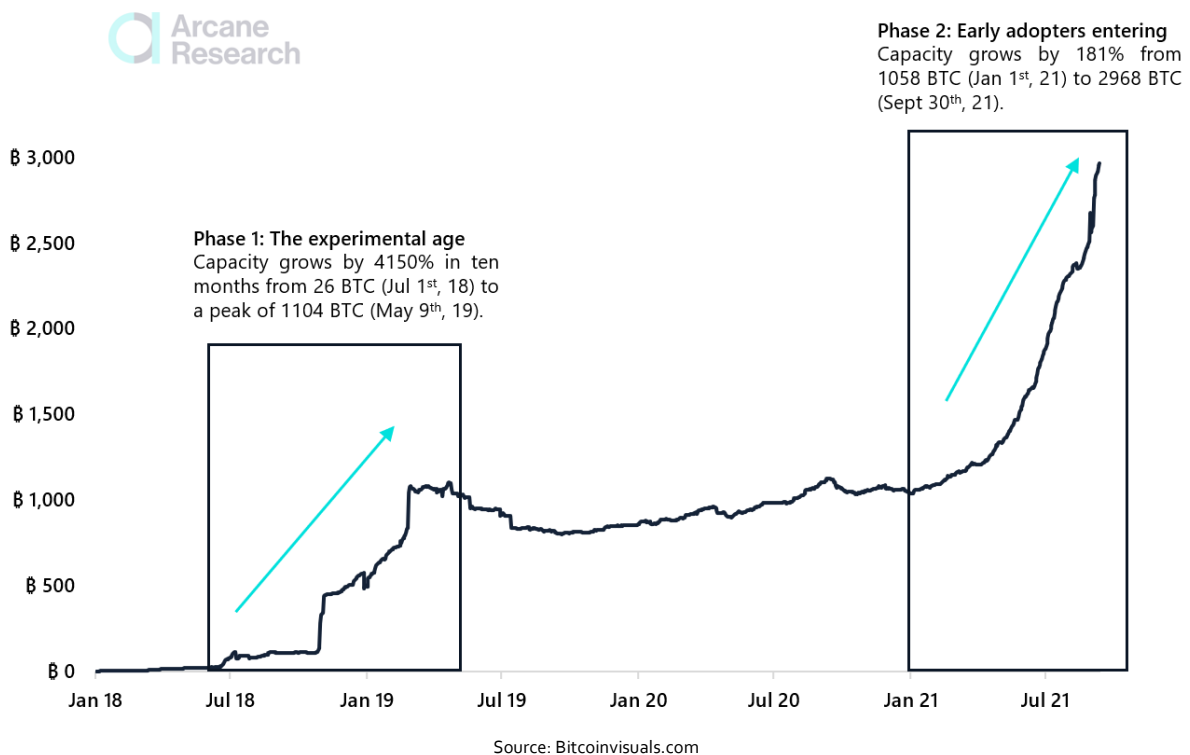
1.4 The Lightning Network in real life

In the previous pages, we illustrated a stylized Lightning Network with 5 participants conducting 20 transactions to visualize the inner workings of Lightning. In reality, the Lightning Network consists of near 100,000 users (per August 2021), creating a far more complex system than we previously sketched out. The following pages cover Lightning's real growth and tendencies since the launch of the Lightning Network mainnet in 2018.

1.4.1 Network capacity

In its nearly three-year history, the Lightning Network has grown to hold a bitcoin capacity of almost 3,000 BTC, with about 17,000 nodes operating on the network and 73,700 unique channels connecting nodes from across the globe. As of writing, the public bitcoin capacity on lightning equals more than \$120 million, with users across the world finding value in the option to conduct near-instant small payments at very negligible fees.

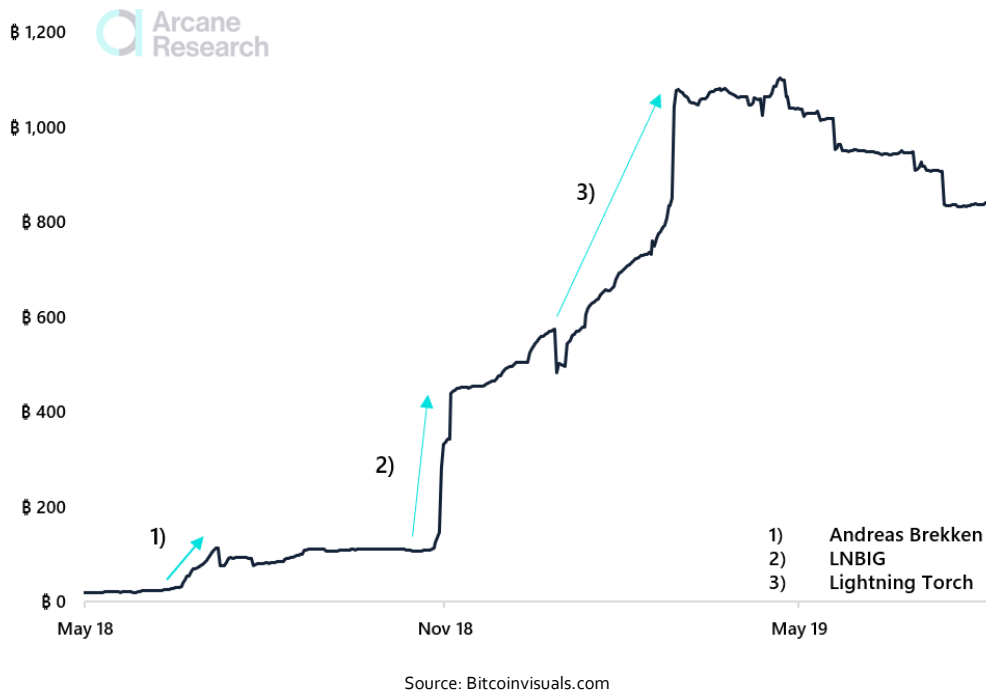
Figure 17 – Lightning Network: BTC Capacity



The Lightning Network has seen two distinct phases of growth. We will cover these periods in detail in the next paragraphs. The first growth phase began shortly after the launch of Lightning's mainnet and can be categorized as a very experimental phase. A slow period in terms of user adoption followed in the latter half of 2019 and 2020. However, while the adoption rate was slow, developers worked full throttle towards improving the network and creating tools and services, setting the stage for a new adoption phase. In 2021, several forces created the perfect storm to ignite Lightning's second major adoption phase.

Let's start with the first growth phase. We characterize the first adoption phase of the Lightning Network from June 2018 to May 2019 as Lightning's experimental age. The period saw the emergence of some massive nodes, drama, and a mythical community-driven effort to spread awareness of the capabilities of Lightning, sparking the Lightning Network to grow from a BTC capacity of 20 BTC to a peak of 1104 BTC in 11 eventful months. The first phase is illustrated below.

Figure 18 – Lightning Network: BTC Capacity, May 2018-June 2019



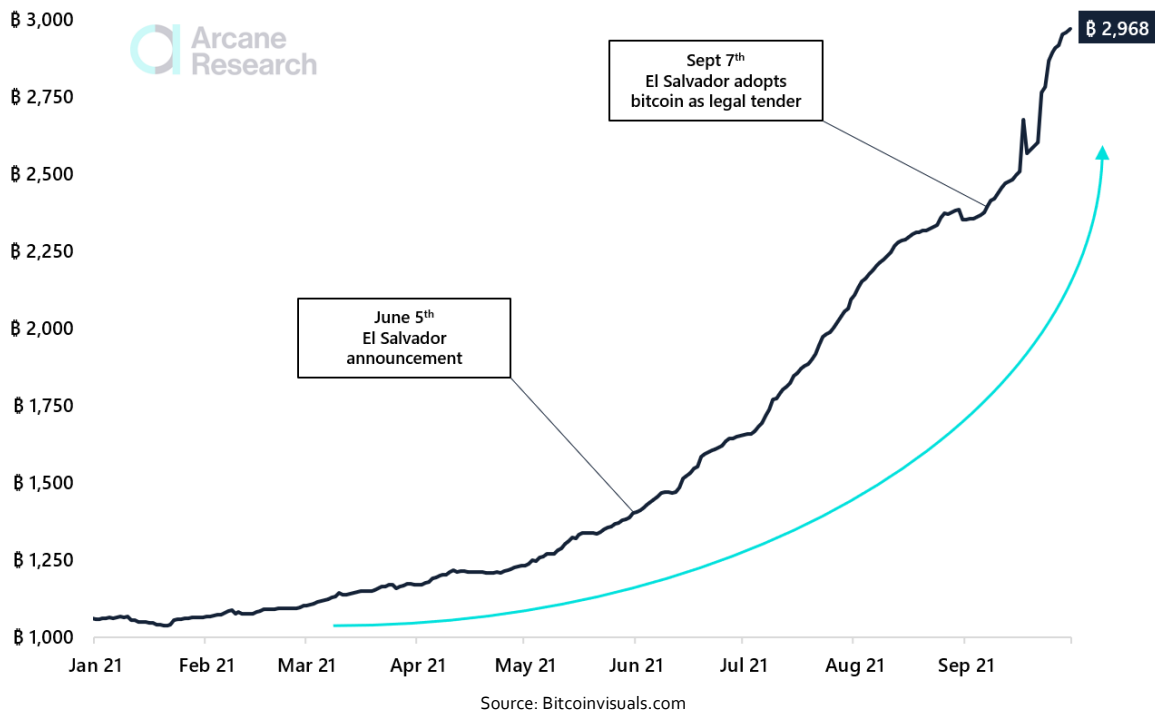
The first significant growth of Lightning's BTC capacity occurred in the summer of 2018. The increase was alarming to many since it was driven by one massive node entering the network accounting for more than 50% of the capacity on the network. The infamous node was named LN.SHITCOIN.COM and was owned by Andreas Brekken, who created the node motivated by experimenting with Lightning and writing down his experiences as he went. Brekken wrote [four medium posts](#) about his experiences. We recommend giving these posts a read, as they paint a picture of the state of lightning in June 2018. The second stage of growth in 2018 was relatively similar to what we saw with Brekken in the summer. In November, LNBIG entered the market, and he went in deep. However, contrary to Brekken, LNBIG did not garner as much attention, and he has also remained active in the network ever since. His nodes are, to this day, acting as important hubs on Lightning.

The third growth phase of these 11 months occurred in January 2019. It can be summarized as a community-driven effort leading the Lightning Network to gain massive attention both within and outside of the bitcoin community. In January 2019, Twitter user Hodlonaut started an experiment where he sent 100,000 sats to the first person he trusted who responded to his tweet. The transaction was under the condition that the recipient added 10,000 sats and then sent it to a new user. This chain of transactions was renamed "The Lightning Torch" and quickly gained attention on Twitter. The torch ended up being passed around by 282 unique participants and was in the hands of many influential people, shedding more attention to this nascent network. The torch was in the hands of Jack Dorsey (Twitter/Square), Reid Hoffman (Former: PayPal COO and LinkedIn co-founder), Fidelity, plus many, many important bitcoin and crypto personalities. Additionally, the torch was sent to an Iranian bitcoin user, a country sanctioned by the West. In total, the torch was passed 282 times, ending

with 0.0429 BTC donated from Torkel Rogstad to Bitcoin Venezuela. Concurrently, the charity also received a 0.41 BTC donation from the bitcoin community. The Lightning Torch ended up as a very successful experiment, leading to a substantial donation and increased awareness of Lightning, likely contributing to pushing the BTC capacity up towards its peak of 1104 BTC.

Throughout 2021, The Lightning Network has once again gained public attention at scale. The 2021 growth is a story of the stars aligning, as seen below.

Figure 19 – Lightning Network: BTC Capacity per September 30th, 2021

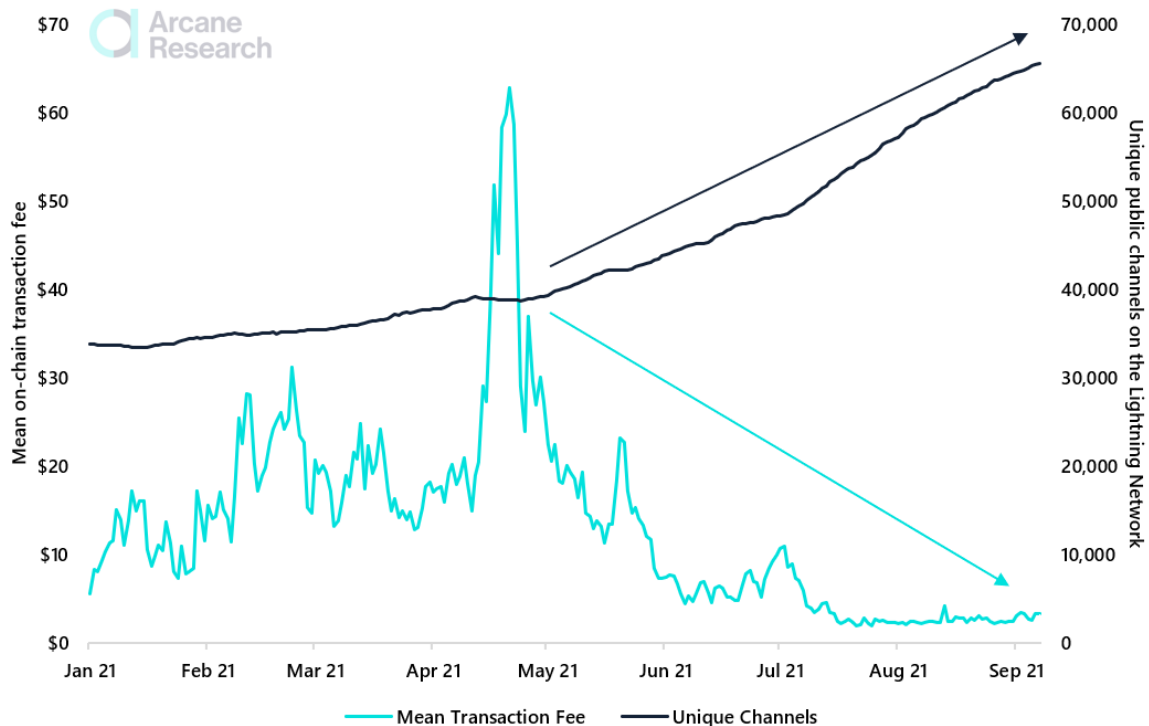


On June 5th, El Salvador announced that they would implement bitcoin as legal tender in the country. The Lightning Network is a crucial ingredient in making this transition economically feasible for Salvadorans. From May 2021, the overall interest in trading bitcoin declined as the bullish momentum from Q1 disappeared. Additionally, more services implemented SegWit transactions. This led on-chain transactions to decline substantially, in turn leading the mempool to clear and on-chain transaction fees to plummet, creating the perfect moment to open new channels on the Lightning Network. Low on-chain fees and high awareness due to the El Salvador news created the perfect storm for Lightning, evident by the blistering growth rate of the BTC capacity. From January 1st, 2021, to September 30th, 2021, the BTC capacity on the Lightning Network grew by 181%, from 1058 BTC to 2968 BTC.

Until now, we've exclusively focused on the bitcoin capacity of the Lightning Network to highlight the growth and history of the network. The increased bitcoin capacity of Lightning has developed in tandem with a massive influx in the public channels on the Lightning Network. From May 1st till September 30th, the number of public channels grew by 80% from 39,281 channels to 70,583 channels, amid a period of unusually low on-chain fees. This does not reflect the complete picture of the number of channels on the Lightning Network, as many channels are private and not broadcast to the entire network. Thus, the actual channel count is likely far higher than what's reflected by the public data.

BitMEX Research estimated that 27.8% of all Lightning channels were private in January 2020. To our understanding from talks with industry-leading experts, the share of private channels on Lightning could be even higher now. Thus, the BTC capacity, channel count, and node count from public data is most likely a significant underestimation of the current size of the Lightning Network.

Figure 20 – On-chain Fees vs. Public Lightning Channels



Source: Glassnode, Bitcoinvisuals.com

Figure 20 illustrates the relationship between the on-chain fees of bitcoin and the opening of Lightning channels. The chart demonstrates that the opening of new Lightning channels has coincided with lower transaction fees. Interestingly, the number of public channels on the Lightning Network has tended to flatten in periods with rising on-chain fees, such as in April, in the middle of May, and the start of July. Since the middle of July, on-chain fees have been remarkably low, while the growth of public Lightning channels has accelerated.

The Lightning Network is an alternative to on-chain transactions, and usage should be in higher demand in periods with high on-chain fees on the Bitcoin blockchain. However, at the time being, we are in the latter stage of Lightning’s proof of concept phase. In this period, entities with a long-term positive outlook on Lightning will seek to scale into the Lightning Network and open channels when on-chain fees are unusually low, such as the fee environment seen in bitcoin since June. By opening channels during times of low on-chain fees, these entities are positioned to interact with the Lightning Network in routing transactions and deliver services in periods where on-chain fees climb again.

