

Research Report

The Lightning Network Grew by 1212% in 2 Years

Why It's Time to Pay Attention



About River

Founded in 2019, River is a Bitcoin technology and financial services company. River offers Bitcoin brokerage and custody services in one easy-to-use mobile app and on [River.com](https://river.com).

River is also a leader in Lightning infrastructure with [River Lightning](#), an enterprise API that allows companies to easily integrate with the Lightning Network. River Lightning powers Lightning transactions for exchanges and wallets in the crypto ecosystem, including El Salvador's Chivo wallet.

Purpose of the Report

For the Lightning Network to achieve its full potential in helping Bitcoin scale to more users, it is important that observers have an accurate understanding of activity on the network. Undocumented activity does not attract investors, nor does it help developers to get funding so they can continue to improve all aspects of the network.

There are no public metrics on how many people use Lightning, so critics point at metrics such as node count, channels, and capacity, which have plateaued over the past year and thus give a false impression that Lightning's adoption may be stagnating or declining.

In this report, we show how the number of users, transactions, and volume have been accelerating significantly over the past years. We also share some River-specific insights and discuss significant growth accelerators for the Lightning Network.

Executive Summary

- Based on data from the operators of nodes comprising 52% of the public capacity on the Lightning Network, we estimate a lower bound of 6.6 million routed Lightning transactions in August 2023. The upper bound could be a multiple of this number if there was data availability of direct and private transactions between participants.
 - This represents a 1,212% increase since the 503k Lightning payments estimate for August 2021 by K33 (formerly Arcane Research). This growth was despite a 44% Bitcoin price drop and a 45% decrease in search interest.
 - It is the equivalent of 2.5 transactions per second, compared to Bitcoin's on-chain average of 4.4 TPS and K33's August 2021 benchmark of 0.2 TPS.
 - Due to the architecture of the network, it is not possible to estimate an upper bound, as direct transactions between only two participants, and private transactions can not be estimated.
 - The primary use cases driving transaction growth that we identified are gaming, social media tipping, and streaming, driving 27% of all growth.

- In August 2023, we estimate that around \$78.2 million was publicly routed using 5,000 BTC in capacity.
 - This is a 546% increase since K33's August 2021 estimate of \$12.1M.
 - On an annual basis, this translates to \$936 million in volume using \$133 million in capacity, at a ratio of 7:1. This ratio outpaces Bitcoin's on-chain velocity of 5.2:1, indicating growth in the medium of exchange use case.
- The average Lightning transaction size on the public network was around 44.7k satoshis, or \$11.84 in August 2023. Size distribution shows that nearly all Lightning payments are unaffordable on the Bitcoin blockchain. Lightning is effectively extending Bitcoin's utility by enabling low-value payments over the Internet.
- We estimate that there are between 279k and 1.116 million monthly active Lightning users as of September 2023, with an estimated ratio of 1:8 non-custodial to custodial Lightning users.
 - Between 1.8-3.7 million Lightning wallets were downloaded to use Lightning, with at least 122 million wallets downloaded that have access to Lightning.
- Routing data shows us that Lightning activity has become much more global, with more equally distributed activity 24/7 than last year.
- The number of Lightning nodes, channels, and capacity have remained steady over the past year. Bitcoin adoption has slowed down due to the bear market, and nodes are professionalizing by becoming more efficient with their capacity.
- We mapped out 179 companies in the Lightning industry across 28 categories and have gathered them in an industry market map on page 20 of this report.
- \$530.93 million was raised by 39 Lightning companies between 2018 and the end of 2022. 19% of all Lightning companies received funding.
 - \$428.46 million of this funding was raised in 2022, an outstanding year for Lightning funding relative to global VC funding, which dropped by 34%.
- River's Lightning payment success rate was 99.7% in August 2023 across 308k transactions.
 - The primary reasons for failure are when no payment route can be found that has enough liquidity, and when a non-custodial wallet user is offline.
- We see companies across 9 different verticals showing strong interest in Lightning.
- Important drivers of future Lightning growth are more exchange adoption, select technical upgrades, as well as non-Bitcoin businesses adopting Lightning.

Introduction

It has been 7 years since the [Lightning Network whitepaper](#) was published by Joseph Poon and Tadge Dryja, and over 5 years since the network has gone live. Ever since the Lightning Network has grown into the biggest second layer scalability solution for Bitcoin. It enables millions of people to trustlessly and instantly move money back and forth, without having to settle each transaction on the Bitcoin blockchain.

Since its release, Lightning has been growing and overcoming challenges, with many more ahead. Protocol development takes time, and Lightning is being held to high standards by critics. These critics primarily look at the publicly available metrics such as node count, channels, and capacity, which have plateaued over the past year and thus give the false impression that Lightning adoption may be declining. We will show the opposite in this report, as growth in the number of users, transactions, and volume has been accelerating.

We will not be diving into the [basic technical functionality](#) of the Lightning Network in this report, but instead focus on adoption trends and how Lightning can continue to grow.

Before we get into that, we want to thank those who helped make this report possible. In [last year's Lightning report](#), we only had our data to share. This year with the cooperation of a range of companies and people in the industry, we were able to provide much more extensive insights into the state of Lightning than we could provide on our own. We are deeply grateful to them for their contributions.

First, the companies that shared their Lightning data with us. Together, they represent roughly 29% of the capacity (1445 BTC) and 10% of the channels (7045) in the network. They are active across exchanges (River, Bitfinex), gaming (THNDR), wallets (Wallet of Satoshi, Breez, Alby), transaction routing (LQwD, Deezy), and ordinals (Deezy).

Companies That Shared Lightning Data



Thank you to K33 (formerly Arcane Research) for a historical view on Lightning in their [volume 1](#) and [volume 2](#) reports, which laid some of the groundwork for this report.

The total reading time of this report is roughly 75 minutes.

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1. The State of the Lightning Network

In this chapter, we cover a range of metrics across transactions, users, and the network itself. We also provide an industry and funding overview.

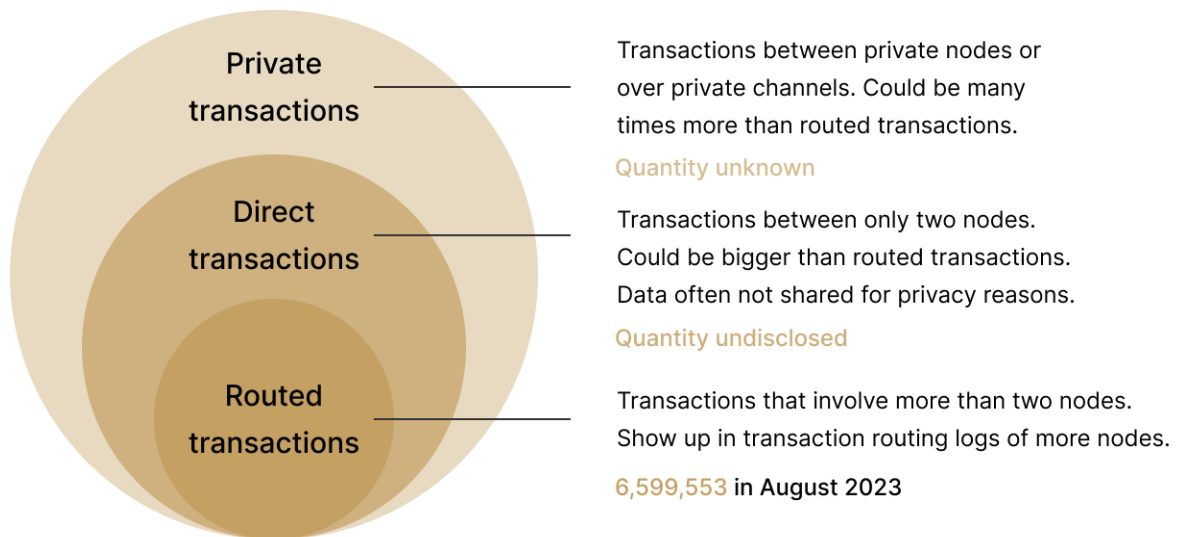
1.1 Transaction Metrics

First, we want to clarify which transactions we are able to identify, as our estimates for both transactions and volume cover far from the entire Lightning Network.

We do not have data on private Lightning transactions, as well as a significant portion of direct transactions between two nodes. The only way to understand their proportions would be by receiving direct or private transaction data from a significant amount of the network, if not all of it.

However, we would never know if we have all of this data, as there is no way to identify all private nodes on the network.

Lightning Transaction Categories Explained



Methodology explained in River's 2023 Lightning Report



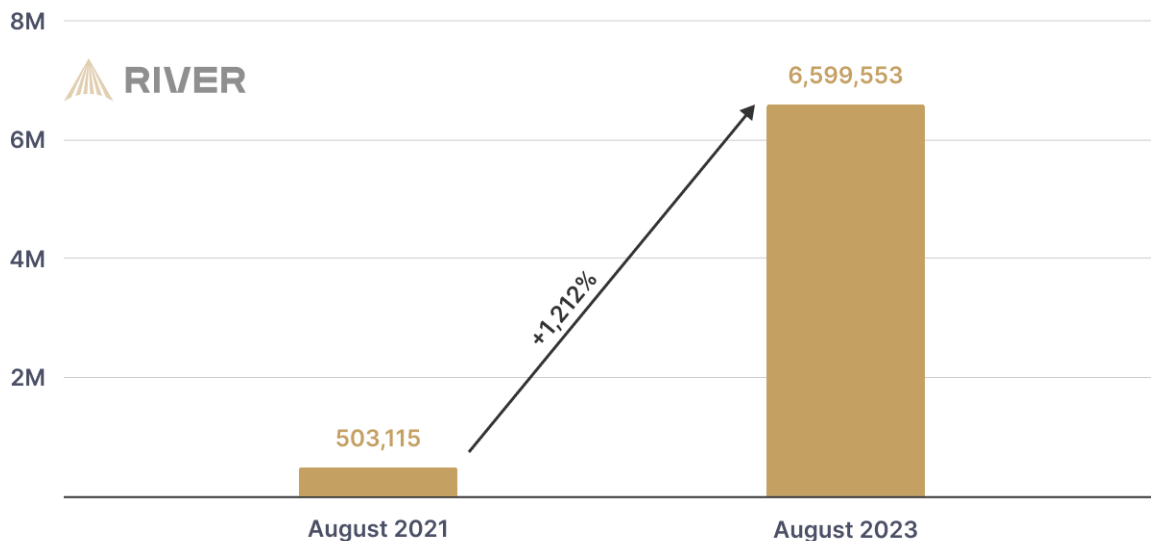
In the absence of direct and private transaction data, we are unable to estimate an upper bound of transactions on Lightning, which could be many times higher than the number of routed transactions.

How Many Routed Transactions On Lightning?

We estimate a lower bound of 6.6 million routed transactions on the Lightning Network in August 2023, or about 213k per day. This is a 1,212% increase since the August 2021 estimate of 503k Lightning payments by K33 (formerly Arcane Research).

Estimated Growth in Routed Lightning Transactions

Lower bound estimates as private transactions are excluded



Methodology explained in River's 2023 Lightning Report

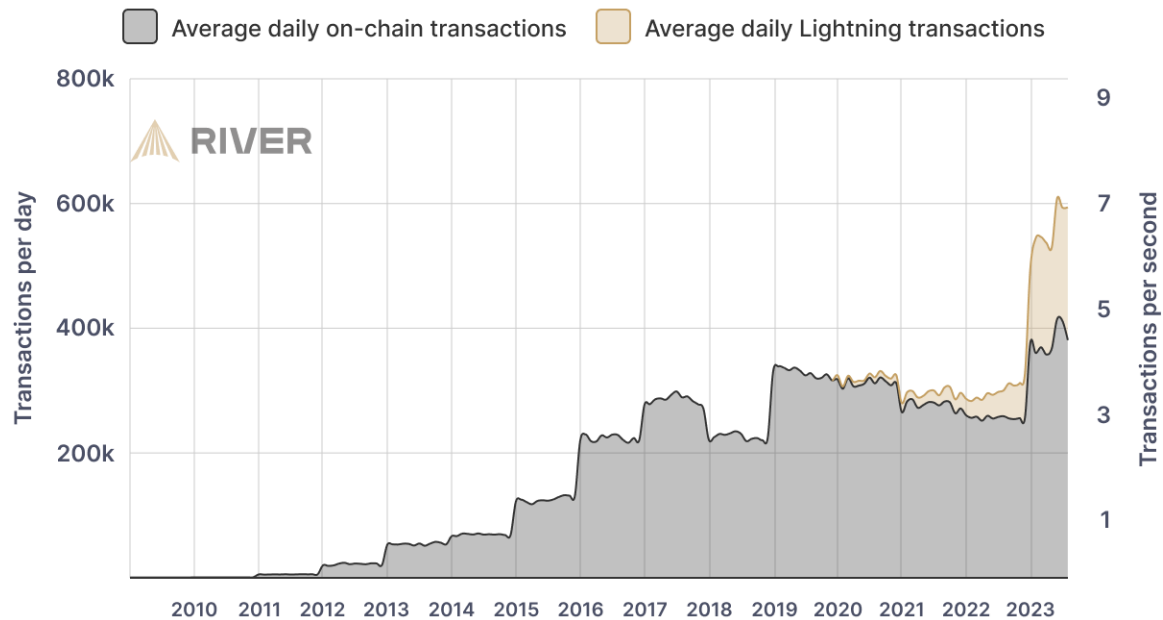
We have outlined our methodology to arrive at this lower bound in the appendix. In short, our estimation is based on data from 52% of the public capacity on the network, which gives us a reasonable level of confidence in its accuracy.

Is 6.6 Million Monthly Lightning Payments Good or Bad?

On average, Lightning is processing at least 47% of Bitcoin's on-chain transactions on a daily basis. Monthly this is the equivalent of 14 days worth of on-chain Bitcoin transactions.

Another way of looking at this number is by examining the monthly average of Bitcoin's daily transactions for both on-chain and Lightning, as well as by looking at these numbers on a per-second basis.

Lightning Is Increasing Bitcoin's Transactions Per Day



As of August 2023, Lightning is processing roughly 2.5 transactions per second, compared to Bitcoin's on-chain average of 4.4 transactions per second.

How should this growth in transactions from Lightning be perceived five years after the network first emerged? As a success? As expected? Or as a failure?

The context below provides more insights to answer this question.

1. Bitcoin's bear market

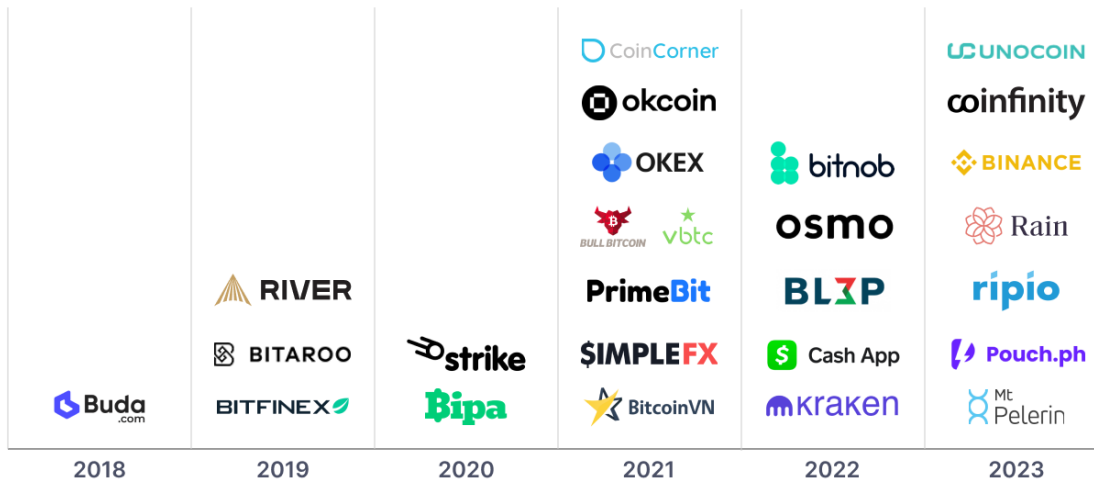
Between August 2021 and August 2023, Google search volume for Bitcoin decreased by 45%, and the price decreased by 44%. Overall interest in Bitcoin dropped significantly, so increased Lightning activity largely had to come from existing users. Getting a roughly 1,212% increase in Lightning activity from existing users is very significant.

2. Some exchanges are lagging with Lightning integration

Many Bitcoin users have never interacted with Lightning. An estimated 70-80% of Bitcoin users have their funds on exchanges today, as we established in [our previous report](#).

For many of these Bitcoin users, their exchange is their only touchpoint with Bitcoin, so when it does not support Lightning deposits and withdrawals, a user may not realize that Lightning exists or never looked into how they could use it.

When Bitcoin Exchanges (to fiat) Enabled Lightning Deposits/Withdrawals



Note: Not endorsements of these exchanges, do your research.



26 exchanges have integrated Lightning since 2018. [Coinbase intends to integrate it](#), but there are still many exchanges that haven't announced anything. More on this later.

3. Bitcoin's Medium of Exchange use case is small

Bitcoin's core function is as a store of value today. While Bitcoin can be used as a medium of exchange as well, only an estimated 11% of users use it for payments today, according to [research by Binance](#). This is not a problem for Bitcoin. Much has been written about the journey of a new form of money, first becoming a store of value, then a medium of exchange, and finally a unit of account.

It is important that people who want to use Bitcoin for payments can do so, and this experience fully exists from buyer to merchant, with a thriving landscape of competing providers among wallets, point-of-sale systems, and on- and off-ramps.

Where Does the Transaction Growth Come From?

We examine the main use cases for Lightning transactions today to dive into this question:

- Gaming
- Social media tipping
- Commerce
- Micropayments for content
- Exchange withdrawals and deposits
- Remittance through exchanges

Transaction Growth From Gaming

THNDR Gaming's data shows 226% growth, from 82k transactions in February 2022 to 267k transactions in August 2023. They are responsible for 3% of network transaction growth. Other Lightning gaming companies have likely seen significant growth too.

Transaction Growth From Nostr

Many people look to Nostr for Lightning transaction growth, due to it gaining popularity as a decentralized network protocol since early 2023, with payments over Lightning built into the applications. Over 1.5 million payments (known as Zaps) have been made according to [data by Nostr.Band](#).

According to Conxole bot on Nostr, an estimated 45% of all zaps are sent through Wallet of Satoshi and 42% through Alby. When these happen from one WoS user to another, these are internal settlements in the WoS database that never appear in the transaction logs of a Lightning node. The number of zaps that happen over the Lightning Network is therefore lower than 1.5 million.

If WoS users have a 45% market share, they have a 45% chance of sending a zap to another WoS user. This means 303k transactions could be removed from the total, which would leave us with 1.2 million zaps across 8 months, or about 150k zaps per month. Nostr would then represent roughly 2.5% of the monthly growth in Lightning transactions.

Low-Value Transactions

A significant driver of transaction growth has been 1-10 satoshi payments. In River's experience, around 25% of the total transaction count fits in this lowest value bucket on average, and this number is reflected in datasets shared by other companies.

However, looking back at historical data, this share was identical throughout 2022, so these low-value payments kept pace with the overall growth in Lightning transactions, rather than making up a larger share of the growth than in the past. Low-value transactions thus accounted for 25% of the total transaction growth, but many of these are from gaming companies and podcasting apps that pay out a small number of satoshis at a time.

Growth From Other Use Cases

It is difficult to determine where the remaining growth comes from. Wallet of Satoshi and Alby have each seen significant growth over the past 1.5 years, but we cannot determine how much overlap there is with the other use cases, nor where their payments are going.