The Lightning Network will likely see increasing adoption in a scenario where BTC grows further, more merchants accept bitcoin, and the on-chain fees reach a sustained high level. In such a scenario, entities will likely find it economically reasonable to open new Lightning channels, so they can conduct indefinite amounts of low fee transactions without having to worry about the cumbersome on-chain fees. In this scenario, routing fees might also provide an additional appealing revenue

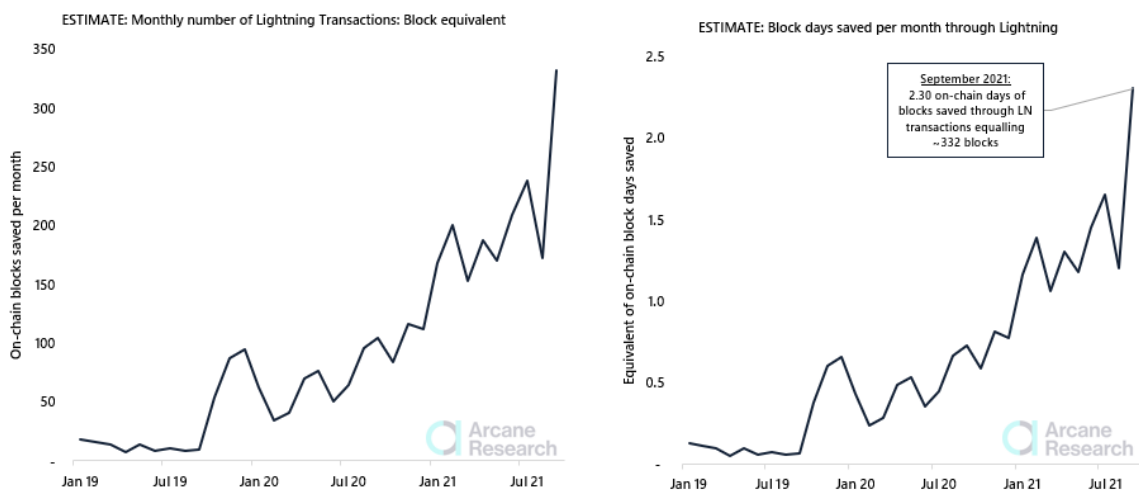
stream, further enhancing the fruitfulness of being a well-connected node. This further incentivizes the opening of more channels in order to route payments from users seeking to pay for groceries, trade on exchanges, or make payments to friends in an efficient manner.

All metrics suggest that the adoption of the Lightning Network is growing with nodes, channels, and capacity, all trending up. Considering that the Lightning Network is a second-layer solution aiming to scale bitcoin, it makes sense to contrast the growth of the Lightning Network with how it helps to scale bitcoin. Below, we attempt to contextualize how the activity on Lightning contributes to reducing the mempool and saving blockspace.

1.4.2 Lightning scales Bitcoin

The Lightning Network is a powerful second-layer scaling solution for bitcoin, as illustrated by figure 21, depicting how Lightning transactions free up block space on the Bitcoin blockchain. The chart is based on estimated transaction data from commonly used wallets on the Lightning Network. We count all transfers to and from wallets in our estimate of the number of Lightning transactions and do not count routing transactions. We are confident that our estimate is close to the actual transaction numbers from these wallets but emphasize that our estimates are, indeed, estimates. Further, the chart assumes that an average Bitcoin block consists of 2000 transactions.

Figure 21 – Estimate of Blocks / Blocks Days Saved per Month Through Lightning Transactions



Source: Arcane Research

Per our Lightning Network transaction estimates, we find that the Lightning Network processed 663,000 transactions into and from commonly used wallets in September 2021. This number of transactions would require 332 full on-chain bitcoin blocks, equaling 2.30 days of bitcoin blocks. Thus, through transactions on the Lightning Network, the on-chain mempool was spared from transactions that would have absorbed a lot of block space. In essence, the bitcoin network gained 2.30 days worth of transactions in September, caused by the growing adoption of the Lightning Network. This helps scale Bitcoin and contributes to lowering the on-chain fees.

These estimations should, of course, be interpreted with a grain of salt. First and foremost, a majority of the transactions occurring on the Lightning Network are micropayments. These transactions would not be economically feasible as on-chain transactions and would thus not be a part of the mempool

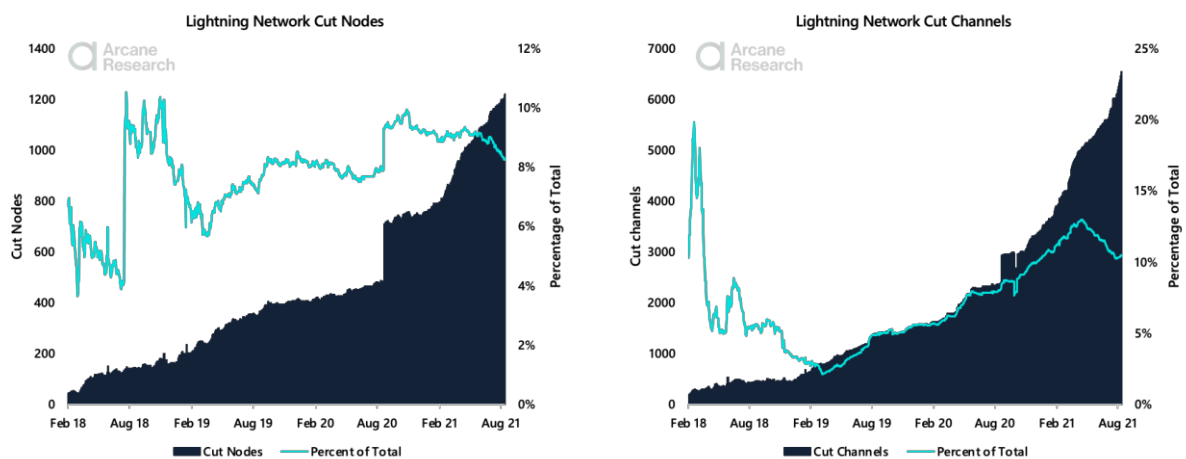
in the first place. Microtransactions are one of the magical features enabled by the Lightning Network. A whole new subset of opportunities emerges as micropayments with bitcoin are enabled. Thus, while Lightning contributes to offsetting some of the on-chain pressure for transactions, the 332 blocks represent an emerging new form of spending bitcoin. This new form of spending bitcoin has led to the creations of hundreds of projects, all working within the Lightning Network utilizing the power of microtransactions to create useful, immersive, and creative tools for users to enjoy.

1.4.3 A centralized network?

One of the key ingredients in the Lightning Network is the payment channels between nodes, allowing users to transfer funds through a series of nodes by using channels, ending up at the desired end-point destination. Lightning's elegant routing feature does not come without a cost. The network structurally rewards the most well-connected nodes (hereby hubs), where hubs are an essential part of the network. This architecture makes Lightning transactions structurally more centralized than on-chain bitcoin transactions. Nevertheless, this structure is a feature of Lightning, and without this feature, the network would lose its finesse. While the design, to a certain extent, leads to centralization, users are free to open channels to avoid the central hubs. Hubs are merely a very convenient feature of the Lightning Network, making sure the network is connected.

Let's take a deeper dive into the importance of certain nodes and channels on the Lightning Network. Below, we illustrate the number of cut nodes and channels on the Lightning Network. A cut channel is a channel between two nodes that connects different components of the network. This channel's removal would prevent other nodes from having a path. A cut node is the same idea, except it's a crucial node instead of a channel. In the Lightning Network, cut nodes and channels can be seen as weak points of the network as their removal would entirely disconnect two parts of the network. Therefore, they should ideally be minimized. This is especially true for cut nodes with many channels or cut channels of a large capacity, as the network heavily relies on them to function successfully.

Figure 22 – Lightning Network Cut Nodes & Cut Channels



Source: Bitcoinvisuals.com

In Figure 22, we see that the percentage of cut nodes has trended downwards since August 2020, currently sitting at approximately 8%. This illustrates that there are some critical nodes in terms of routing on Lightning at the moment. Still, the entrance of new hubs has contributed to reducing the

vulnerability of specific nodes being cut. The percentage of cut channels has also been trending down since May 2021, currently sitting at 10%.

Figure 23 – Lightning Network Clustering



Source: Bitcoinvisuals.com

The figure above illustrates the average clustering of the Lightning Network. A value of 1 indicates that nodes form cliques. In layman's terms, a clique is a closed group of nodes, not reaching the broad network. A value of 0 means that the average node is a hub, with none of its peers being connected. The average clustering coefficient has trended down since February 2019, aligning with the growth of cut channels in the same period, witnessed in Figure 22 (previous page). The declining clustering coefficient indicates that peers on the Lightning Network make increasingly more rational decisions when opening new channels. In general, channels now tend to be opened with nodes that are connected to a subset of nodes, which the channel creator has not opened a channel with. The opening of this channel gives the channel creator a route to this subset of nodes and the ability to route transactions to these nodes. Given these nodes also tend to be connected to another subset of nodes, the channel creator gets the ability to route a transaction more efficiently on the broader network. While this increases the importance of hubs and increases the percentage share of cut channels, it also contributes to making the Lightning Network a more efficient and well-connected payment network.

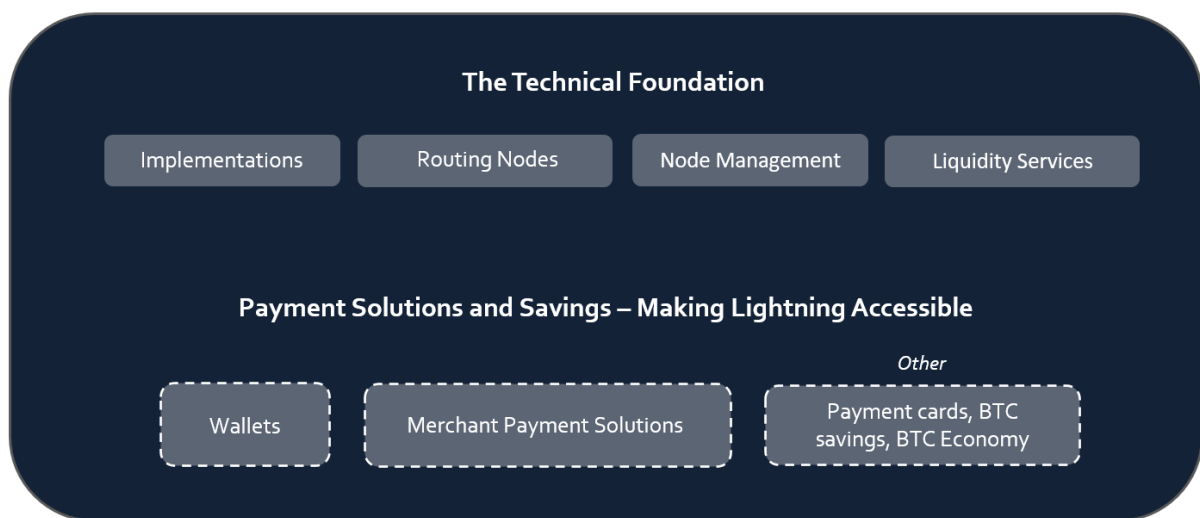
In sum, the Lightning Network is more centralized than the Bitcoin blockchain when accounting for hubs and payment paths. However, this is a desired feature of the Lightning Network, enabling users to find a cost-efficient path to the recipient of a transaction. Users always have the option to open their own channels, both private and public, without relying on the large hubs. Thus while the hubs in some sense lead to increased centralization of the Lightning Network, the network itself is not inherently centralized, it's merely a property of the network that users may opt to take advantage of, or avoid utilizing, and an interested and motivated party can also always launch a new hub node.

2 Who participates in The Lightning Network ecosystem?

In the previous section, we showed how the Lightning Network has grown by using public metrics. Behind the scenes, several companies and projects are contributing to this growth. In the following, we will highlight what these companies do and who they are.

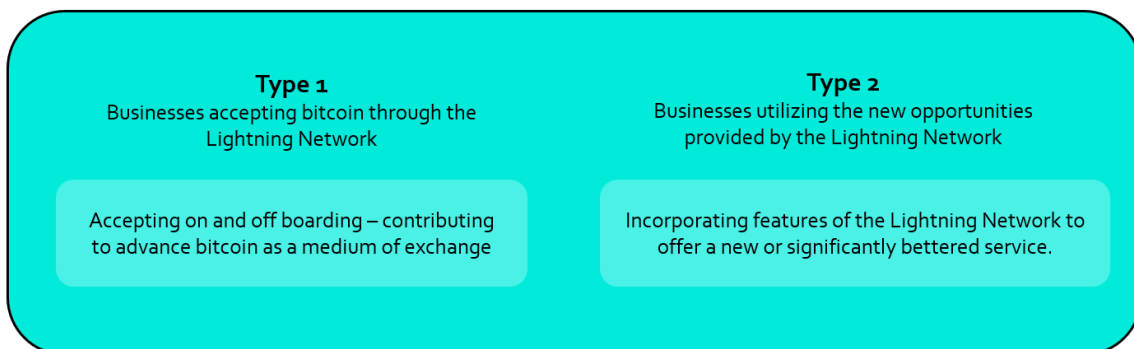
Initially, we categorize the projects into two broad categories. The first category consists of the companies laying the foundation for bitcoin to function as money on the Lightning Network. This group consists of companies developing the technical foundation and solutions that make Lightning payments available to a broader group of people and businesses.

The Foundation to Function as Money

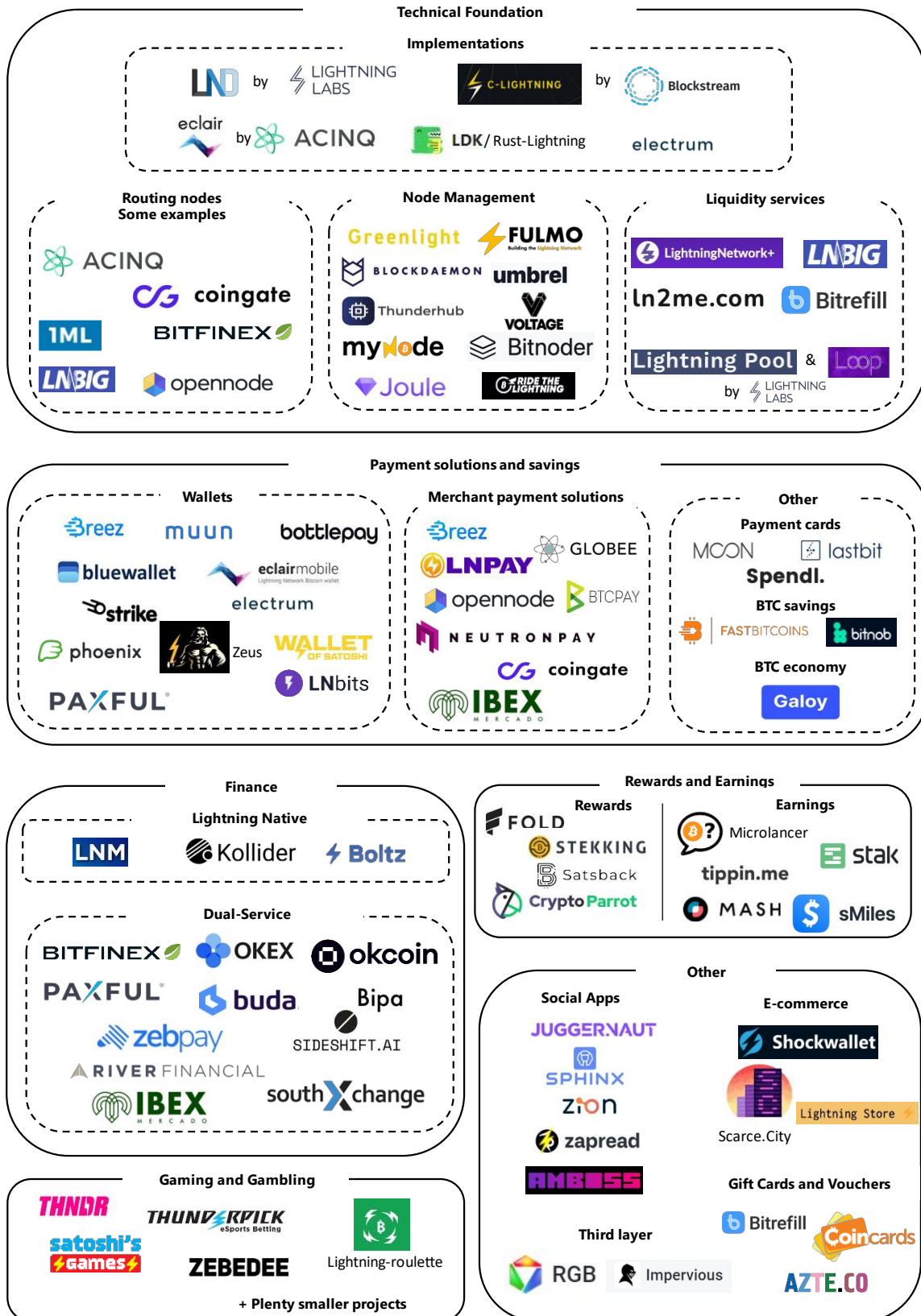


The other category consists of businesses that accept Lightning payments for their goods or services or use Lightning payments in their services (for instance, satsback through the Lightning Network for credit card payments). We label this broad category as commerce, then divide it into two conceptually different subcategories. The type 1 Lightning commerce company is a company accepting Lightning payments as a medium of exchange. Usually, it will be by accepting customer payments on the Lightning Network. The type 2 Lightning commerce company also accepts Lightning payments, but in addition, these companies have incorporated some attributes of the Lightning Network to improve their service significantly or to enable their business model.