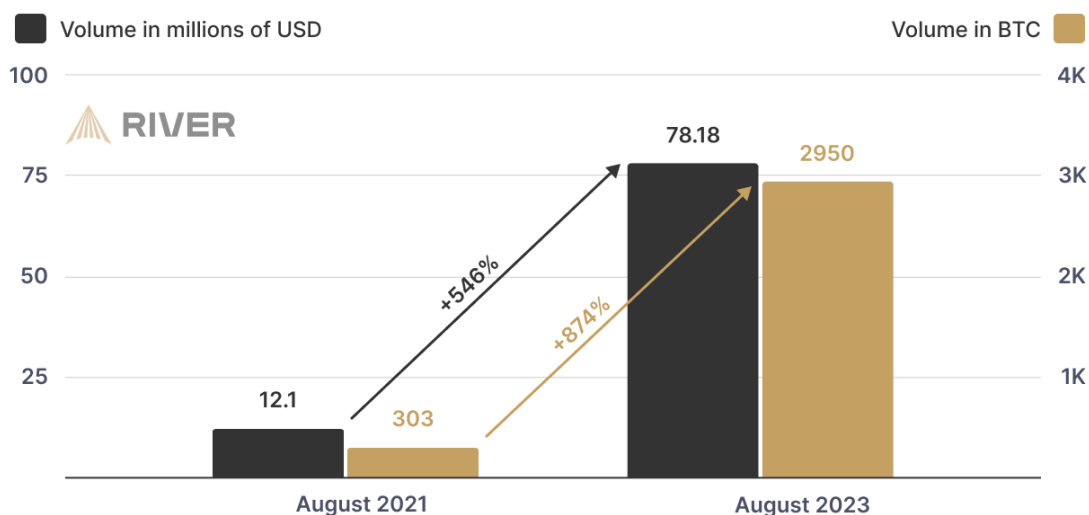
Due to relatively low on-chain fees, we believe it is unlikely that exchange withdrawals and deposits have been responsible for significant growth. Not much data or content has been shared around remittance use cases, which leads us to believe that remittances are unlikely to have driven a significant portion of overall growth so far.

How Much Volume on Lightning?

We estimate that around \$78.2 million was publicly routed on the Lightning Network in August 2023, which is 2,950 BTC. This represents a 546% increase since the August 2021 estimate of \$12.1 million by K33 (formerly Arcane Research). We have outlined our methodology to arrive at this estimated range in the appendix, as it was part of the same exercise to determine transaction count.

Estimated Growth in Monthly Routed Lightning Transaction Volume

Lower bound estimates as private transactions are excluded



Methodology explained in River's 2023 Lightning Report

On an annual basis, \$78 million per month would result in \$936 million in public volume using \$133 million in capacity, which is a ratio of 7:1. If we would be able to include private volume, it likely pushes this number well over a billion dollars per year.

If we compare this to activity on Bitcoin's base layer, we can see through Glassnode's estimate that between January and August 2023, 30 million BTC worth \$792 billion was exchanged on-chain, on an entity-adjusted basis. This means that internal transfers within the same entity, such as an exchange or an individual moving between their addresses, were attempted to be excluded. Since 70% of all bitcoin hasn't moved in a year, that means 30% of the supply, or roughly 5.8 million BTC, was on average exchanged 5.2 times.

While it is not a perfect comparison, it shows that Lightning is already outperforming the main chain in velocity, which is the measurement of the rate at which money is exchanged in an economy. Moving forward, this will be an interesting metric to monitor, as it is an indicator of Bitcoin becoming more of a medium of exchange.

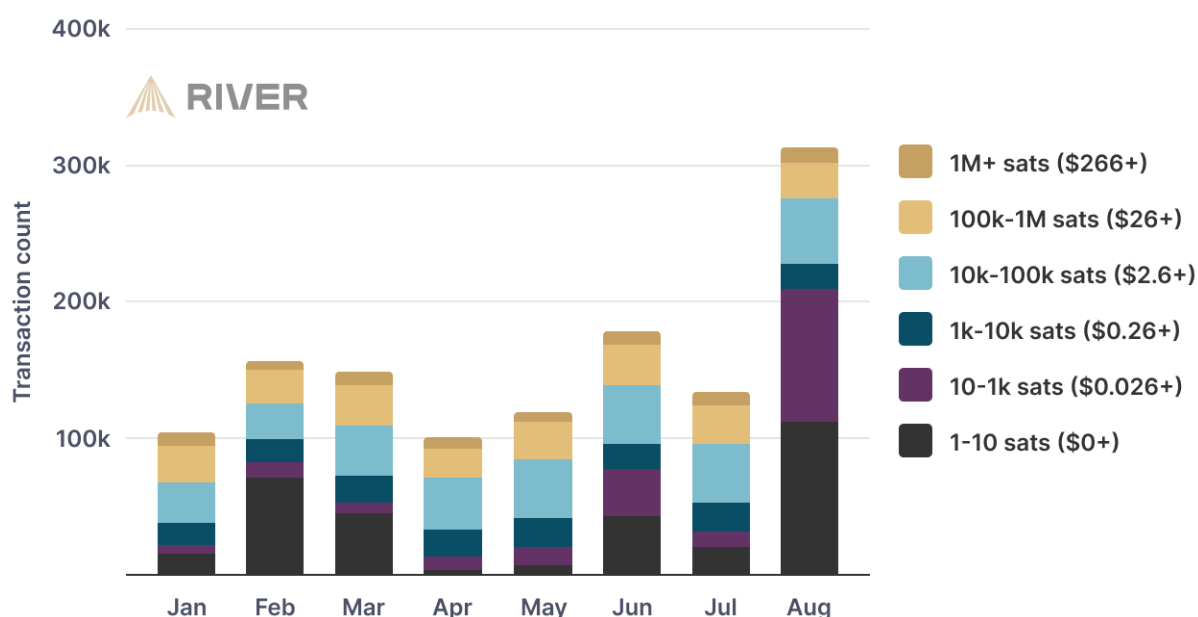
There are orders of magnitude in growth possible by reusing the same capacity and thus becoming more capacity efficient. Capacity efficiency refers to how much of a node's capacity is actively contributing to forwarding transactions and generating fees.

Lightning Transaction Size and Distribution

In August 2023, the average transaction size on the public Lightning network was 44.7k sats, or \$11.84. This is calculated by dividing 2,950 BTC in volume by 6.6M transactions. The average may be lower if there are more micropayments happening than we know of.

Alongside the average transaction size, it is also interesting to examine distribution to get a better understanding of network activity.

Lightning Payment Size Distribution on River's Nodes in 2023



- Around 25% of network activity happens between 1-10 sats which is gaming/streaming territory.
- Another 25% happens between 10-1k sats, which is more likely to be tipping-related, alongside the 1-10k sats range of more generous donors.
- From 10k sats and upwards activity is focused on commerce, remittance, and node rebalancing.

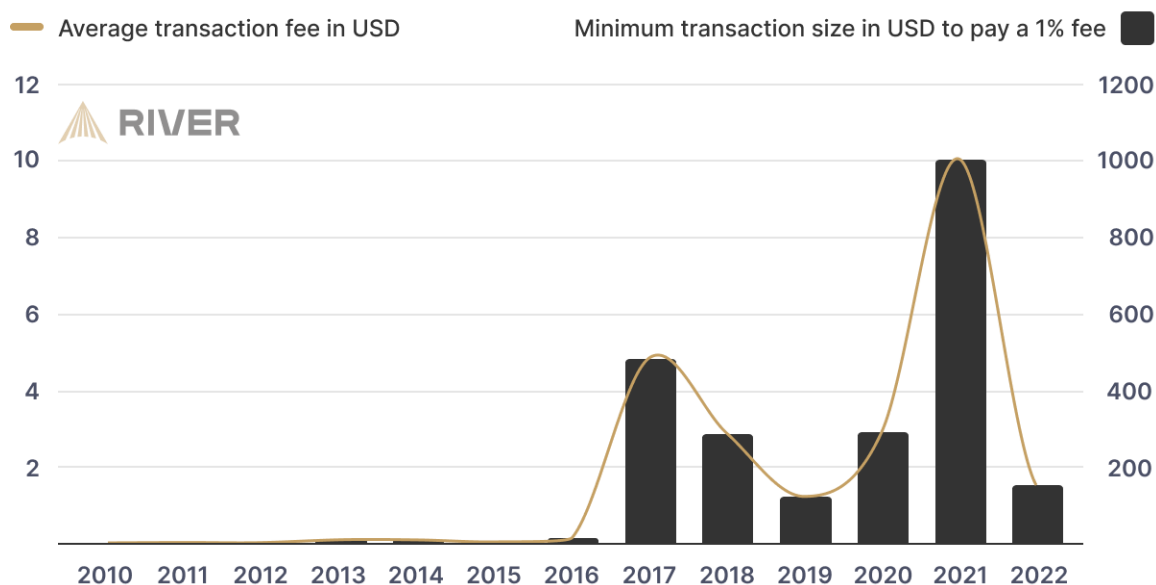
The most important takeaway from the average transaction size and distribution is that Lightning solves a clear need for low-value payments that would be unaffordable on the blockchain. Lightning is effectively extending Bitcoin's capabilities and utility.

Why would low value payments not be affordable on the blockchain? Because Bitcoin blocks have limited space, and thus if there is high demand, fees rise, and low value payments get priced out.

The overview below shows the minimum size a bitcoin transaction would need to be in USD terms for the fee to only be 1% of the total transaction value.

Minimum Viable Bitcoin Transaction Size in USD vs Average Fees

High on-chain fees push low value transactions to Bitcoin's Lightning Network.



Over the years, this minimum value has gradually been rising and was \$153 as of 2022. This does not mean a transaction lower than \$153 would not be able to go on the blockchain, but you would pay relatively high fees and be better off using the Lightning Network or an alternative payment method.

As more people begin to use Bitcoin, more use cases that are considered normal on-chain today will move to layers built on top of Bitcoin such as Lightning, but some users may also seek out different solutions if they are not aware of how the Lightning Network can be used.

1.2 User Metrics

Now that we have established a baseline of activity on the network, we examine how many users Lightning has, across which wallets, when they are using Lightning, and from where.

How Many People Are Using Lightning?

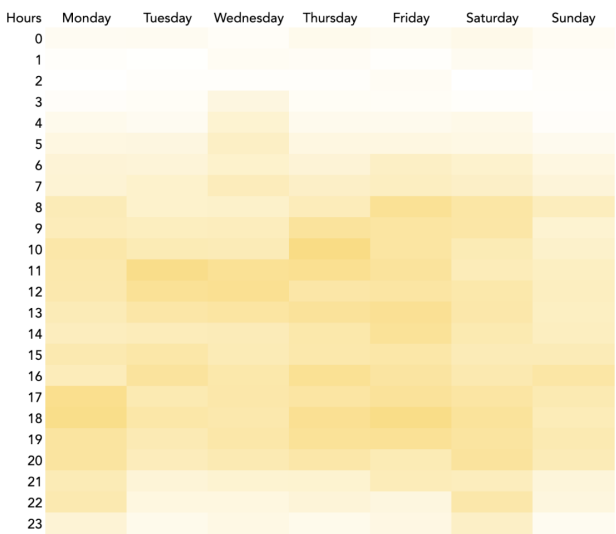
We estimate that there are between 279k and 1.116 million monthly active Lightning users as of September 2023, with a ratio of 1:8 non-custodial to custodial Lightning users. This analysis is based on public wallet install numbers, as well as monthly active user counts of several wallets. We were unable to narrow this range down further, and have shared our methodology in the appendix.