Commerce



In the following sections, we will take a closer look at the different subcategories under our broader definition, explaining their role in the Lightning ecosystem and highlight the prominent companies and projects. The Lightning ecosystem is presented below, with a range of companies as illustration.

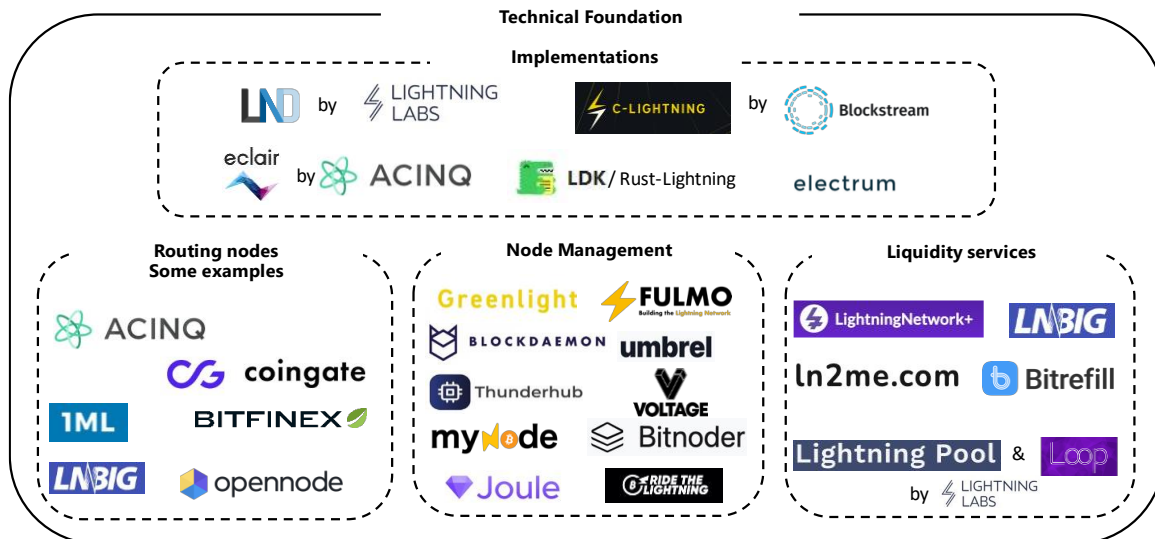


Source: Arcane Research

2.1 The foundation to function as money

We have divided the broad category of companies working on creating the foundation for payments on the Lightning Network to function as money into two broader sub-categories; The Technical Foundation and Payment Solutions and Savings. In the first part of this subsection, we will look at the entities laying the technical foundation and then move to the companies making Lightning payments more accessible for everyday use.

Technical foundation



The **technical foundation** is listed at the top of our ecosystem, and this is not by coincidence. At the very core of the Lightning Network ecosystem lays a technical foundation of code **implementations**, which everything else in the Lightning network builds off.

The key ideas behind the Lightning Network were first described in a [draft white paper](#) authored by Joseph Poon and Thaddeus Dryja in 2015, but it would take three years to translate the concept into a working code. There is no specific Lightning Network company; it is an open protocol. However, there are three key developing teams behind the interoperative implementations of the Lightning Network technology: San Francisco-based Lightning Labs and Blockstream and Paris-based ACINQ. The different implementations maintain interoperability by conforming to the Lightning Network specifications, called BOLT (Basis of Lightning Technology). The Lightning Network specification is maintained and developed through a community effort.

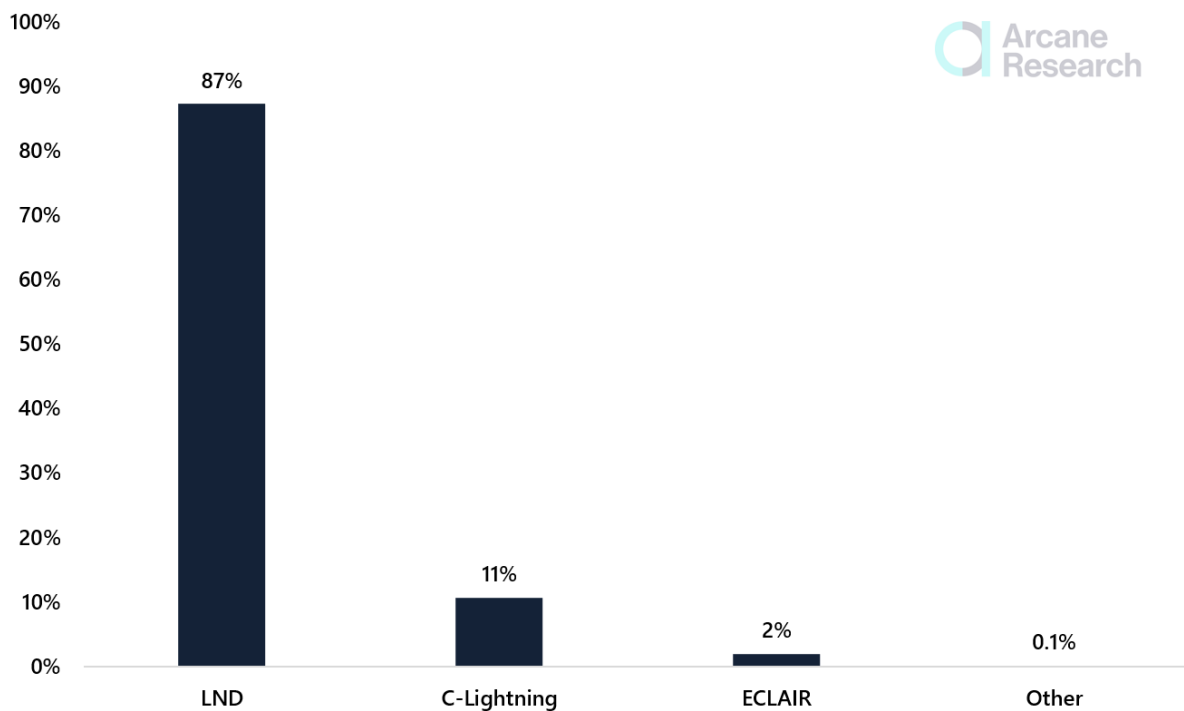
Lightning Labs, founded in 2016, has developed the Lightning Network Daemon (LND) client for the Lightning Network called, which is the most used implementation as illustrated in Figure 24. LND is designed as a developer-friendly implementation that facilitates application development on top of it. It is a stand-alone client with an extensive set of features available.

Blockstream, founded in 2014, is involved in much of the Bitcoin development, and the Lightning Network is no exception. The company has contributed heavily to the Lightning specification documents and is behind the c-lightning client. In the main, Blockstream is a specification and implementation team focused on security features and plug-ins, which involves self-hosted and open-source projects.

ACINQ, founded in 2014, is the company behind Eclair, the client considered to be one of the most mainstream implementations of the Lightning Network. It is written in Scala and supports both Java and Java Virtual Machine plug-ins, making it very useful for mobile wallets as many Android OS apps are written in Java. ACINQ has developed a collection of products based on Eclair, including the Phoenix wallet, ACINQ Node, and Strike.

[Zabka et al.](#) estimated the use of implementations in The Lightning Network using gossip data in January 2021. They found the LND implementation to be the most used, with 87% of nodes running on LND. 11% used the c-lightning implementation, and 2% used the Eclair implementation. Very few public nodes use any other implementations. Zabka's research only reflects the public part of the Lightning Network, so these figures might not necessarily portray the overall implementation usage when accounting for the private part of the network.

Figure 24 – Distribution of Implementations used on the Lightning Network
As of early 2021



Source: Zabka et al.

Payments often rely on efficient routing hubs that are routing payments from the sender to the recipient. These hubs are integral for the network, allowing users to transfer funds and interact with the ecosystem without interacting on-chain by opening unique channels to each recipient.

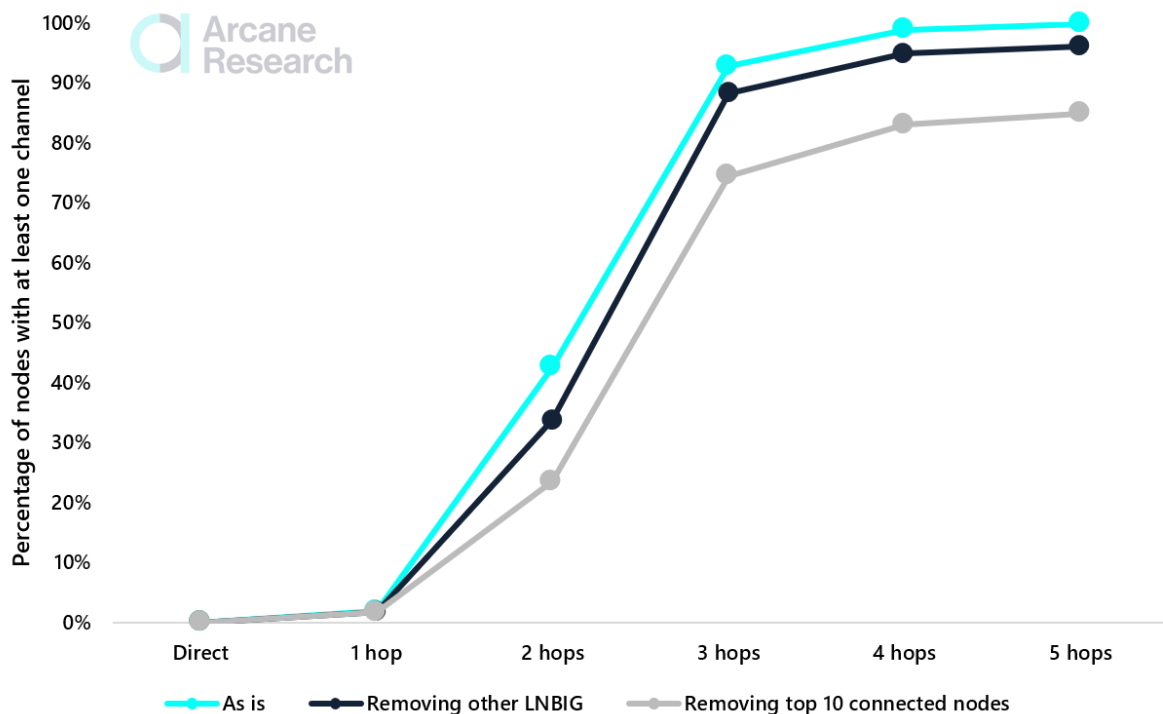
We can use the [Acinq Lightning Network Explorer](#) to visualize the importance of routing hubs for efficient use of resources in the Lightning Network. The node with the alias john-msi runs out of Nairobi, Kenya. She or he, let's call him John due to the alias, wants to send and receive Lightning transactions from anywhere in the world. John possibly only has a small amount of money and can therefore not open multiple channels to send or receive the amounts he wants. Consequently, he needs to find a route to as many as possible and preferably with as few hops as possible to keep expected routing fees down.

To solve this issue, John has opened a single channel to a well-connected LNBIG.com-node. This node directly has channels with 281 nodes, so in two hops, John can reach 281 nodes, equivalent to 2% of the public nodes with channels. In the next two hops, the net widens. John can theoretically reach 6540 nodes (43%) by two hops, and by the third hop, he can reach 14,049 nodes (93% of available nodes).

After this, the growth rate in reachable nodes naturally declines, with John reaching 98.8% after four hops and 99.9% after five hops, reaching practically the entire public network.

To test the status quo importance of routing hubs, we first remove the other LNBIG node-hubs and remove the other ten most connected nodes. The results are shown in the figure below. John's ability to reach many nodes in a couple of hops, and ultimate reach all, reduces significantly when we remove some of the big routing hubs.

Figure 25 – Reachable Nodes After a Given Number of Hops for john-msi Under Different Assumptions.



Source: 1ML.com, Arcane Research

Maintaining and managing your own node is a technical challenge. Some avoid this issue by relying on custodial systems on top of Lightning. Still, there is also an abundance of companies providing services enabling easier maintenance of self-hosted nodes on the network, services we call node management in this report. These services are essential for the likelihood of widespread adoption in a non-custodial way.

Liquidity problems can arise for a multitude of reasons. One common problem is in channels with a tendency to move funds in a specific direction. To avoid having to close and re-open channels with the adhering on-chain fees, nodes will have to rebalance their channels in another way. For many nodes, this can be hard to do by themselves. To mitigate the problem of imbalanced channels for these nodes, they can use various liquidity services provided on the Lightning Network.

Payment solutions and savings – making the Lightning Network accessible

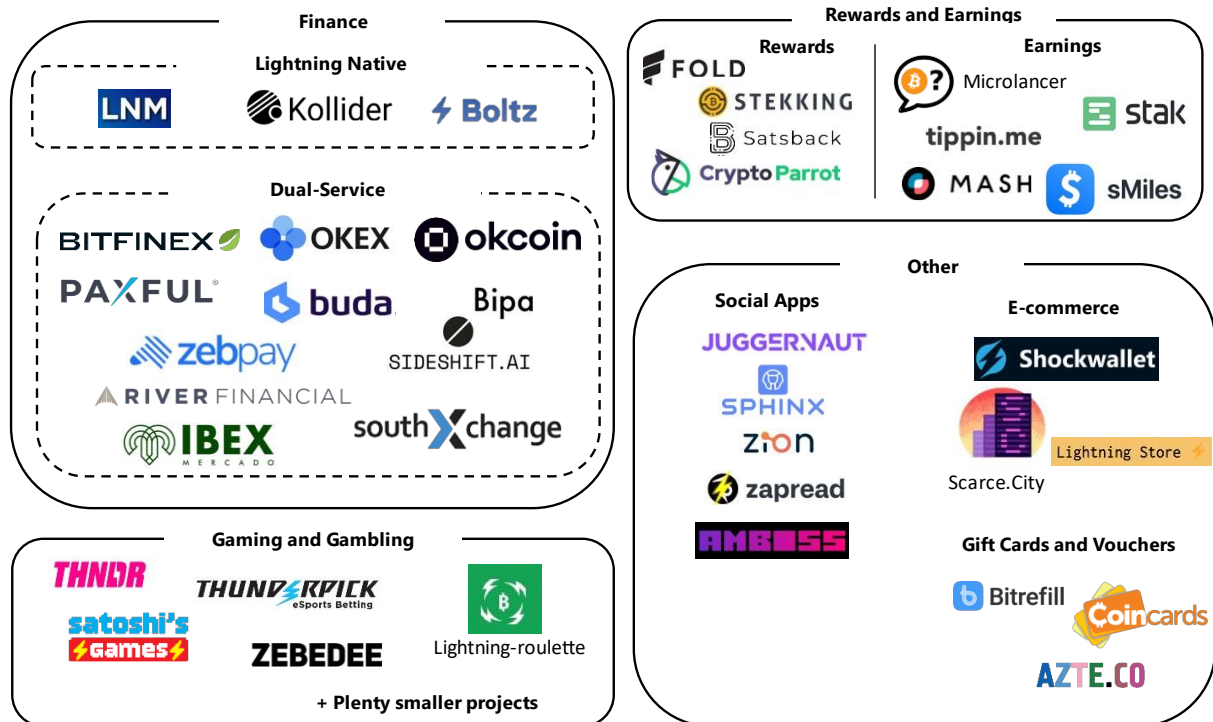


The technical foundation enables others to build services on the Lightning Network. To make bitcoin widely adopted as a medium of exchange, companies develop easier-to-use solutions for holding, spending, and receiving bitcoin on the Lightning Network.

Users interact with Lightning through wallets. You can run your own wallet without relying on the services of others, but this is a challenging technical task. Most users avoid this and choose one or more of the available wallet solutions. The architecture of these wallets can be set up in different ways. The different wallets serve various needs. Some focus on ease of access, while others prioritize the self-sovereignty of the holders.

Merchant payment solutions enable Lightning integration for merchants worldwide. This will often include providing the merchant with a wallet, but businesses need additional features to comply with tax rules, legislative regulation, etc. Some merchant payment solutions enable instant conversion of BTC to fiat and vice versa. Other focus on ease of access to advanced API systems, offering merchants optionality to customize the service for their needs. These payment processors strive to make it easier for merchants to start accepting bitcoin payments or utilize the instant payment feature enabled by Lightning to facilitate fast settlement when purchasing goods or services.

2.2 Commerce



Great wallets and payment solutions are of little use if there is no place to spend or use your satoshis. Businesses accepting Lightning payments are therefore essential for the Lightning Network's success. At the beginning of this chapter, we separated commerce into two broader subcategories. The Type 1 subcategory consists of businesses accepting bitcoin through the Lightning Network as payments, without any essential change in their business model due to the Lightning Network. The companies in the type 2 subcategory also accept bitcoin through the Lightning Network and utilize the features of The Lightning Network in their offering.

The distinction between Type 1 and Type 2 commerce is not apparent in all cases. For instance, is there an inherent difference between a company accepting Lightning payments for gift cards and a casino accepting Lightning deposits and withdrawals in how they utilize the Lightning Network? There doesn't have to be, but in most cases, there are. The gift card seller will generally offer gift cards denominated in dollars or another fiat currency. Buying a gift card with a small amount of satoshis then really doesn't make sense since its fiat value is so low that you can't use it for anything. In addition, such a small amount will not cover the behind-the-scenes cost of the seller, so they will either not sell it or require a fee many times the gift card's value.

However, in the Lightning casino's case, you can still access the casino with your small amount of satoshis and get full access to the service. The only difference between a small and significant amount is the value change of your holdings. The internet is filled with casinos offering the opportunity to deposit and withdraw with fiat currency, so how is the Lightning casino a new type of casino?

Firstly, the fiat payment systems require payments of a certain amount before anyone is willing to relay the payment. The limit for how low this payment could be is multifold lower on the Lightning Network than, for instance, through debit cards or bank deposits. Deposits are usually instant in online casinos, but withdrawals take days. This is not the case with the Lightning casino; withdrawals are just as instant as deposits.

To conclude, the Lightning casino utilizes the Lightning Network's ability to relay micropayments and instant settlement way more than the gift card seller and provides a significantly different offering than traditional online casinos. In our type differentiation of businesses utilizing the Lightning Network, the gift card seller would be a Type 1 and the Lightning casino a Type 2.

In the following parts of this subsection, we will take a closer look at the different offerings users can access via the Lightning Network.

Rewards and earnings

The Lightning Network is a perfect fit for instant micropayments. Companies offering bitcoin rewards or earnings leverage this fact. Whether something should be called "rewards" or "earnings" is in many cases an issue of definition. In this report, rewards refer to services where you must spend something to get your reward. For the above-listed companies offering rewards, this is in the form of so-called "satsback" for online fiat payments. Earnings refer to the user doing something without spending to obtain the satoshis or earns satoshis based on their skill in non-chance games. This is done in many forms. There are tipping services that let users send satoshis to services or persons they like, like a funny video posted by a user or as just released by Twitter, to a Twitter profile they like.

With the increased popularity of bitcoin, satsback-offerings have seen a sharp increase in popularity, and now also on the Lightning Network. The absolute levels are still relatively low on the Lightning Network based on our gathered information.

Gaming and gambling

Gaming is closely linked with both earnings and wagering on the Lightning Network. Many games offer earnings based on the user's in-game performance, without the user staking anything. Other services allow you to bet on yourself while playing games. For instance, you can use Zebedee to stake satoshis when playing Counter-Strike on Steam. Whether you win or lose satoshis is determined by your in-game performance. Various gambling services are also offered through the Lightning Network. Most popular are typical casino games offering fair and transparent odds – in other words, without the house edge.

Finance

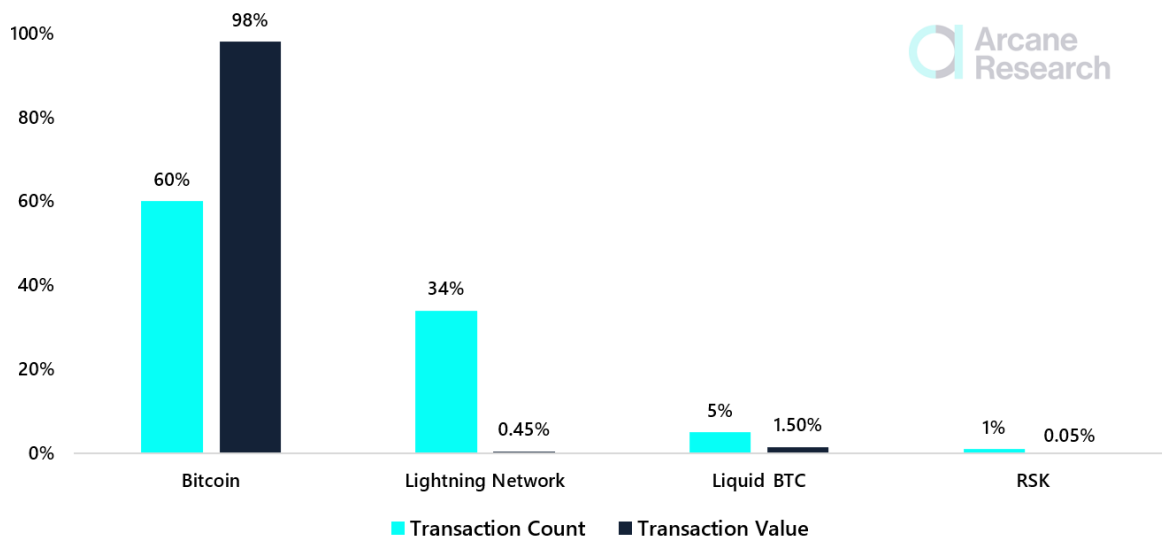
We have divided the financial services using the Lightning Network into two subcategories. The first is what we call Lightning native financial services. These services were first offered through the Lightning Network. Dual-service finance refers to companies offering Lightning Network services in addition to other alternatives. For most of the companies in this group, this is simply the possibility to on and off-board their pre-existing service through the Lightning Network.

The **dual-service** subcategory involves several well-established crypto exchanges entering the Lightning Network seeking to expand the usability of their platforms. Bitfinex, Okcoin, and OKEx have already implemented a Lightning integration, while Kraken is in the process of implementing a Lightning integration. The low fees of the Lightning Network are the core motivation for most of these exchanges in implementing Lightning integration. As we have already mentioned throughout this report, Lightning's key feature is the low fees, making fast and small transactions economically feasible while also scaling Bitcoin.

A deeper look into the available data helps elevate our understanding of both the reasoning behind the Lightning implementations of the well-established exchanges and some common traits among the users transacting with Lightning. Bitfinex dipped its toes into the Lightning Network in December

2019. After being live for nearly two years, users have had the time to discover and engage with these new services, allowing us to understand the usability of Lightning for dual services and the perks they enable. Examining deposit and withdrawal data from Bitfinex from July 15th to August 14th highlights that Lightning transfers are frequent, accounting for 34% of all bitcoin-related transactions in the period. Meanwhile, only 0.45% of the transaction value in the period was based on Lightning transactions, emphasizing that Lightning transactions indeed tend to be smaller than on-chain transactions, as one would expect.

Figure 26 – Deposits and Withdrawals at Bitfinex by Transaction Method (15 July – 14 Aug)



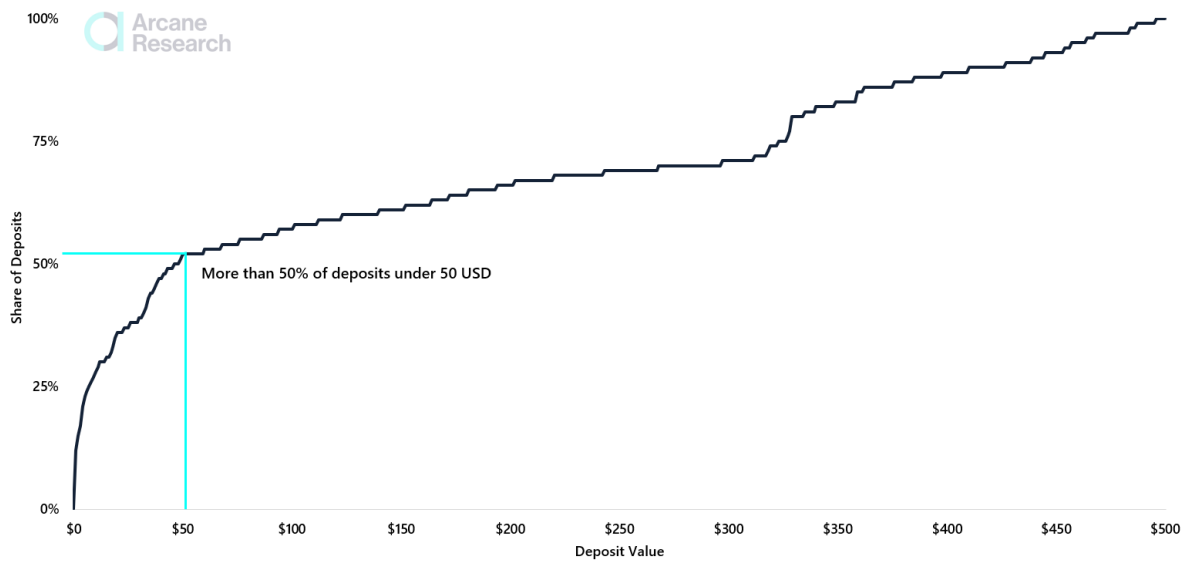
Source: Paolo Ardoino (Twitter)

The **Lightning Native** services have entered the market from a different angle, building their services with the Lightning Network as the core building block for their concept. These financial services are more experimental in their nature but deliver interesting products nevertheless. Boltz is a marketplace where users may convert lightning bitcoin to on-chain bitcoin or altcoins without user registrations. The goal is to implement a non-custodial intermediary-free solution to swap between assets.

Within the financial sector of Lightning Native services, there are also services emerging, experimenting with enabling derivative markets through Lightning. LN Markets² is the most noteworthy derivative exchange on Lightning thus far. It is a trading platform built on the Bitcoin Lightning Network and uses Bitcoin, paid and settled over the Network as collateral for derivatives trading. Another developing project in its alpha testing stage within the derivative scene is Kollider. Kollider builds a peer-to-peer orderbook based derivatives market using Lightning to fund the account. By examining data from LN Markets, we find values similar to what we see across the Lightning sector in general. The deposits tend to be small, per our chart below, more than 50% of all deposits on LN Markets were smaller than \$50. Approximately 30% of all deposits were smaller than \$10. This suggests that many use LN Markets to experiment with Lightning while also being exposed to the thrill of speculating on bitcoin with leverage. However, the company has a cumulative trading volume of nearly \$250 million since they launched, which shows real demand for derivatives trading through the Lightning Network.

² Arcane Crypto owns 16% of LN Markets

Figure 27 - Cumulative Distribution of Deposits to LN Markets



Source: LN Markets

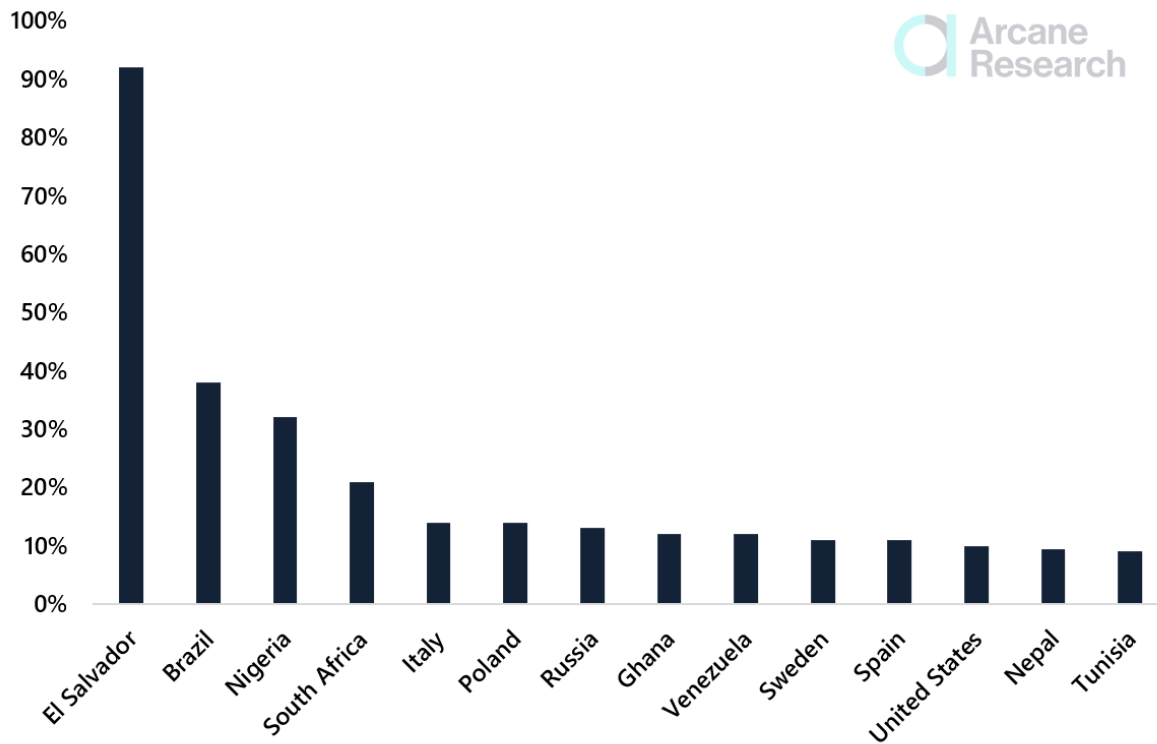
Other

Including the categories mentioned above, we've merged a subset of other services offered within the Lightning Network's commerce sector. Within the broad "other" category, we find various market niches. The e-commerce sector represents stores where people may buy physical goods and artwork. The social apps include services based on encrypted messaging, allowing users to chat and pay over the Lightning Network. However, the most widely used subsector within the far-reaching "other" category is the gift card and voucher providers.

The gift card and voucher services enable users to spend satoshis on gift cards, book travels, and top-up their phones. These services are popular within the Lightning Network, and Bitrefill offers the most widely used services within the sector.

Data from Bitrefill illuminate the Lightning penetration in certain countries. The data illustrated in the figure below shows Bitrefill's data on the share of Lightning payments received from a given country relative to the total amounts of payments received from the country in August 2021. This data set illustrates that some developing nations have a very high Lightning penetration. More than 90% of all payments on Bitrefill originating from El Salvador were conducted through the Lightning Network. Additionally, more than a third of the payments originating from Brazil and Nigeria were conducted through the Lightning Network.

Figure 28 - Lightning Network Payment Count Percentage, Bitrefill



Source: Bitrefill

3 The evolution of usage on the Lightning Network – gradually then suddenly?

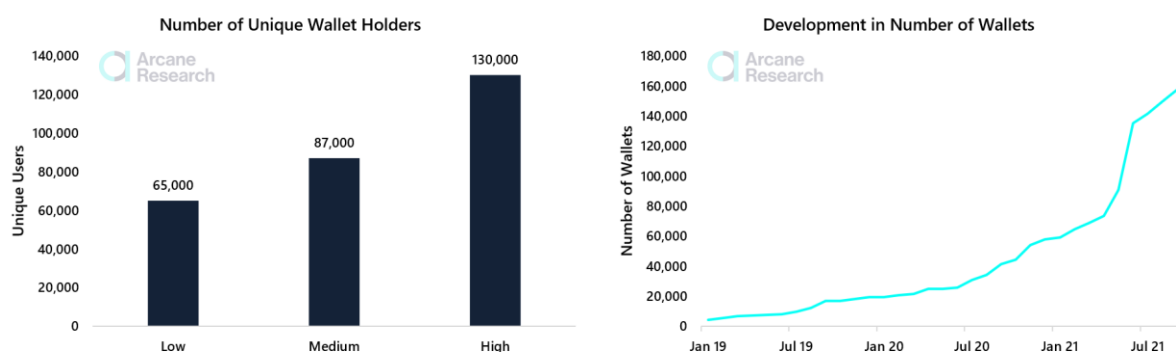
We are now seemingly in the midst of the Lightning Network’s first take-off phase. The Lightning Network serves a crucial role for El Salvador’s recent adoption of bitcoin as legal tender to succeed. Likewise, the low fee finesse and ease of use of Lightning have led Twitter to integrate bitcoin tipping into their platform. To understand the impact of these events and reflect on the future growth potential, we create an industry benchmark highlighting the state of Lightning until August 2021 and provide future projections based on the trends identified in our data.