To put these estimates into context: roughly 33 million entities have interacted with the blockchain throughout Bitcoin’s entire history, and an estimated 48-98 million users are holding Bitcoin on exchanges today, per our previous report on [Bitcoin vs. the \\$156 Trillion Global Payments Industry](#).

When Are People Using Lightning?

Like in last year’s report, we created a heatmap of transactions routed by River’s nodes.

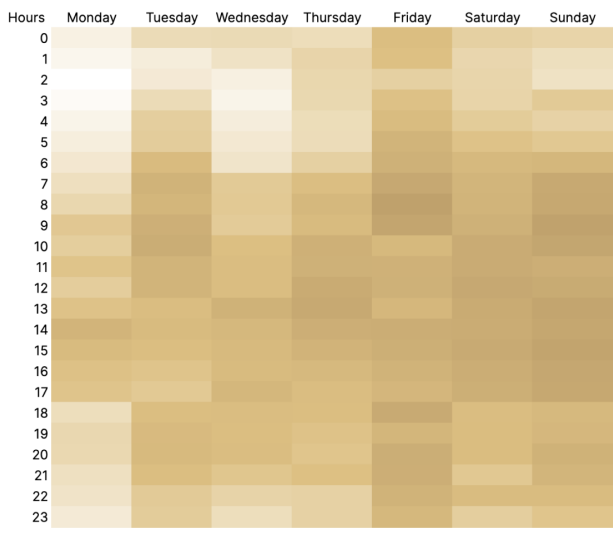
Lightning Transaction Heatmap July 2022 (UTC-6)



Source: River's Lightning nodes in July 2022

RIVER FINANCIAL

Lightning Transaction Heatmap Aug 2023 (UTC-6)



Source: River's Lightning nodes

RIVER

The biggest takeaway is that this year’s values are much closer together. Last year, the lowest hour had just 96 transactions with the highest 1,077. This year the lowest is 892, and the highest at 2,676. This is a sign of more activity around the clock, while last year’s map was much more US-based. This is a very positive sign for the network.

Where Are People Using Lightning?

To understand best practices in growing Lightning adoption, it helps to uncover insights into where people are using it disproportionately often. Due to the architecture of the network, this is difficult to map out at scale, as this data is not publicly available.

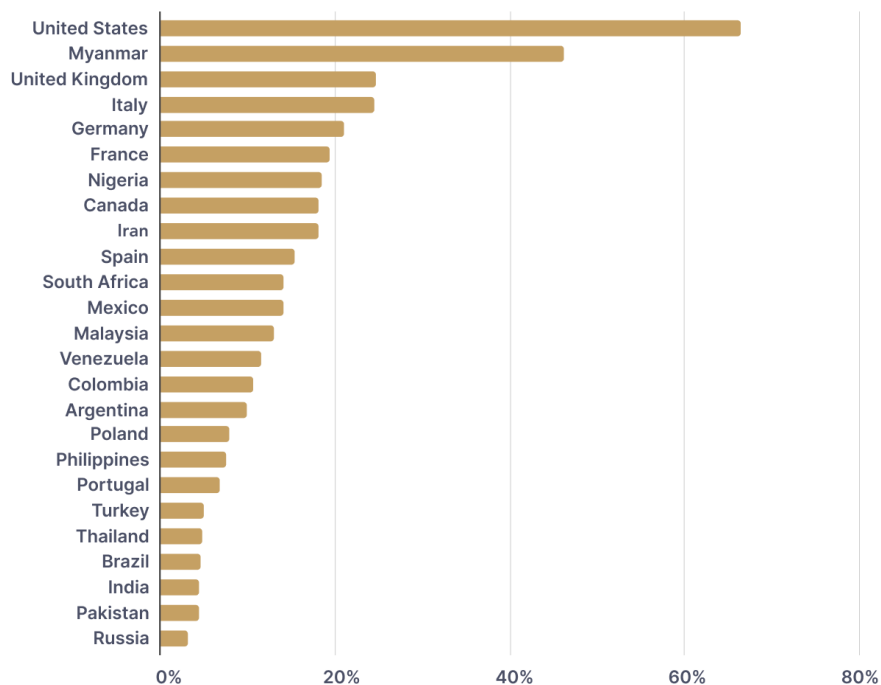
From a node perspective, the majority of nodes are run in the US and Germany, with 47% of them running in data centers from Amazon and Google to ensure a high uptime with minimal effort. Geographical node distribution is not indicative of where Lightning is used, as anyone can be a client of these providers, which do not have a data center per country.

Lightning usage starts with access to the ability to send Lightning transactions through a wallet. Thanks to unique data from THNDR Games, we can gain some insights into Lightning wallet penetration by country, specifically for their user base.

As part of THNDR's onboarding flow, they check the user's device to see if they already have a Lightning wallet installed. If not, they notify the user to install one. Their team split the data by users that are searching for THNDR, and users reached through owned media.

Lightning Wallets Installed by Country Based on THNDR Games' Organic Search Data

As part of onboarding, THNDR checks if a user already has a Lightning wallet.



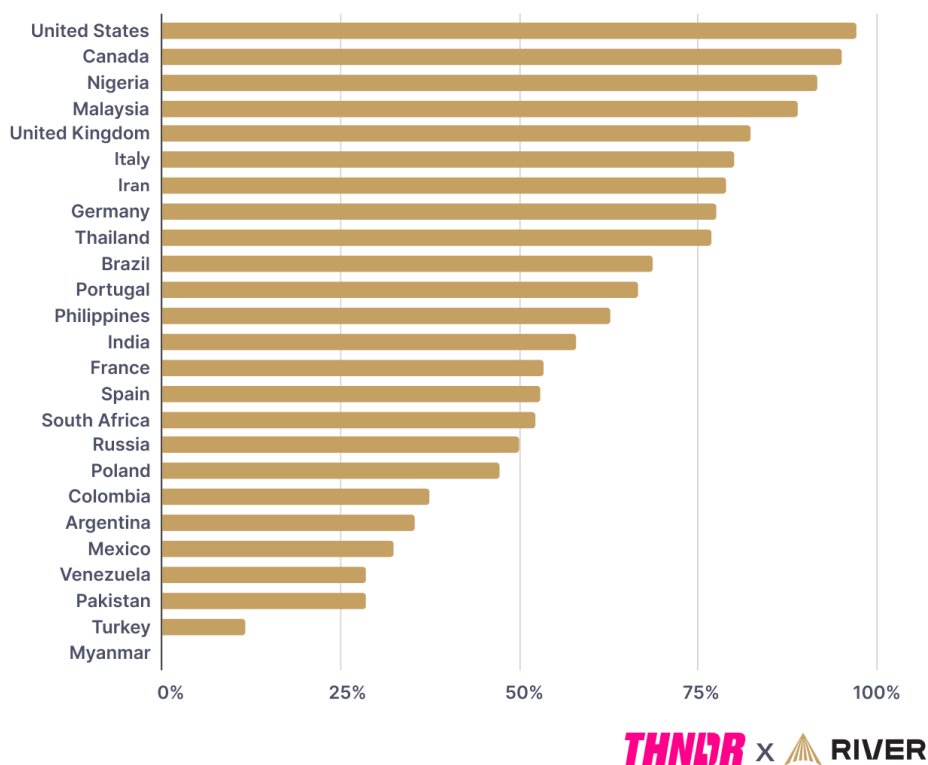
THNDR x RIVER

It is worth noting that these values can strongly differ from Google Trends' search interest for Bitcoin. This can happen for a variety of reasons, such as app stores featuring a THNDR Games game, or users following popular video guides that tell them to first install a wallet.

In these overviews, Turkey is a clear outlier. It is one of the most popular countries when it comes to Bitcoin search, but Lightning interest is lagging and has much room for growth.

Lightning Wallets Installed by Country Based on THNDR Games' Owned Media Data (web, social, cross-app)

As part of onboarding, THNDR checks if a user already has a Lightning wallet.



As an additional data point on where people are using Lightning, it is also worth examining the other side of these value exchanges.

[BTCMap.org](https://btcmapping.org/) shows over 4,300 merchants that accept Lightning payments in physical locations around the world, but there is not yet a filter for the map to find the most popular countries, which could be a loose indicator of higher in-person usage.

Bitrefill, the largest e-commerce platform in the industry, shared that in Q1 2023, the share of Lightning payments was [7%](#). Yet in El Salvador, where bitcoin is legal tender, it was [73%](#).

Finally, the Lightning communities all around the world that we highlight in the industry overview later in this chapter are hotspots with disproportionately high activity.

1.3 Network Metrics

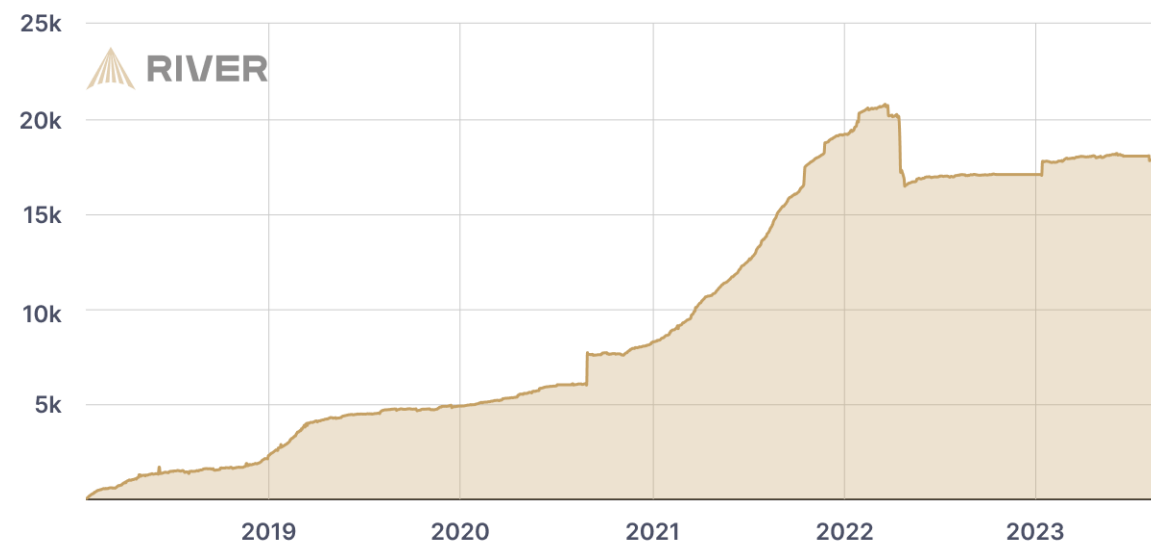
After examining activity on the network itself, we provide context on the high-level network metrics that are most commonly shared.