3.1 Setting the benchmark – Lightning until August 2021

We have previously shown that the publicly available Lightning Network metrics have increased sharply this year. However, public metrics such as channel capacity, number of nodes, etc., do not tell us anything explicit about adoption on the Lightning Network. For this report, we have gathered private data from several companies in the Lightning ecosystem, among other popular wallet providers. Using these data and calculating relative market shares between wallet providers from service payout data, node activity, and like, we can estimate numbers for all transactions for the commonly used wallets³. Of course, some people run their own wallets and nodes without using a wallet provider. Still, we believe that estimating numbers for the commonly used wallets gives great insight into mainstream usage and adoption.

By the method stated above, we estimate that there are about 160,000 easy-to-use Lightning wallets. Some users hold more than one wallet, and controlling for this fact, we estimate that there are 87,000 unique wallet holders. It must be stated that these wallet and user estimates contain uncertainty. To highlight these uncertainties, we have stretched our central assumptions to the lowest and highest value we think are in a realistic range to obtain upper bound and lower bound estimates for the number of users.

Figure 29 – Left: Low-high estimates for the number of unique wallet holders as of August 2021. Right: Development in total number of easy-to-use Lightning wallets.

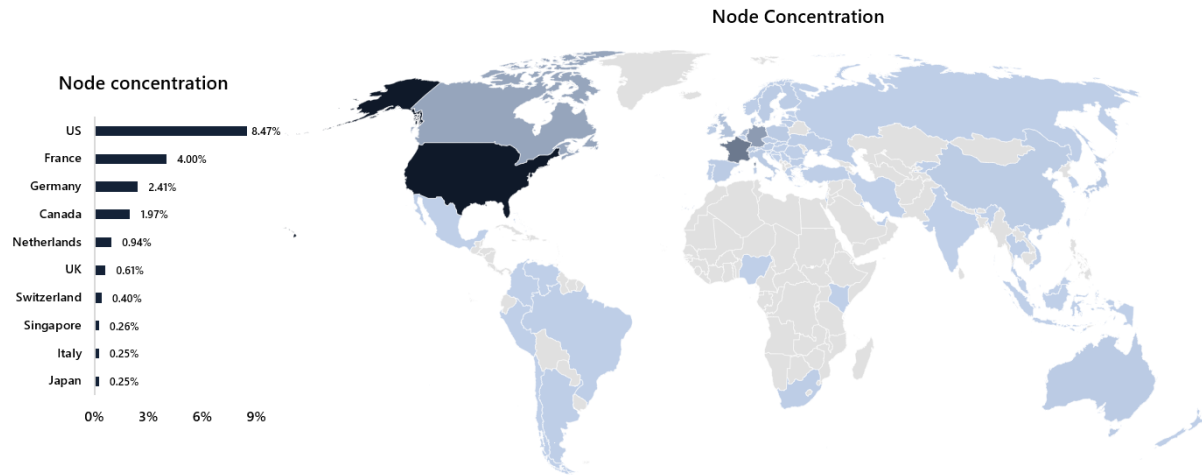


Source: Arcane Research

³ Commonly used wallets and easy-to-use Lightning wallets are used interchangeably in the report. These terms refer to Lightning wallets such as Wallet of Satoshi, Breez, Phoenix, BlueWallet, Muun etc. who likely have accounted for most mainstream usage on the Lightning Network. Be aware that the estimated numbers do not contain the activity from developers, channel rebalancing, most b2b transactions, etc.

Bitcoin’s development community has historically been stronger in North America and Europe than in the rest of the world, and this is clearly true for Lightning as well. Nodes are concentrated mainly in the Western hemisphere, with the US holding the most significant share of the nodes on the Lightning Network, per data available through 1ML. France, Germany, Canada, and the Netherlands follow.

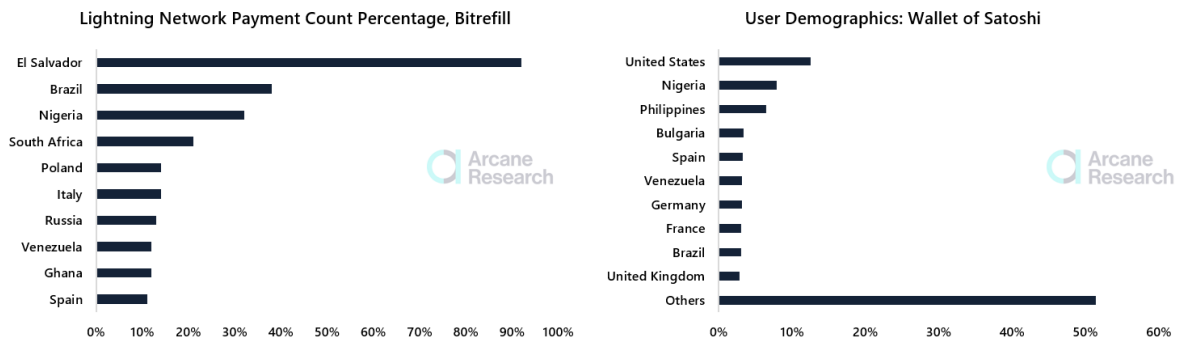
Figure 30 -Node Concentration Worldwide



Source: 1ML.com

However, the usage of Lightning is global, and users in the emerging markets are clearly present. While the development and nodes are based mainly around the Western hemisphere, data from industry participants clearly suggest that the usage is global. Based on data from Wallet of Satoshi, developing nations such as Nigeria, the Philippines, and Bulgaria have a significant presence on the network. Further, data from Bitrefill suggests that users from developing countries tend to prefer to utilize Lightning payments over on-chain payments. Salvadoran, Brazilian and Nigerian users on Bitrefill are the most frequent users of Bitrefill’s Lightning integration.

Figure 31 -Left: Lightning Network Payment Count, Bitrefill
Right: User Demographics, Wallet of Satoshi

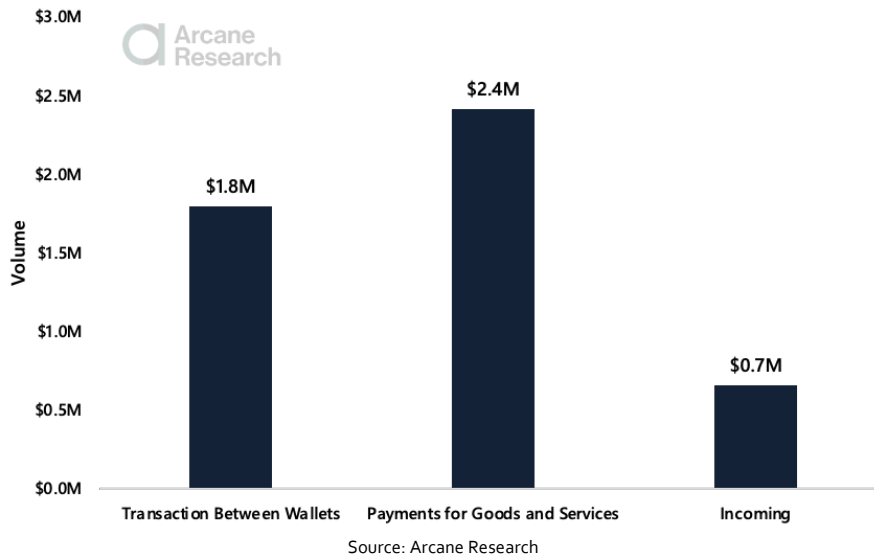


Source: Bitrefill, Wallet of Satoshi

The number of users tells us something about how widespread adoption is on the Lightning Network. Still, additional metrics such as transaction value and the number of transactions can tell us more about adoption in terms of usage. Until August 2021, use in absolute dollar value terms has been

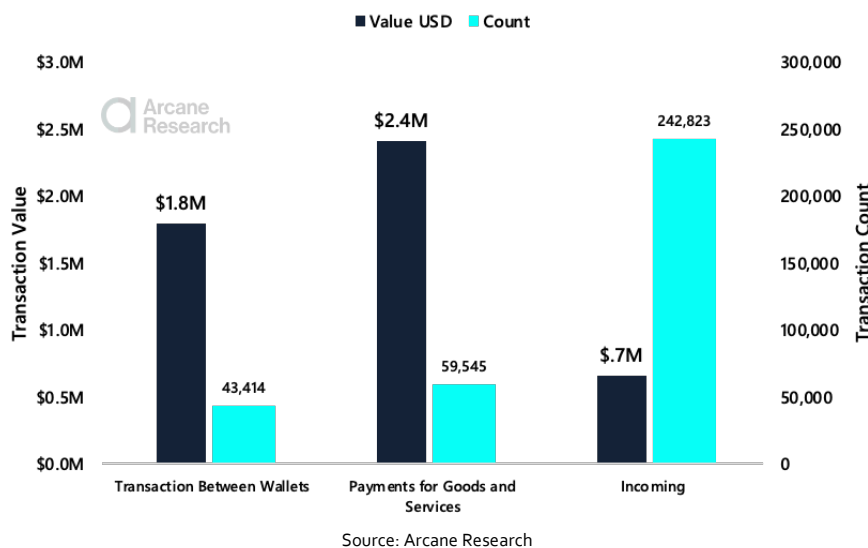
relatively low. Our estimates show that the aggregate incoming and outgoing transaction values were close to \$5 million for the commonly used wallets combined⁴. About half of the transaction value is used on payments for goods and services, with these payments totaling \$2.4 million in August 2021. “Between wallets” transactions account for a large percentage of the remaining transaction value, estimated at \$1.8 million for August 2021. Only a small fraction, around 15%, of transactions stem from incoming transactions, excluding wallet to wallet transfers.

Figure 32 - Lightning Wallet Statistics – Transaction Volume in August 2021.



Volume is not the only measure of Lightning usage. If we look at the number of transactions, the picture changes quite drastically. Though accounting for a small part of transaction value, incoming payments make up the brunt of volume in terms of the number of transactions. In August 2021, we estimate that there were almost 250,000 incoming transactions. We will revisit what these incoming payments are shortly. We further estimate that there were just under 45,000 transactions between wallets and 60,000 payments for goods and services in August 2021.

Figure 33 - Lightning Wallet Statistics – Transaction Count August 2021

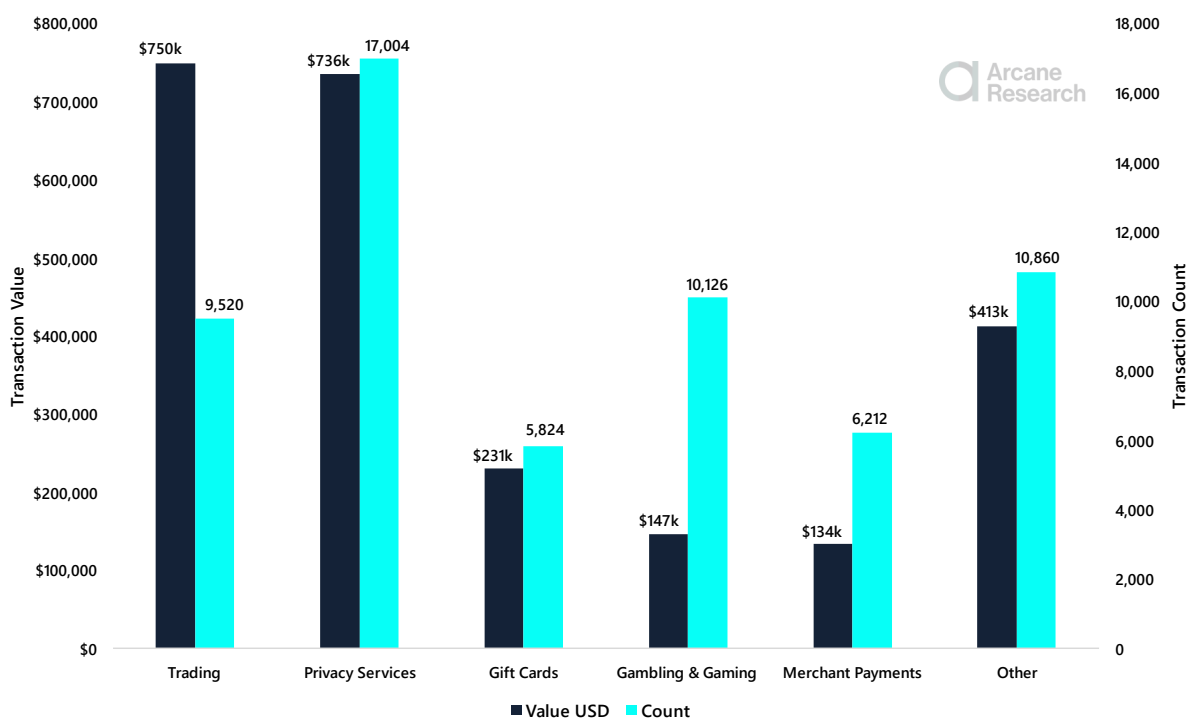


⁴ Adjusted for double counting of “between wallets” transactions. One paid Lightning invoice is only counted once.

Transactions between wallets can, in large part, be divided into two groups. The first group consists of those exploring and playing with the Lightning Network, whereas the second group consists of those who use it to transfer value. Unfortunately, we have found no reliable method to split between these two groups.

However, for payments for goods and services, we can provide reliable estimates on how the Lightning users spend their satoshis. In Figure 34 below, we have categorized the spending in August 2021. In terms of payment value, trading and privacy services account for a large portion of spending, totaling about three-quarters of a million dollars each. We further estimate that about \$230,000 was used on gift cards, \$150,000 for gambling and gaming, \$130,000 for merchant payments, and \$400,000 for other purposes.

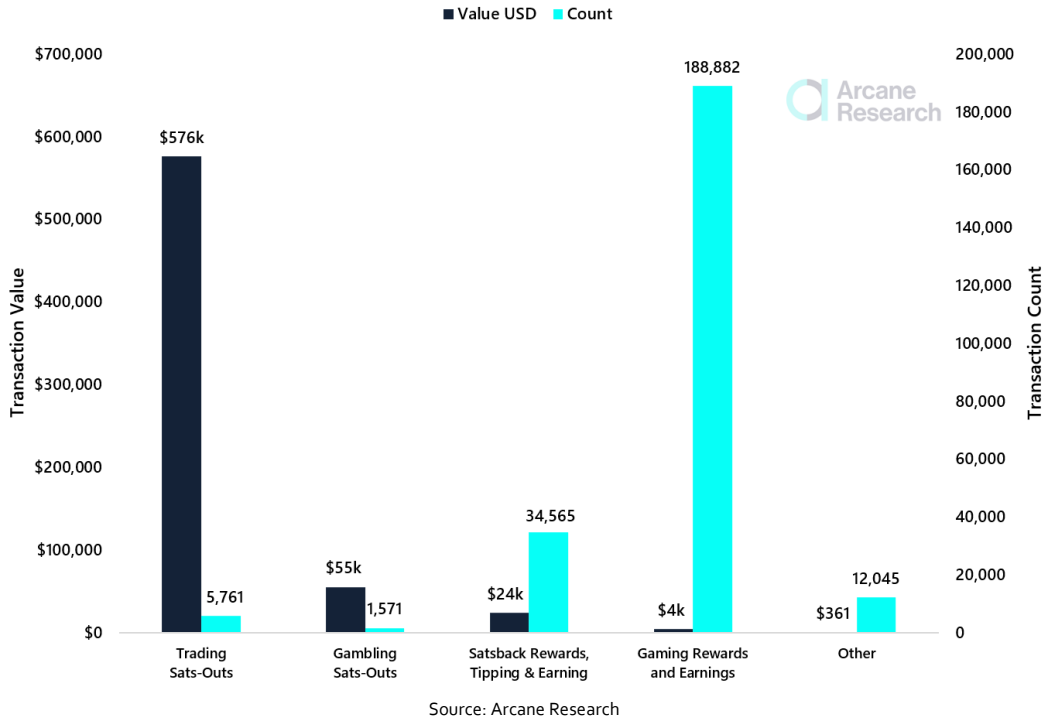
Figure 34 – Lightning Wallet Statistics – Distribution of Payments for Goods and Services (August 2021)



Source: Arcane Research

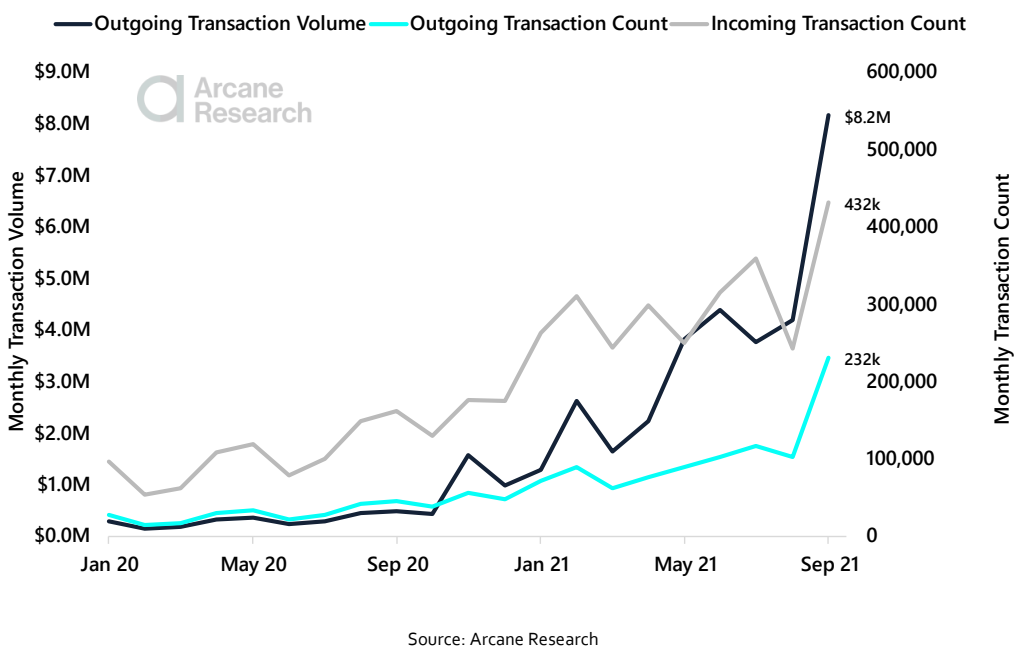
We promised to revisit the large number of incoming transactions, and here we go. The distribution of incoming transactions is shown in Figure 35 on the next page, and the picture is quite clear. In terms of the number of transactions, a considerable amount comes from various reward programs, with online gaming rewards being the most significant source. However, the average reward is small, and the reward categories account for a small percentage of incoming transactions value. Most of the incoming transaction value comes from withdrawing portions of earlier deposits for trading or from gambling, with the former being behind the large brunt of volume.

Figure 35 – Lightning Wallet Statistics – Distribution of Incoming Transactions (August 2021)
Excluded wallet-to-wallet



We have now looked at the status of mainstream usage on the Lightning Network as of August 2021. Even though still relatively low in terms of transaction value, growth has been high. From August 2020 to August 2021, the value of payments from the wallets (outgoing) increased from \$0.5 million to about \$4.5 million. In September, growth went parabolic, largely driven by the introduction of bitcoin as legal tender in El Salvador.

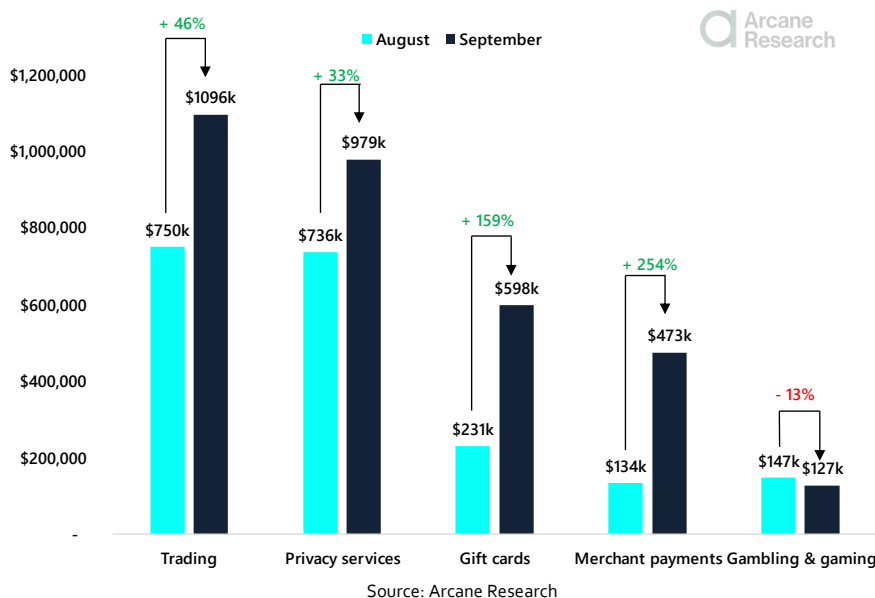
Figure 36 – Lightning Wallet Statistics – Development in outgoing transaction volume, outgoing transaction count, and incoming transaction count.



Payment value has risen significantly more than the transaction count since October 2020, coinciding with the large increase in the bitcoin price. The price increase for bitcoin is, however, only a fraction of the explanation behind this development. A large share of Lightning payments is for goods and services or a transfer of a certain amount to someone else. For these types of transactions, the buyer and seller or sender and receiver still price or think of value in fiat currency. The relationship is, therefore, mainly in the opposite direction. Higher bitcoin price will result in lower amounts of bitcoin being sent, rather than increasing the dollar value of payments.

Looking forward, it seems like the recent growth spike will become just a flat line along the bottom of the y-axis. When examining the composition of payments in August with September, a clear narrative emerges. Payments for typical everyday use grew multifold in September and further fueled the trend over the last year where these payments make up increasingly more of Lightning payment volume. We estimate merchant payments to increase by 250% in September, and gift cards and between wallet transfers to increase by more than 100%. Trading and gambling are estimated to increase by the least significant percentage, with gambling expenditure actually going down.

Figure 37 – Lightning Wallet Statistics – Payment volume for selected services in August and September.



Projected growth in transactions for September 2021 is impressive, but peeling one more layer back, the possibility for an exponential increase in adoption is evident. We estimated that there were in the region of 90,000 Lightning wallet holders in August 2021. Since then, a lot has happened. El Salvador introduced bitcoin as legal tender on September 7th. In the process, all citizens will get a 30 USD handout if they install and set up the Chivo Wallet, a dual on-chain-Lightning and fiat wallet rolled out in El Salvador. As of October 1st, El Salvador President Nayib Bukele stated that 2.7 million Salvadorans had been onboarded to the app. This is not equivalent to 2.7 million more active Lightning users, but 2.7 million Salvadorans now have access to pay with the Lightning Network on their mobile phones. The case of El Salvador is highly promising for the adoption of bitcoin as money, but Lightning is not only looking promising there. On September 14th, Paxful, a peer-to-peer platform for payments and fiat-to-crypto currency exchange, announced its Lightning Network integration. With their userbase, this means that another seven million people soon have access to Lightning payments in their pocket. Further, on September 23rd, Twitter launched a tipping service with Lightning integration, enabling Twitter's 186 million users to send small tips to each other through utilizing the Lightning Network.

3.2 The future of Lightning

To predict the future of Lightning is a complicated task. Nevertheless, this section will present a few steps on how this emerging technology can radically change how we make payments, but also touch on remittances and the potential of streaming money. This could not only change the use cases for bitcoin but revolutionize certain services we deal with on a daily basis. We're not alone in predicting a bright future for the Lightning Network, as seen by the quotes we've collected from several industry leaders.

Elizabeth Stark
CEO – Lightning Labs



"In the not too distant future, users won't even know they're using bitcoin and Lightning, much like users of the internet don't know they're using TCP/IP. People will be able to natively and seamlessly send money in any application on the internet, similar to how they can send photos today. Bitcoin can be the protocol that underpins transacting on the internet, from cross-border payments, to payments embedded in chat apps, to gaming and supporting artists and creators. Most of the biggest use cases in the future will be things that would sound insane to us today, kind of like how an encyclopedia that anyone can edit would have sounded crazy to people in the pre-Wikipedia era."

Ray Youssef
CEO – Paxful



"The Lightning Network will enable Bitcoin to scale like we've never seen before. With its low fees, Lightning offers a mainstream option for micropayments—so buying a cup of coffee or remitting abroad with Bitcoin becomes a reality for the masses. As an example, Paxful is on the ground right now in El Salvador, where Bitcoin is taking off even in more rural cities like Santa Ana, a small and vibrant town. Walking down the streets, you'll see handwritten "Accept Bitcoin" signs over shops. This is just the start and has massive implications for consumers, merchants, businesses, lawmakers, and economies. Eventually we anticipate many people choosing Bitcoin over local currency—as with Lightning it is instant and essentially free globally. What excites me is that mainstream adoption will happen in the emerging world first, they have already pioneered Bitcoin as a means of exchange and are leading adoption. The vision leads us to a world where money flows freely and enriches everyone. Bitcoin will be remembered for many things but being the spark that helped finally solve financial inclusion for all, and ensure that emerging markets across Africa, India, Latin America, and Asia are all included."

Nicolas Burtey
CEO – Galoy



"In these early days, Lightning will be most readily adopted and useful in jurisdictions where: 1) People generally do not have access to the legacy banking system, and 2) Regulatory and compliance burdens are relatively low. Last year Galoy chose to build our a proof of concept ,the Bitcoin Beach wallet, in a country that exemplifies these characteristics: El Salvador. Our Bitcoin Beach Wallet has rapidly grown to be the largest community owned Bitcoin bank in the world. We have shown that Bitcoin banking works at scale today, inclusive of Lightning payments that have instant settlement and no fees. Our efforts in El Salvador are just the beginning. There will be many new expressions of organizations onboarding to the Bitcoin network via Lightning in the next few years -- including banks, companies, governments and a wide array of communities (such as towns, religious organizations and educational institutions)."

João Almeida
Co-Founder & CTO - OpenNode



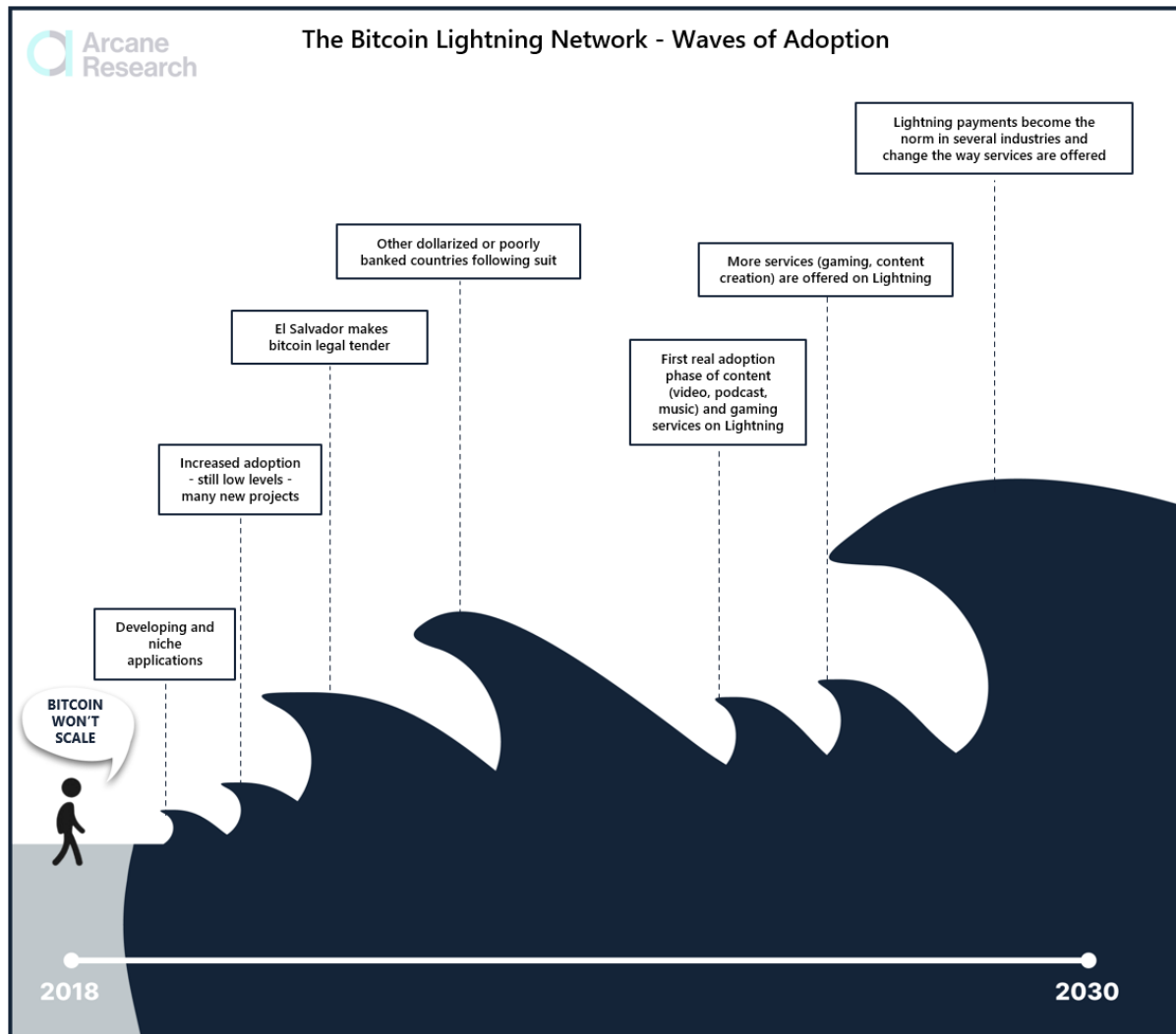
"We're excited about the growth demonstrated by the Lightning Network in recent months. Lightning Network participants are seeing the network effects that have supported Bitcoin growth, and are well placed to bring their data together to qualify and quantify progress. With scalability provided by Lightning, and the regulatory clarity of Bitcoin the asset, Bitcoin clearly becomes the best way to hold and transfer value. Moving forward, we see LN payments adoption accelerating, spurred by Bitcoin adoption and a growing global Bitcoin economy."

Christian Decker
Researcher - BlockStream



"We, the Lightning developers, are continuously improving the Lightning Network over time and the current deployment is likely to be just the foundation on which we'll continue to build. It is encouraging to see the steady growth over time in terms of adoption, use-cases and ease of use as more and more people are onboarded onto the network, and we are gathering feedback to inform our future development efforts. Initially we expect Lightning adoption to be primarily in the sectors that need it most, such as online and micro-payments, remittances and in regions with financial instability, but over time we expect Lightning to become a payment option as common as cash or credit card payments are today."

The illustration below showcases several possible phases of lightning adoption in the future. We see these as likely steps in the Lightning Network's ongoing growth cycle.



Source: Arcane Research

3.2.1 General means of exchange in poorly banked countries

Based on what we've seen so far in 2021, it's clear that the bitcoin as a medium of exchange narrative is emerging. At the time of writing, El Salvador is taking the first big step. On September 7th, El Salvador made bitcoin legal tender, meaning that you by law must accept bitcoin payments if the customer wants to use bitcoin. In concurrence with the introduction of bitcoin as legal tender, the government launched a dual USD/bitcoin mobile wallet with a Lightning Network integration. And the Lightning Network integration is hugely important for bitcoin to be a viable medium exchange for daily payments.

El Salvador incentivizes adoption and learning by airdropping \$30 worth of BTC to every Salvadorian who downloads the new Chivo Wallet. In a tweet on October 1st, El Salvador President Nayib Bukele stated on Twitter that the Chivo Wallet has 2.7 million users. It is, however, important to note that 2.7 million Chivo Wallet users are not equivalent to 2.7 million Lightning users by no means.

We do not know how the number of users and usage of the Lightning Network in El Salvador will develop. Still, it is interesting to play with some numbers to see how big this could be in terms of activity on the Lightning Network. In the following, we make some assumption-based projections on the usage of the Lightning Network by Salvadorans.

Our projections are calculated through two steps. In the first step, we make assumptions on the development of users with access to Lightning payments. In the second step, we make assumptions on to what degree these users actually use the Lightning Network. Combined, these two factors will result in an amount of spending and number of transactions on the Lightning Network.

Our projections start by looking at the number of users with access to Lightning payments. We use the population above 15 years as the relevant measuring stick for our calculations. Further, we divide this population into three groups, the banked, the unbanked with internet access, and the unbanked without internet access. The banked is just a single group, as we assume all banked citizens in El Salvador have access to the internet. The number of users within each of our relevant populations is shown in **Table 1**.