Lightning Nodes

Lightning nodes are servers run by participants in the network that allow users to send and receive Lightning payments. There are 15-18k public Lightning nodes as of September 2023, with five data sources ([Bitcoin Visuals](#), [CoinMetrics](#), [Mempool](#), [Amboss](#), [Glassnode](#)) providing different numbers due to the complexities of mapping the entire network.

Nodes in the Lightning Network

A plateau has been reached in node count at Bitcoin's current adoption levels and Lightning tech.



Data source: bitcoinvisuals.com

The total number of public Lightning nodes has been relatively flat for the past two years, which does not come as a surprise for two reasons:

- Historically, Bitcoin adoption tends to drop during bear markets, so mostly existing Bitcoin users are the ones setting up new Lightning nodes.
- Many new Lightning users join custodial services for convenience.

For now, it appears that the number of people willing to run Lightning nodes with the current technology has plateaued. Once new upgrades go live that have been under development for the past years, or if Bitcoin adoption grows significantly, we may see this number increase again.

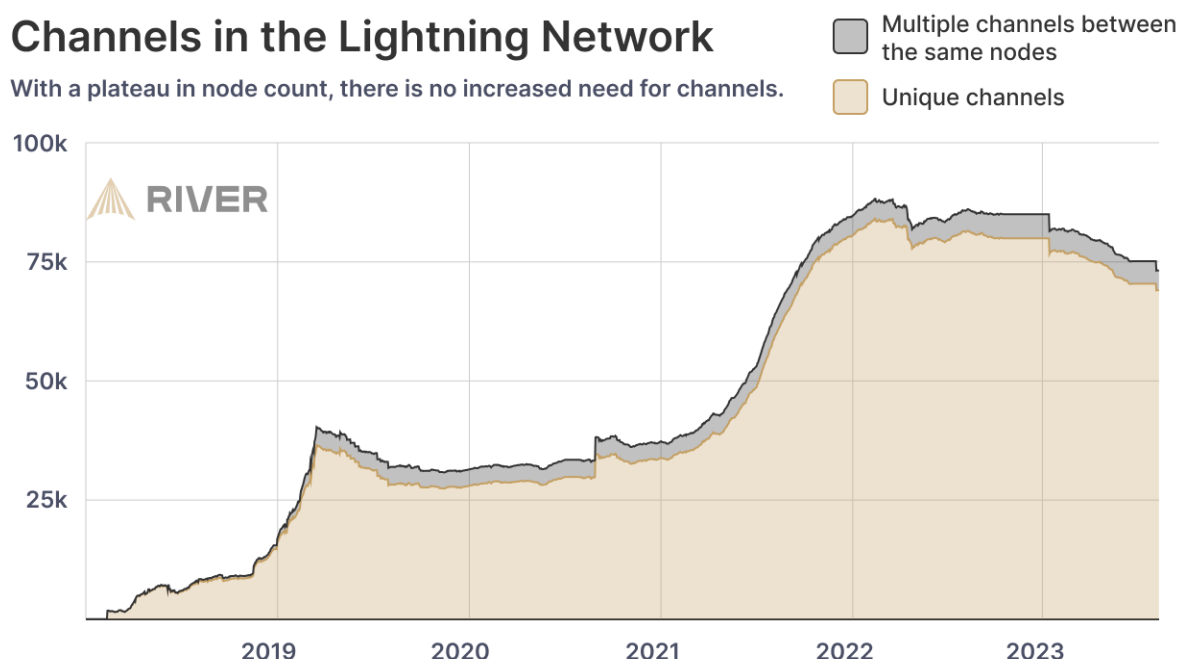
The reason that monitoring non-custodial Lightning usage matters is that if Bitcoin adoption grows exponentially, the vast majority of users will not be able to transact on the blockchain itself due to rising transaction fees and limited block space. These users would only interact with Lightning, and if they can only do this in a custodial way, they need to trust their service provider(s). This is the reality today with many Bitcoin users holding their Bitcoin on exchanges, but Bitcoiners hold Bitcoin and Lightning to higher standards and aim to create the possibility for anyone to self-custody their Bitcoin if they want to.

Lightning Channels

Lightning nodes are connected via channels. There are an estimated 68-73k public Lightning channels as of September 2023.

Channels in the Lightning Network

With a plateau in node count, there is no increased need for channels.



Data source: bitcoinvisuals.com

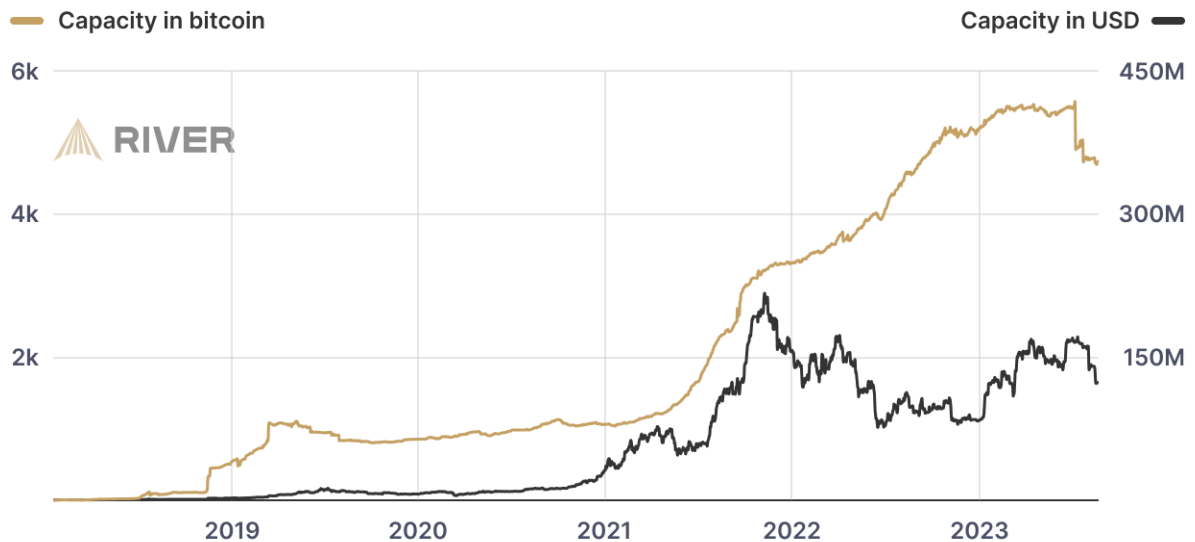
The number of channels has been trending down over the last 12 months by around 11%. Without growth in the number of nodes, it is to be expected that existing node operators re-evaluate their open channels and close the ones that are not getting much activity. Having more channels is not better by definition, what matters is if they have meaningful activity in them.

Lightning Capacity

Unlike Lightning nodes, the capacity on the Lightning Network has more than doubled over the past two years, from ~2,300 BTC to ~5,000 BTC. As of September 2023, this is roughly \$133 million held in Lightning channels, which represents just 0.024% of all issued bitcoin.

Capacity on the Lightning Network

Growth in 2022 despite a node & channel plateau. River's Summer cleanup caused a large drop in 2023.



Data source: bitcoinvisuals.com

As mentioned in the transaction metrics under the volume section, this 5,000 BTC worth \$133 million processed an estimated 2,950 BTC worth \$78 million in August 2023.

Over five years into the Lightning Network being live, some people expected one or two orders of magnitude more capital on Lightning by now. This expectation often emerges when comparing Lightning to the Total Value Locked (TVL) on the scalability solutions of other cryptocurrencies, some of which have billions of dollars in them.

Evaluating Lightning against these solutions is an apples-to-oranges comparison. Lightning is used for payments, while most of the solutions it gets compared to focus on staking, lending, or trading. Given the overall crypto hype over the past years, it is no surprise that more people are interested in those use cases than in payments.

Ignoring this comparison, it is still useful to evaluate why more capital hasn't been deployed on Lightning.

Why Hasn't More Capital Been Deployed on Lightning?

- Bitcoin's main function is not as a medium of exchange today. Most users prefer to hold their bitcoin, while the world continues to discover how big its role as a store of value can be. Bitcoin can be used for payments, but for now, this appeals to a minority of users who have no better options or who are passionate about advancing it.
- Fees on Bitcoin have been relatively low, reducing the need for Lightning payments.
- With a lower need to use Lightning for the time being, less capital is deployed as the potential returns are not there.
- Growth in Bitcoin adoption has been limited over the past two years.

If the demand for Lightning payments increases, we expect an exponential increase in capital deployment that seeks returns for routing these payments.

Lightning Capacity Should Be Efficient

An increase in capacity on Lightning is not a good thing by default. What matters is the efficiency of this capacity. If someone moves 10,000 bitcoin to Lightning tomorrow and increases the overall capacity by 200%, it makes no difference if this capacity is not being used. It is a vanity metric to gauge interest in the network.