Table 1 – Population above 15 years old in El Salvador

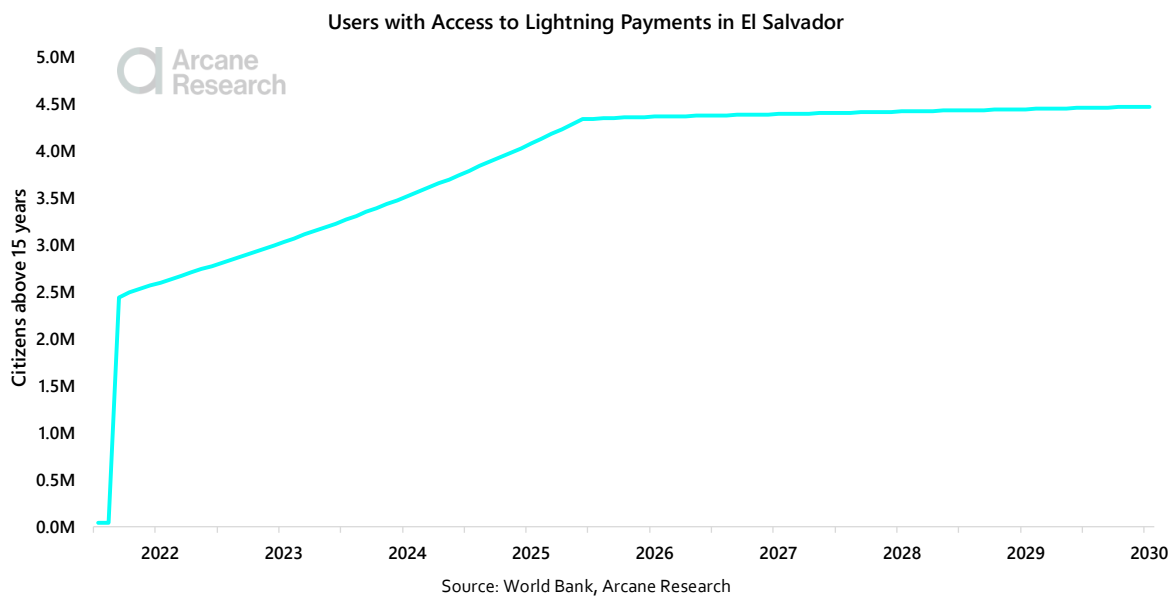
Population above 15 years old in El Salvador		
Banked w/ internet access	Unbanked w/ internet access	Unbanked w/o internet access
1.44 million	1.39 million	1.92 million

Source: World Bank

Further, we assume that only people with internet access can get access to Lightning payments. The number of internet users in El Salvador is increasing sharply, so we have assumed the same continued growth in internet users as observed between 2018 and 2019. This means people will move from being unbanked without internet to unbanked with internet over time. We assume that the newly posted numbers on users from President Bukele are accurate and use these as projections for September 2021. In the continuation, we assume a monthly increase of 1 percentage point in adoption rate among the unbanked with internet and 0.5% among the banked. Both adoption rates top out at 90%, simply cause of the fact that things seldom become 100%. The above, combined with some more but less critical assumptions, lead to the development of users with access to Lightning payments in El Salvador, shown in Figure 38. As we can see, the number of users with access to Lightning payments rises from about 2.5 million in September 2021, hitting the roof of adoption when 90% of the population has access to Lightning payments in 2025.

Figure 38 – Assumption-based projection for the number of Salvadorans with access to Lightning payments

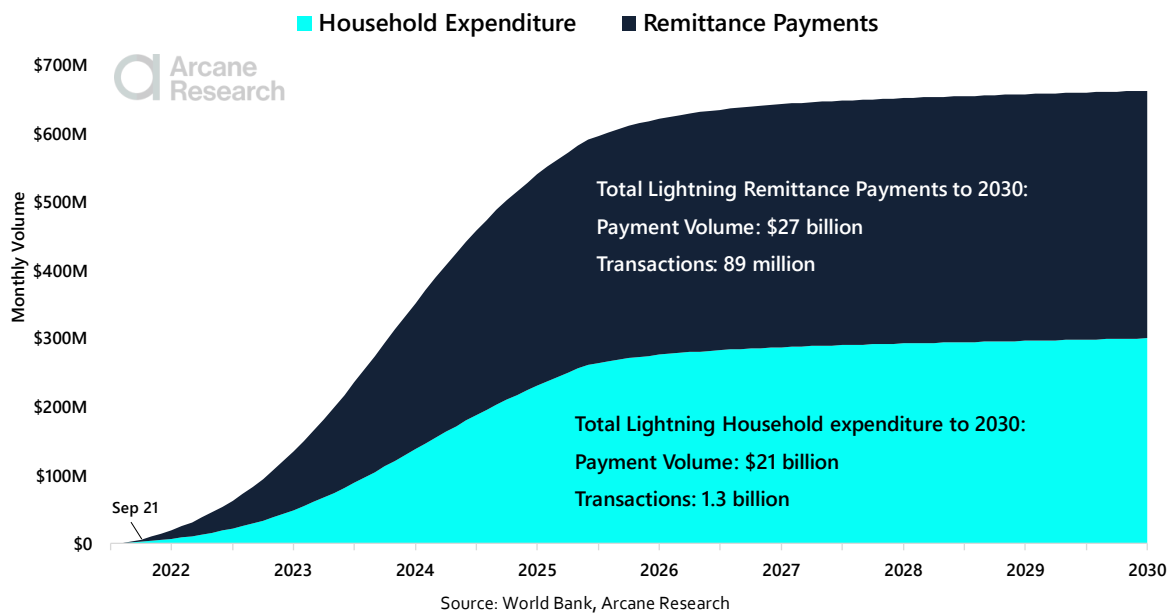
Assumption-based projection for the number of Salvadorans with access to Lightning payments	
Central assumptions	
-	Users – people above 15 years with access to wallet with Lightning capability (like Chivo) not equivalent to active Lightning users
-	Assume statements from Nayib Bukele is true with regards to <u>number of users</u> on Chivo wallet is true (about 2.5 million in late September)
-	Assume 1 percentage point of growth monthly up to a maximum user adoption of 90% for both previously banked and unbanked citizens
-	Assume people must have internet access to be a user, and that internet coverage grows by 15% a year (same as 2018 to 2019)
-	This does not tell anything about usage of the Lightning Network by Salvadorans.



As previously stated, users with access to Lightning payments do not directly equate to users and usage of The Lightning Network. We, therefore, must make further assumptions to see what the sketched user growth entails in terms of use on the Lightning Network. Overall, we assume adoption in terms of usage starts slowly and develops in an S-shape. We use figures from previous household expenditure surveys in El Salvador to translate usage adoption into transaction and spending numbers. The average household comprises three people above 15 years and has an expenditure of \$400 a month on 30 transactions for the unbanked and double the dollar expenditure for the banked. In accordance with World Bank Data average monthly remittance per household is \$300. To not overstretch our sketched projections, we assume that usage adoption for expenditure tops out at 50% for the unbanked and 25% for the banked. We believe the potential adoption could be higher for remittance payments, and we top this one out at 75%. The resulting projections in terms of monthly transaction count are outlined in Figure 39. By December 2021, the projections say there will be about 360,000 monthly Lightning transactions for a total of \$14.8 million. A year later, the number of monthly transactions will have increased to 2.8 million for a total value of \$120 million. Based on our assumption, growth in Lightning activity from El Salvador will flatten at around 20 million transactions monthly for a total value of above \$600 million by late 2025.

Figure 39 - Assumption-based projection for the usage of the Lightning Network by Salvadorans

Assumption-based projection for the usage of the Lightning Network by Salvadorans	
Central assumptions	
-	User adoption as stated earlier
-	One household comprises of 3 people above 15 years old and spends: \$400 monthly in 30 transactions for the previously unbanked. Double the value for the previously banked population.
-	Average remittance payment of \$300 per household monthly in accordance with World Bank Data.
-	Usage adoption, as percentage of household expenditure and transactions increases gradually in an Sshape. Starting at just below 1% for the unbanked in September 2021 and rises to about 50% in 2025 before flattening. The banked population both starts lower and tops out at about 25% Similar for remittance payments but these top at 75%.



Other countries could follow suit

El Salvador is not the only poorly banked country in the world, and we’ve already seen representatives from other countries being advocates for the bitcoin path. Based on a set of criteria, we have made a list of countries that would not be unthinkable to follow El Salvador in adopting bitcoin based on their attributes. The common denominator among the countries is that they are poorly banked, high reliance on remittances, and have a low GDP per capita. The exact criteria and the number of countries satisfying the criteria per region is outlined in Table 2 below.

Table 2 – List of criteria for the country to be included, the number of countries satisfying this criteria per region, and the sum of their unbanked populations.

Country must satisfy one of the following criteria:					
<ul style="list-style-type: none"> - Less than 40% of the population has a bank account - Less than 50% of the population banked, remittance above 8% of GDP, and GDP per capita under 10,000 USD - Inflation above 100% 					
Africa		Middle East and Asia		South and Southeast Asia	
27 countries satisfying criteria	Unbanked population of 610 million	12 countries satisfying criteria	Unbanked population of 330 million	8 countries satisfying criteria	Unbanked population of 215 million
Americas and Caribbean		Europe			
7 countries satisfying criteria	Unbanked population of 120 million	3 countries satisfying criteria	Unbanked population of 5 million		

Even though satisfying our criteria, it's highly unlikely that a large portion of these countries will adopt bitcoin as a general medium of exchange in the near future. And even if the likelihood is unknown, some countries appear to be more likely than others. Among the more likely countries, we find countries with a high reliance on the US dollar. These countries have already fully or partially lost control over their monetary policy and are therefore not as incentivized to keep the reigning currencies as the only mediums of exchange.

Most currency substitutions have been a result of economic crisis. Ecuador and El Salvador in Latin America, Zimbabwe in Africa and Cambodia in Southeast Asia are a few examples where the dollar is the main currency.

These economies have all been dollarized for various reasons. The core reasoning behind the dollarization stems from instability (high inflation) caused by the former national currency. High inflation causes uncertainty, malinvestments and erodes savings. We label three kinds of dollarized economies, all with distinct variations.

- 1) A fully-fledged dollarized economy using USD or a USD equivalent as legal tender.
- 2) A national currency with a fixed peg to the USD. The fixed peg requires that the nation avoids the temptation to overspend, in turn force the fixed exchange rate to be devaluated as confidence is lost amid deficits.
- 3) The people's opinion. In these countries, USD is the preferred medium of exchange, as the general public has lost confidence in the local currency's stability. Cambodia is a prime example of this.

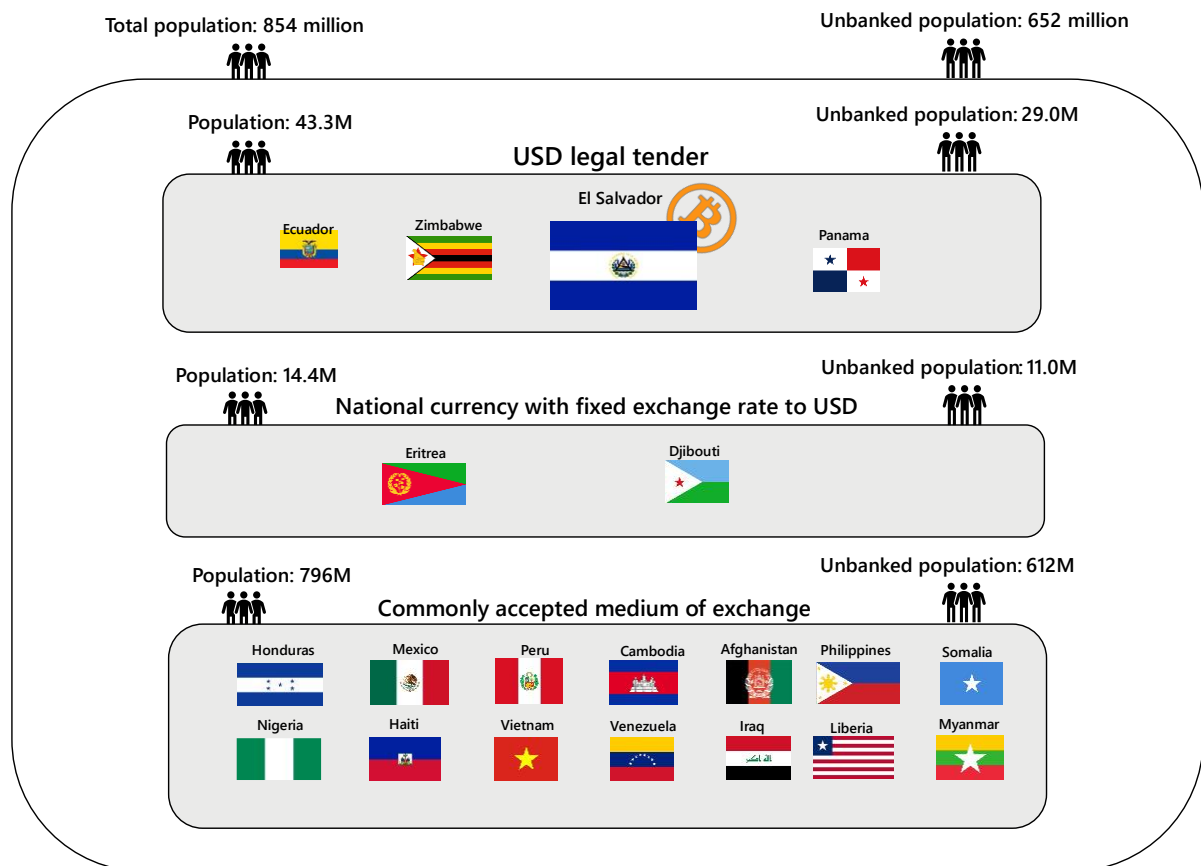
Dollarization involves several benefits, with the key benefit being enhanced confidence in the country's monetary policy. This may attract new foreign investors to the economy, leading to economic growth. However, following the dollarization, a key disadvantage is that the flexibility in the national economy is given up, while the economy is closely tied to the American economy. The dollarized nation has less room to initiate monetary policies based on the current business cycle of the economy. Correspondingly, the USD is affected by decisions made by the Fed to manage the U.S. economy. The U.S. business cycles or Fed's monetary policies may not align with the situation in the dollarized nation.

Would a dollarized country be better off as a bitcoinized country? El Salvador has opted for a dual solution when adopting bitcoin as legal tender. The hope is that friendly crypto regulation may invite more foreign investments while also opening the economy to the global market.

Bitcoinization enables rapid remittances at a low cost, while it also represents an alternative to the close link to the U.S. economy. While bitcoin is far more unstable in terms of day-to-day volatility than the USD alternative, optionality may be beneficial. The dollarized economy gains more monetary independence from the U.S., while also involving other benefits such as increased foreign investments and more efficient remittances.

In sum, the points above might attract other dollarized and poorly banked economies to emulate the El Salvador approach, introducing bitcoin as legal tender and further enhance the Lightning Network adoption. The figure below illustrates the heavily dollarized and poorly banked economies today, having a combined population of more than 850 million and more than 650 million unbanked people. Some of these may opt to follow El Salvador's lead in the coming years.

Poorly banked and dollarized countries



Source: World Bank

Panama could potentially be the next country to follow El Salvador. Opposition politician Gabriel Silva recently said that he seeks consensus to make bitcoin legal tender in the country. He plans to present a bill next month and said that Panama's current constitution prohibits the government from mandating only certain currencies as legal tender, facilitating the incorporation of bitcoin as a currency. A similar movement has been seen in Paraguay, where Paraguayan congressman Carlos

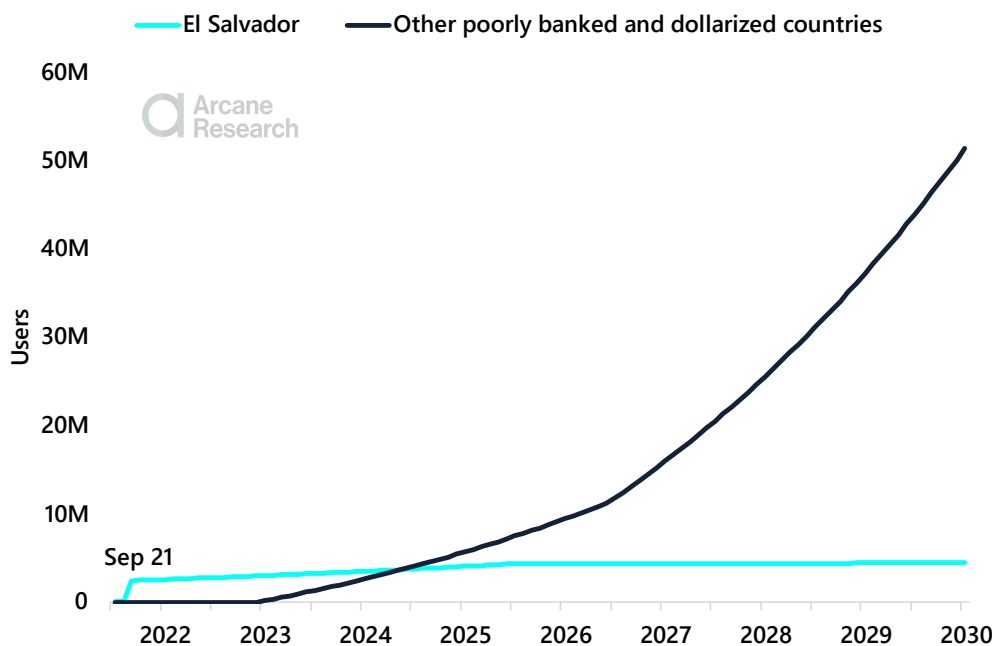
Rejala [tweeted](#) a photo of himself with laser eyes and wrote that the El Salvador announcement prompted him to not be afraid and think that this can be real in his country as well.