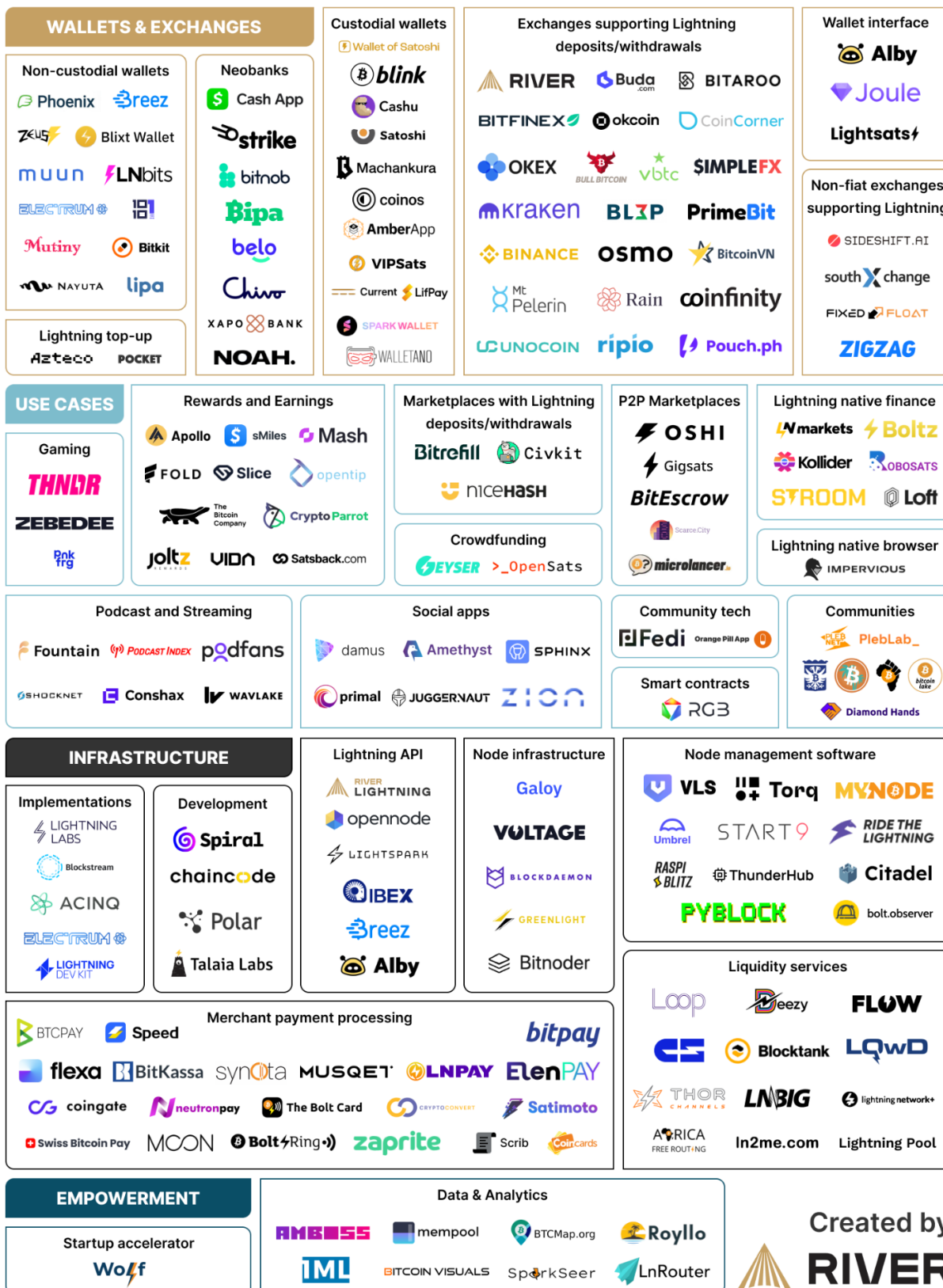
There is an argument to be made for reducing capacity, which River did in July, and again in August by 48% from 315 BTC to 151 BTC. These capacity drops stand out in the capacity graph above. Through analysis, we found that closing channels to reduce our locked-up capital would not affect payment success rate or payment volumes. On the contrary, both have gone up since. Meanwhile, this reduction ensures that less bitcoin is exposed to an internet-connected wallet, as is the case in Lightning, which reduces risk for the company.

1.4 Industry Overview

As part of this research, we have scouted the entire Lightning Network industry to map out as many of the companies and projects participating in the network as we could find. In total we mapped 179 companies across 28 categories.

Below the overview, we provide explanations of what each of the categories means. Our categorization won't be perfect. Companies tend to see themselves as slightly different from competitors, but articulating that in one graphic is highly complex. If you are interested in finding a partner in a specific vertical, it is useful to orient yourself and understand their differences.

The Lightning Network Industry Market Map 2023



Wallets & Exchanges:

Companies that enable users to move bitcoin between on-chain and Lightning.

- **Non-custodial wallets:** Lightning wallets in which a user controls their funds.
- **Custodial wallets:** Lightning wallets in which the provider controls user funds.
- **Wallet interface:** An integration of a Lightning wallet into a browser.
- **Neobanks:** Lightning wallets that also allow users to hold and send fiat currencies.
- **Exchanges supporting Lightning deposits/withdrawals**
- **Non-fiat exchanges supporting Lightning:** Only trade crypto to crypto.
- **Vouchers:** A method to purchase bitcoin on Lightning through physical vouchers.

Use Cases:

Companies that enable users to use, spend, and earn bitcoin on Lightning.

- **Marketplaces supporting Lightning deposits/withdrawals**
- **P2P marketplaces:** Users pay each other using Lightning for goods and services.
- **Crowdfunding:** Platforms on which users can crowdfund over Lightning.
- **Community technology:** Solutions that enable communities to use Lightning.
- **Communities:** Groups of people that virtually or locally support Lightning adoption.
- **Lightning native finance:** Financial markets built on top of Lightning.
- **Lightning native web browser:** Lightning payments built into a browser.
- **Payment infrastructure:** Enables businesses to interact with Lightning.
- **Podcast and streaming:** Content creators and consumers can financially interact.
- **Gaming:** Gamers can be paid over Lightning and participate in tournaments.
- **Rewards and earnings:** Users can earn rewards for completing actions.
- **Social apps:** Users can tip each other for publishing content.
- **Smart contracts:** Extending the functionality of Lightning through new apps.

Infrastructure:

Companies and solutions that provide reliable Infrastructure for the Lightning Network.

- **Implementations:** Software programs for running a node on the Lightning Network.
- **Development:** Companies that focus on the Lightning protocol and tooling.
- **Lightning API:** Interact with Lightning without needing to manage infrastructure.
- **Node infrastructure:** Providers of Lightning infrastructure.
- **Node management software:** To manage liquidity, channels, and more on a node.
- **Liquidity services:** Ensure you can always send and receive payments on Lightning.

Empowerment:

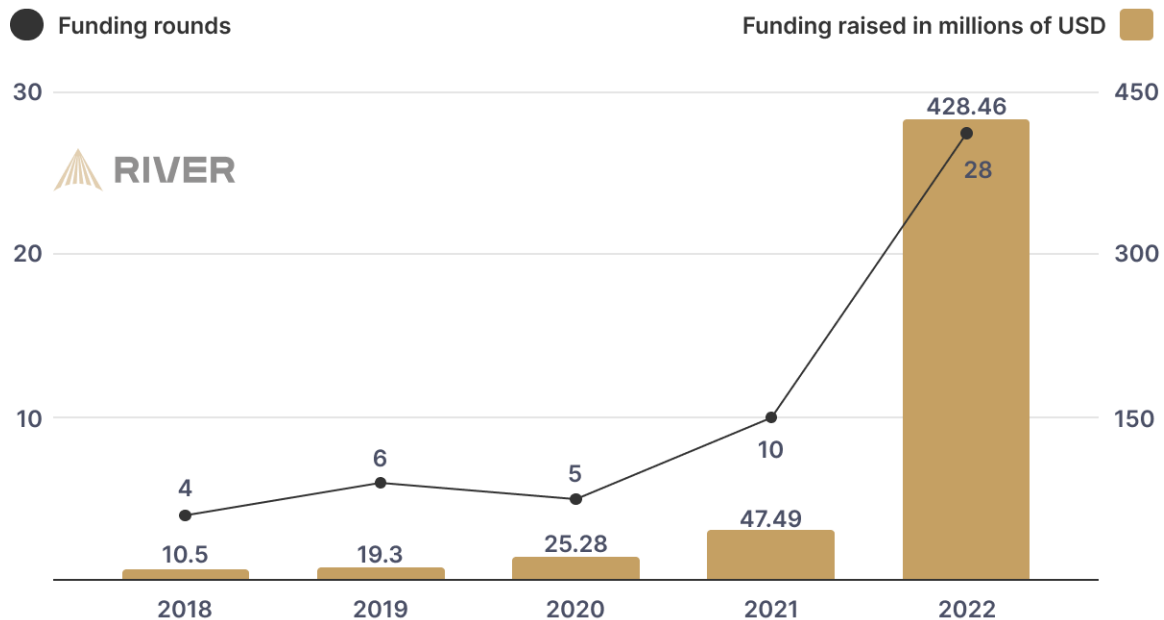
Companies that support the industry through data and business intelligence.

- **Startup accelerator:** Business accelerators that support new companies.
- **Data & Analytics:** Platforms that provide insights into Lightning activity.

1.5 Funding Raised by Lightning Companies

Funding data helps to understand market expectations of a particular technology. Over the past years, investors are increasingly buying into Lightning's value proposition.

Funding Raised by Lightning Network Companies

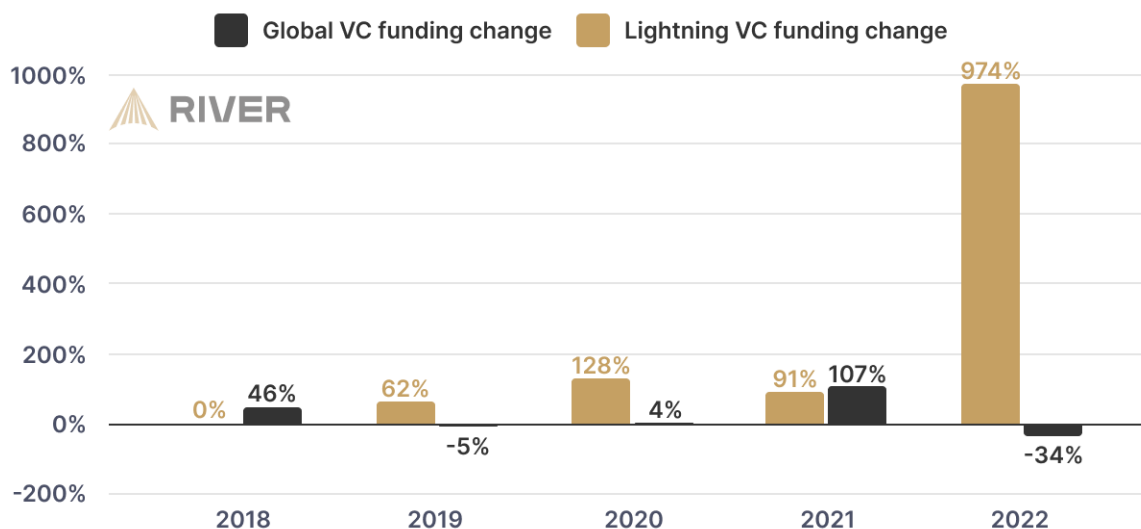


A few key metrics to highlight:

- \$530.93M was raised by Lightning companies between 2018 and December 2022.
- 24 Lightning-focused companies have been funded with disclosed rounds.
- 15 Lightning-focused companies have been funded with undisclosed rounds.
- 19% of all Lightning projects had received funding by December 2022.
- The average funding raised was \$23 million and the median was \$4 million.
- The largest 3 rounds were Lightspark's \$175M Series A, Strike's \$80M Series B, and Lightning Labs' \$70M Series B.
- In addition, \$1.347B was raised by companies that have built integrations with Lightning, but their funds were raised for purposes other than building products or services on or for the Lightning Network. Examples here are:
 - Blockdaemon, which raised \$431.3M but only offers third-party Lightning plugins to be installed into its Bitcoin nodes.
 - Various exchanges and brokerages raised tens of millions of dollars for international expansion while showing no signs of building on Lightning beyond deposits and withdrawals.
 - Blockstream's mining-focused funding rounds.

Below, we put these funding numbers into perspective relative to global venture capital investment trends.

2022 Was a Great Year for Lightning VC Funding Relative to Global VC Funding Trends



Data source for VC funding data: Dealroom.co

The graph underlines why 2022 was such an outstanding year for Lightning funding. Global venture capital investments dropped by 34%, from \$734 billion in 2021 to \$483 billion in 2022. Expectations for Lightning are high nonetheless. Investors realize the challenges that must be overcome, but they are optimistic about the developer momentum, the pace at which problems are being solved, and the likelihood that Lightning will stick around in the long term as a critical building block to help Bitcoin scale to the masses.

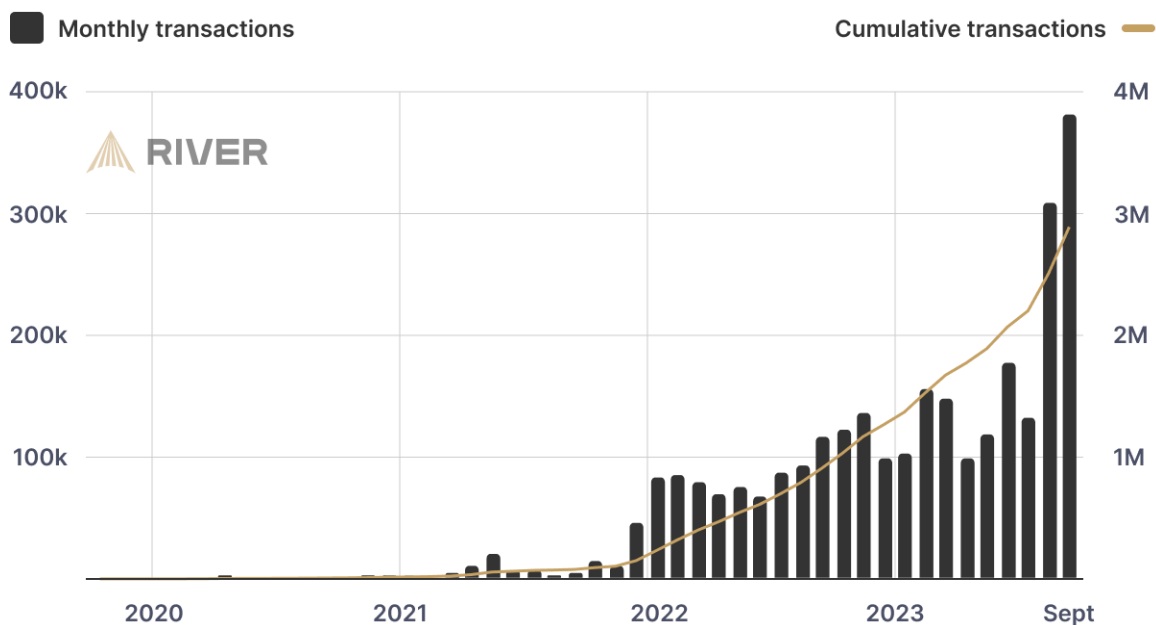
In the coming years, we will see how the funds raised in 2022 will impact the network.

2. River's Additional Lightning Insights

In the first chapter, we shared a range of statistics that were partially informed by River's Lightning nodes. In this chapter, we want to share some additional insights for which we did not receive data from other providers for comparison. We will also outline what kinds of companies we have been speaking to with River Lightning, what their interest in Lightning is and what the hurdles to adoption are.

First, some context on how many transactions we are routing.

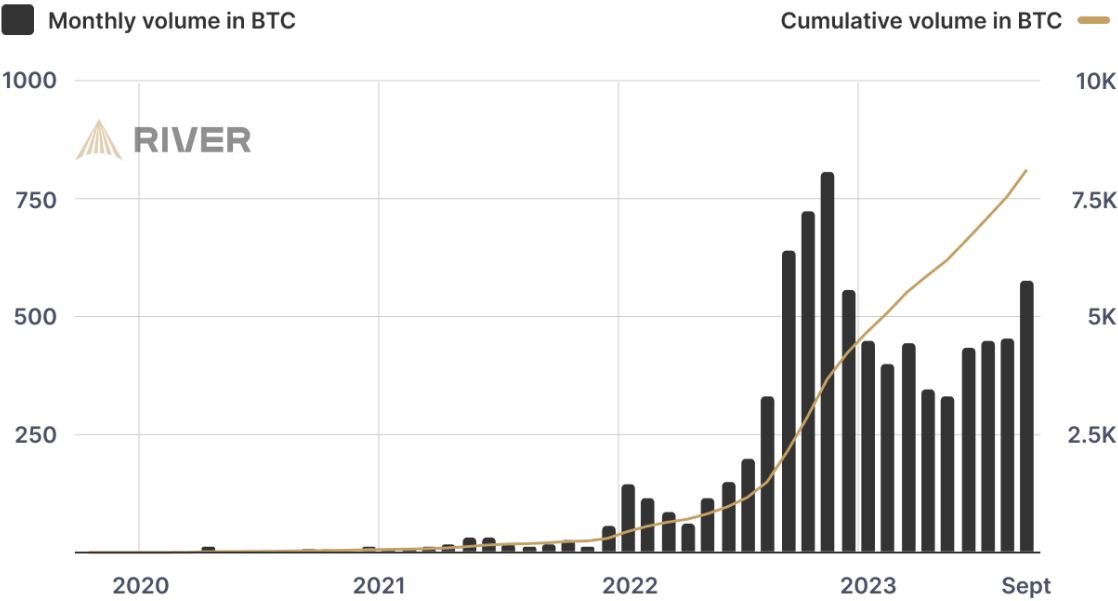
Monthly Lightning Transactions Routed by River's Nodes



We are seeing all-time highs in transaction counts for the past two months. Even ignoring these two outliers, there was already a gradual increase in transactions over time.

Volume is similarly on the rise, though not as high as in late 2022 as we are primarily seeing growth in lower value payments.

Monthly Volume Routed by River's Lightning Nodes

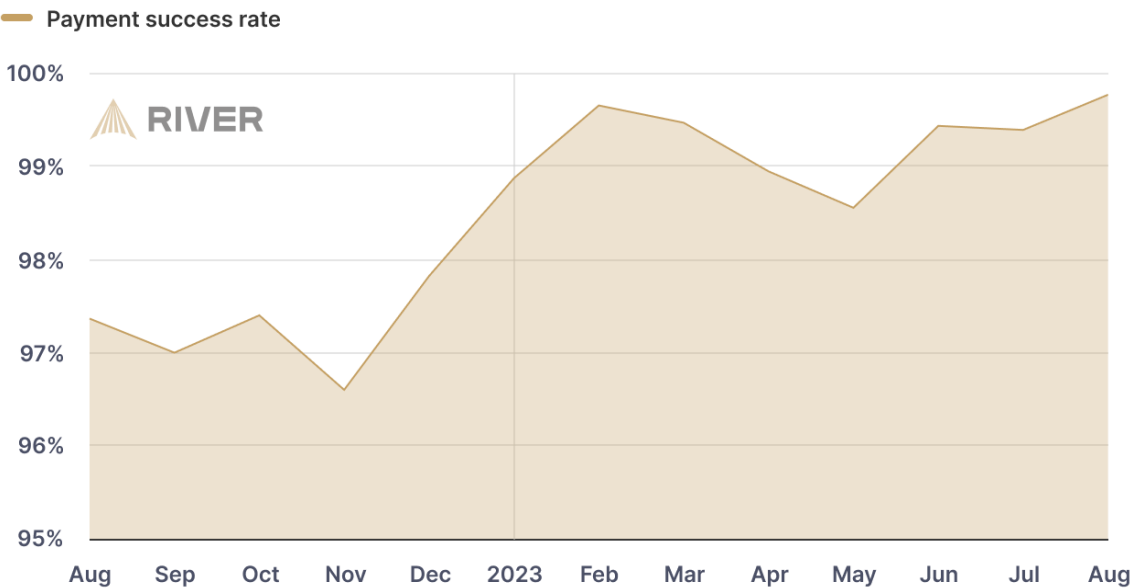


We love to see more transactions and volume, but reliability is the most important for us.

2.1 Payment Success Rate

River's payment success rates have improved significantly in 2023.