There's undoubtedly a big step from speaking publicly about bitcoin to get real adoption in a country, but 2021 has shown us that a new bitcoin narrative has emerged, and the Lightning Network will be highly central if this trend continues. We have played a bit more with numbers in a what-if scenario where some of the poorly banked and dollarized countries adopt bitcoin as a medium of exchange.

To scope the impact on Lightning Network users and usage from more countries following El Salvador, we start at the list of poorly banked and dollarized countries above. Further, we apply the same methodology as used in El Salvador's case above, with some tweaks. Firstly, some of the most likely countries for bitcoin adoption are poorer, and the average households do fewer transactions a month than Salvadorans. We have therefore revised the average spending and number of transactions per household down from earlier. Secondly, most of these countries will probably not adopt bitcoin. We have therefore adjusted for this by setting the adoption rate in terms of users to 10% of the total population above 15 years old by the end of 2029 in these countries. We further assume that the next wave of countries adopting bitcoin starts in early 2023. Both user and usage adoption are gradual, like in the El Salvador case.

By applying these assumptions in our projections, we see that there is potential for another massive influx of Lightning users if more poorly banked and dollarized countries adopt bitcoin. In the above-outlined scenario, the number of Lightning users from poorly banked and dollarized countries will grow to more than 50 million people by the end of 2029. In Figure 40, we show this growth together with the projections for El Salvador. With a relatively modest adoption rate of 10% by the end of 2029, we see that the number of Lightning users in other poorly banked and dollarized countries is ten times the number of El Salvador when entering 2030.

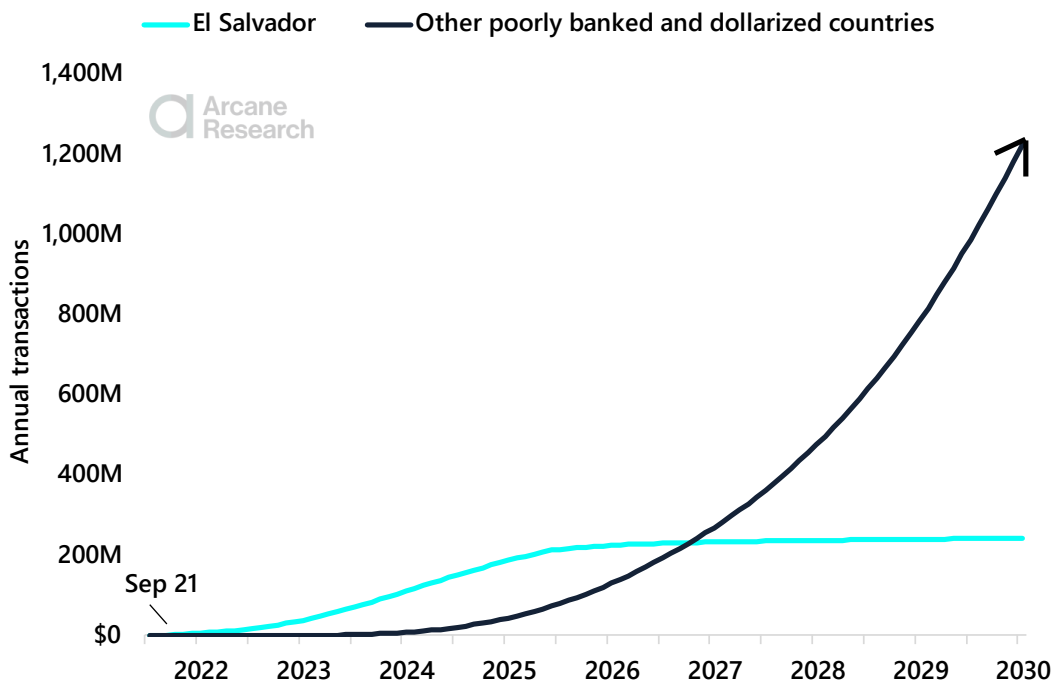
Figure 40 – Lightning users from poorly banked and dollarized countries adopting bitcoin. Assumption-based projections.



Source: World Bank, Arcane Research

Lightning transactions from these users will evolve similarly as seen before, although with the lower per head transaction count mentioned above. The most eye-catching is the number of transactions these user numbers imply. In Figure 41, we show the annualized transactions performed by the users in our assumption-based projections. By the end of 2029, El Salvador and other dollarized countries that have adopted bitcoin will make in the region of 1.3 billion Lightning transactions yearly, with growth accelerating in the early 2030s by the users onboarded in the 2020s alone.

Figure 41 – Lightning usage on household expenditure and remittance payments from poorly banked and dollarized countries adopting bitcoin. Assumption-based projections.



Source: World Bank, Arcane Research

Change how we do remittance payments

Remittance payments are an important part of our projections above. Low- and middle-income countries received \$540 billion in 2020, according to The World Bank. Remittances below \$200 to Sub-Saharan countries is the most expensive to transfer, with an average cost of 8.2%. The global average was 6.5% in 2020. Remittance payments between countries are even more costly. For example, sending money from South Africa to Zimbabwe cost 14%, according to the World Bank. These overburdensome costs are due to a combination of an inefficient and uncompetitive banking market and a reliance on legacy financial communications systems such as SWIFT.

The most updated numbers from The World Bank shows that the average cost of remittance is 6.38%. Interestingly, banks are highlighted as the most expensive service provider, with an average cost of 10.66%. Regardless of the high costs, remittances are hugely important in many countries and a key component of economic income. One example is El Salvador, which is already approaching bitcoin. The nation is deeply dependent on money sent back from abroad, and remittances equal 24% of the country's gross domestic product (GDP). This totaled \$5.9 billion last year, and president Bukele has

asserted that the use of bitcoin will reduce the annual commissions on remittances through services like Western Union by about \$400 million.

3.2.2 Changing the way services are offered

As illustrated in the above sections, the Lightning Network can radically change payments and money transfers both in local markets and globally. Not only as a cost-reducing alternative but as a more available and trustable alternative, bringing the power to the user.

It doesn't stop there. The Lightning Network, and the possibility to perform micropayments instantaneously, will most likely change how we pay for certain services. We already see the first steps, but the alternative *to stream money* will revolutionize many popular services in the future.

While we're used to streaming content, we pay for this the same way we pay for a gym membership or how they paid for milk delivery in the 1950s. Subscription-based services have been a part of society for a long time, perhaps so long that we don't question these models anymore. Spotify, Netflix, HBO are all examples of subscription services where we today stream the content.

The possibility of streaming money can disrupt the business model of these services. Why shouldn't you be able to pay per minute you listen to songs on Spotify or per second you watch of a movie on Netflix? Why should you give away your credit card details to a content service provider if you could pay directly from your Lightning wallet without giving away any information about yourself?

The Lightning Network makes this possible. We already see the first steps towards a society where we use streaming payments to pay for content. Podcasting is the first form of media to experiment with this, with Sphinx.Chat, Fountain.fm and Breez, among others, being early. Will streamers on YouTube, Twitch and other creator-focused platforms be next?

This also shows us how the control can be moved to content creators and away from powerful third parties via external payment rails. Podcasters, music artists, and other content creators can move to pure value-for-value models, where you pay directly for the content you get, fully peer-to-peer. It is estimated that around 500 million people use audio streaming services today, showing the potential market for new innovative payment structures and setups for content creators.

While content-creators may be the first adopters of streaming payments, we'll likely see disruption on the subscription models from Netflix and others in the future. The potential impact on the activity on the Lightning Network can be enormous, bringing millions of users, if not billions, onboard.

Netflix is the leading streaming service worldwide and had over 200 million paying subscribers by the end of 2020. However, it is estimated that over 500 million people use the service, according to eMarketer. This is expected to increase to more than 670 million by 2024. While Netflix is the streaming giant today, it is far from the only option out there. Amazon Prime, Tencent Video, Disney+, and Youku are other services, all with around 100 million subscribers. We estimate that 75% of all users of streaming services are users of Netflix. This leads to an estimated 900 million users by 2024 and more than 1 billion by 2030 if the growth continues.

Another industry with a staggering number of users is gaming. It is estimated that 3 billion people worldwide are playing video games, either on smartphones, PCs, consoles, or tablets. Monetization of this industry is on the rise, and it is estimated that the 3 billion gamers worldwide will earn the global gaming market an estimated \$190 billion this year. It is not hard to understand how the Lightning

Network can have an impact on this industry. We're currently seeing the beginning of Lightning payments in gaming, as mentioned earlier in the report. This could be instant earnings based on the user's in-game performance, or for example, staking satoshis when playing where you win or lose funds based on your performance.

Why Lightning?

There are several reasons for why the Lightning Network will play a vital part in these industries in the future. This is not only related to instant micropayments to make a more seamless experience, where consumers meet a simple QR code when they want to pay for goods and services and payments are instant, but also in terms of privacy. We will gradually move over to using services that require less personal information, credit card information and other details connected to your profile. Why? Because the only tool you need to access your Lightning wallet will be you. This will also enhance privacy from what we see with on-chain bitcoin transactions today, as the public won't know what you're using your Lightning funds for.

In addition, the problems of counterparty risk in settlement and chargebacks will be removed, and payments will be settled instantly. So, this will not only benefit consumers but businesses offering services as well. Today, businesses are connected to payment systems like Visa and Mastercard. Typically, consumers can charge back payments up to 90 days, leaving a lot of uncertainty for the businesses. These payment providers can also have processing fees as high as 2-3%, often passed on to the consumer. If the businesses switch to Lightning payments, these fees disappear and significantly improve margins.

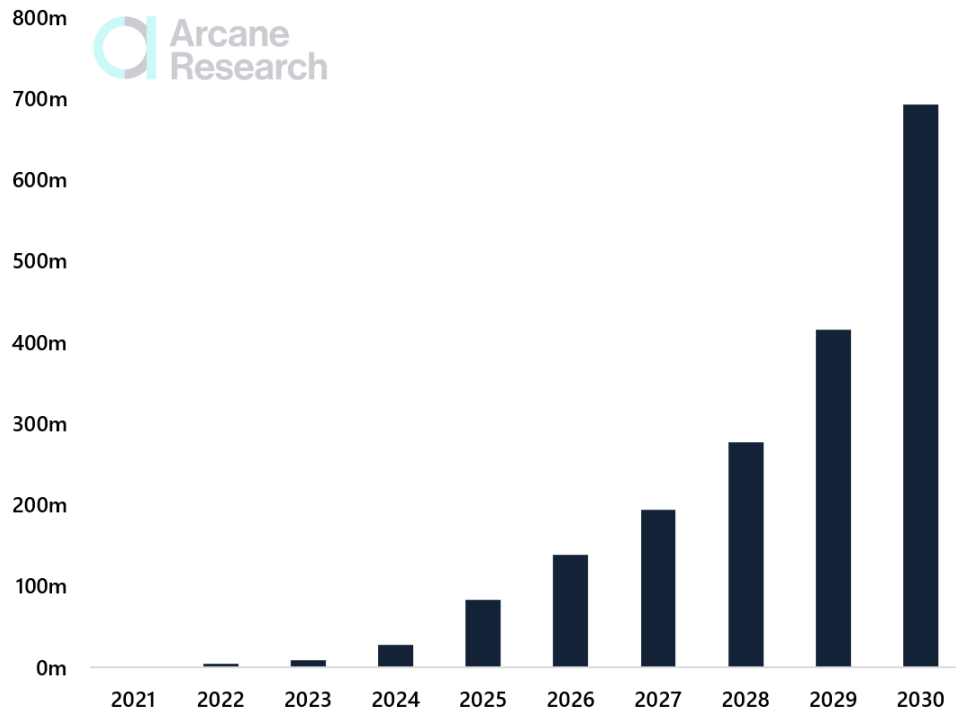
Not only will the Lightning Network make payments cheaper and more private but make both consumers and businesses less dependent on third parties.

The figure below gives us a rough overview of potential industries that the Lightning Network can penetrate. We don't know where the adoption will happen first, but the potential is enormous.



The chart below illustrates the potential impact on the Lightning Network, showing the growth in users who pay for their gaming, video and audio services through Lightning.

Figure 42 - Users of Gaming, Video and Audio Services Paying with Lightning



Source: Arcane Research

To estimate the potential number of users on the Lightning Network from gaming, video and audio, we pool the users of the various services into one group. Unfortunately, this is not done by simply adding the numbers. Two caveats complicate the calculation of this pooled group of users relevant for the Lightning Network. Firstly, a large portion of the gaming users only consumes free games, mainly on mobile phones. These people are then likely not relevant for activity on the Lightning Network. We choose to be conservative and assume that 1.1 billion of the 3 billion gamers consume paid gaming services. The second caveat is that there are considerable overlaps between users of the three types of services. We again choose to be conservative and just pick the highest number, the 1.1 billion gamers. Implicitly, we have then assumed that all people paying for video and audio services also pay for gaming services. This is likely not the case, but we pick this method for its simplicity and the relatively low impact of introducing more assumptions.

We further assume that 25% of the consuming time of gaming, audio and video is done on services requiring streaming of money. Many users will split their time between services requiring streaming money and services requiring more traditional payment options. The resulting number of users on the Lightning Network will therefore be between 25% and 100% of the 1.1 billion users. We keep it simple and land somewhere in the middle, indicating about 700 million users paying for gaming, video and audio through the Lightning Network by 2030.

To the best of our knowledge, no streaming services are close to integrating Lightning in 2021. Hence, an adoption level of 0-1% is used until 2024, with a growth of up to 10% by 2028. From 2028 to 2030, we've assumed the adoption level to go from 10% to 25%.

Another estimation that will likely blow your mind is the number of potential Lightning transactions this could equal. The figure above shows the potential of almost 700 million users on the Lightning Network from gaming, video and audio in 2030. We now use the conservative estimate of 1 hour used per day on these services and that, on average, 25% of this time is spent on services with Lightning payments. With streaming of Lightning payments through these services, we assume one microtransaction per second. Our estimate then equals no less than 364 trillion Lightning transactions per year.

While this is nothing but an estimate, it's hard to grasp the potential impact the Lightning Network can have on the services we use today. New, innovative companies will emerge. If these services move the power away from the provider and down to the user by switching out old business models with streaming of payments, the giants we know today must act. Over 700 million people using these services with Lightning by 2030 is not unlikely, but the question is, will they use Steam, Netflix and Spotify, or a completely new service that has built its service around the Lightning Network?

All these estimates might seem farfetched and ridiculous. However, we must not forget the innovation and extreme growth that we have seen on many fronts over the last decades. What the Internet did to information sharing worldwide was impossible to predict. Many were skeptical of the Internet and how it could be used to transfer files, emails, audio, and other content. These technical challenges were solved quicker than many expected. Today, 5 billion people use the Internet. Bitcoin and the Lightning Network are also based on open-source protocols and software, in the same way as the Internet, making another Internet story much more likely, with innovation and contribution from all parts of the world.

Google has just been around for two decades and now processes around 100,000 searches per second. More than 3 million emails are sent per second, and more than 60 billion messages are sent from WhatsApp each day. Statista estimates that 376 billion emails will be sent per day worldwide in 2025, giving us an estimated 137 quadrillion emails per year. This is only a brief calculation of the numbers of emails we send each year, and we're already at a number far higher than the estimated Lightning transactions that we will see in 2030.

What the Internet has done for information, Bitcoin and the Lightning Network will do for money.

- Elizabeth Stark, CEO Lightning Labs

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