Lightning Payment Success Rate on River's Nodes

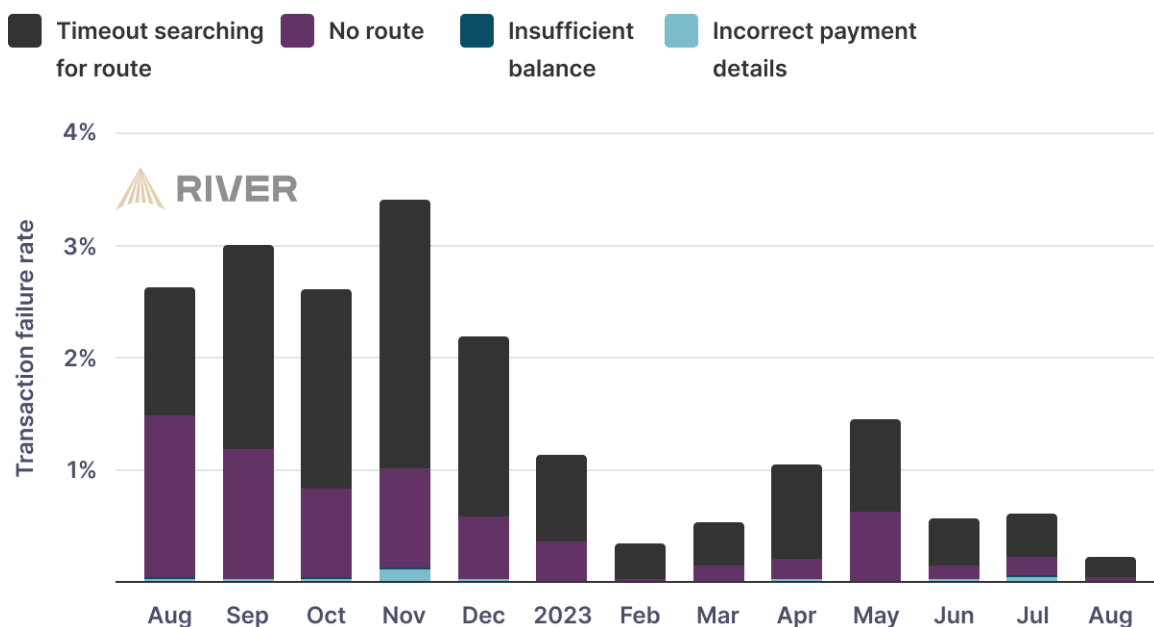


For readers of last year's Lightning report, a discrepancy with the data we shared may stand out. In 2022, we shared that our failure rate was 1.3-1.5%, while now we are displaying 2.6-3%. The reason for this gap is that we have now filtered out data for River Lightning clients and only focused on routed transactions, to provide a more accurate benchmark for the rest of the network.

A high payment success rate is our core focus with River Lightning. We service business clients such as El Salvador's Chivo wallet and undisclosed large companies. It is critical for Lightning's long-term adoption that they have a reliable payment experience. If they would stop using Lightning and publicly cite "not reliable" as the reason, this could set back the industry significantly with critics eagerly jumping in to amplify such a message. It is both a privilege and a major responsibility to service large companies.

A common criticism of Lightning is that payments do not always succeed. This is a hard problem to completely solve, especially when developers have limited insight into what is causing payment failures, due to the architecture of the network. Later in the report, we will talk about what work is being done to improve payment success rates, for now, we share data into why Lightning payments fail from the perspective of our nodes.

Transaction Failure Rate & Reasons on River's Lightning Nodes



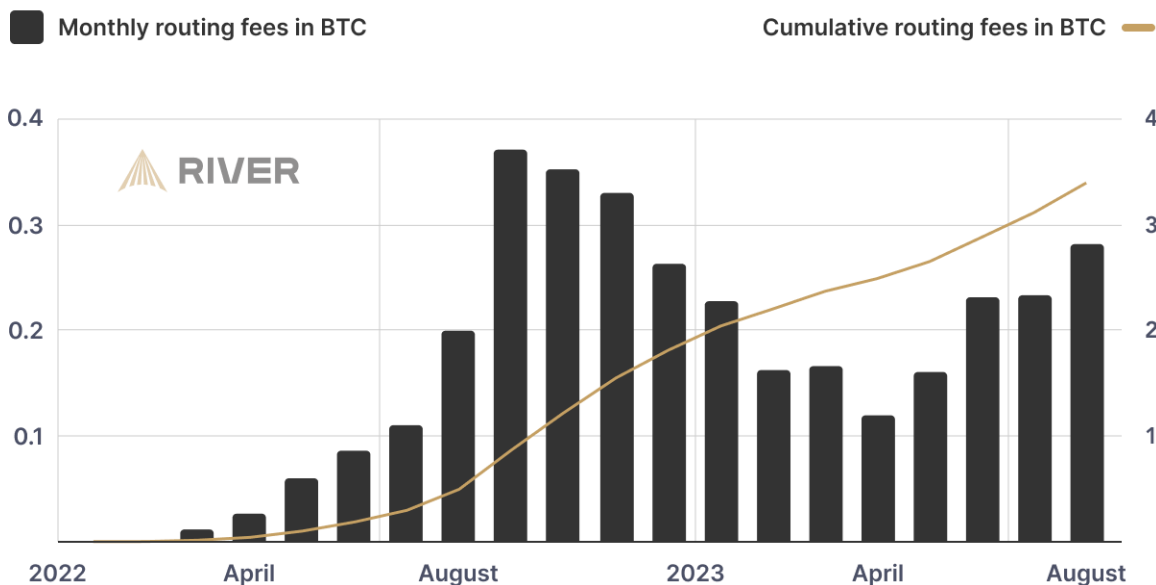
The most common reason why a Lightning payment fails is a timeout when searching for a route. This happens when no route can be found that has enough liquidity across the entire path. The second reason is that no route can be found at all, which is often the case when the receiver is offline and has a non-custodial wallet. Other reasons rarely occur anymore.

2.2 Earnings & Profitability

While River is not focused on running a highly profitable Lightning node, fee revenue is still being earned from the volumes we are routing. Naturally, people are interested in the market for earning a return on Lightning, so we are sharing our numbers like last year.

Routing Fees Earned by River's Lightning Nodes

Note that our focus is on reliability for River Lightning clients, not on profitability.



Our fees earned have dropped despite the transaction count going up throughout the year. Our focus is first and foremost on reliability so that we can ensure a smooth experience for River Lightning clients. The current return rate on our capacity is expected to be around 1% in 2023, given that we recently lowered our capacity significantly.

If our focus is not on profitability, why not charge no fees at all? The reason is that when we charge no fees, routing volumes increase significantly which requires more rebalancing, increases failure rates unless we significantly raise our capacity to have more redundancy, and there is no cost to potential attackers if they try to disrupt our payment reliability.

2.3 On-chain Footprint & Compression Ratio

As a later addition to this report (February 2024), we are including data on our on-chain footprint and compression ratio, as requested by Lightning developer [Rene Pickhardt](#).

- **On-chain footprint:** how much space is taken up on the blockchain by transactions to open and close Lightning channels.
- **Compression ratio:** how many Lightning payments are made for each on-chain transaction. A higher ratio means Lightning is scaling more effectively.

This data provides a reference point to Lightning developers and researchers on how much scale Lightning is effectively, rather than theoretically, accomplishing today.

We started running our first Lightning node in October 2019. Between then and February 2024, we opened 3,905 Lightning channels and closed 1,824, through a total of 5,236 on-chain transactions as some transaction batching was used. Over this same period, a total of 616,650 Lightning channels were opened or closed according to [data from TXStats](#). River accounted for 0.85% of these, and for 0.003% of all on-chain transactions.

Over the same time, 21,060 channels were opened to us by peers, and 24,323 were closed by them. As one of two participants who agreed to these channels being set up, we consider ourselves responsible for 50% of the on-chain transactions to create these channels since we also use them, so our footprint is 16,259 on-chain transactions.

Time period	Oct 2019 - Feb 2024 (1592 days)
Lightning payments River routed	3,974,445
Channel open transactions by River	3,412
Channel close transactions by River	1,824
Channels opened by peers	21,060
Channels closed by peers	24,323
River's on-chain transaction footprint	15,766 (3,412 + 1,824 + 21,060 / 2)
River's compression ratio	252

For each on-chain transaction we directly made, we facilitated an average of 759 Lightning payments. If we include channels that were opened to us by peers, this drops to 252. Of course, many Lightning payments involve more participants, which we dive into below.

Network-wide Compression Ratio

While our compression ratio is 252, many Lightning payments pass through more than just two nodes. Each of the nodes we are not directly connected to requires additional on-chain transactions that reduce the effective compression ratio.

Because of Lightning's design, it is unknown how many hops the average payment makes. The average number of hops to reach any node on the network from any other node is 9 according to [Bitcoin Visuals'](#) data, but this does not mean that this is how far the average Lightning payment has to travel. Many payments happen directly between two nodes.

If, for example, the real average number of hops is 5 across a total of 6 participants then a compression ratio of 252 would drop to 50. To check if this assumption is somewhat accurate, we will use [Arcane Research' Lightning payments data](#) as a benchmark.

Benchmarking the Compression Ratio

Arcane Research estimated that 11.43 million Lightning payments were sent between January 2020 and February 2022. In this same period, a total of 214,656 on-chain transactions were made to open and close channels, resulting in an effective compression ratio of 53 Lightning payments per on-chain transaction. In January 2020 there were already 30,000 Lightning channels, some of which likely remained open, so in the worst-case scenario the compression ratio would be 47 for that period.

As a result, it's possible that the average number of hops per routed Lightning payment could be around 4.75 ($252 / 53$), which would mean an average of 5.75 participants since connecting 6 nodes across a route requires 5 channels for example.

Extrapolating the Compression Ratio Across the Lightning Network

Between January 2017 and February 2024, 616,650 on-chain transactions were made to open or close Lightning channels. At a compression ratio of 53, this would mean they facilitated 32.68 million Lightning payments, or an average of 384,499 per month. Channel opens and closes took up 0.08% of the on-chain transaction count of 782 million during this time and extended Bitcoin's transaction throughput by 4.18%.

We also evaluate our August 2023 snapshot of an estimated 6.6 million routed Lightning payments. 8,564 on-chain transactions were made to open or close channels during this month, while 13,975,517 on-chain transactions were made in total. The effective compression ratio is 167.5 due to prior investments in opening Lightning channels, which is over 3 times higher than our all-time estimate. It increased Bitcoin's transaction throughput by 47.2%, taking up just 0.06% of new on-chain transactions in that month. If 10% of on-chain transactions had been Lightning channels and the compression ratio held up, this would add up to 89 transactions per second.

How Much Better Can the Compression Ratio Get?

The compression ratios above by no means represent the upper bounds of what is achievable. Two nodes with a fee rate of zero can send millions of payments between them in a single day, without external observers being able to realize this is happening. Of course, this is rare behavior in a real environment, where flows are nearly always unbalanced.

In practice, the effective compression ratio can further increase, which is one of the Lightning Network's strengths. However, when more nodes get involved, especially in cases where the operators do not have a personal relationship, there are limitations to how far the compression ratio can grow. Without communication, it is impossible to know if the other participant in a channel will move liquidity back to the other side. This unknown may eventually lead to the channel being closed by their counterparty. Even if such communication was happening, it does not scale well, and it is usually impossible for the other party to even anticipate if this liquidity will get used again. We can therefore assume that there will always be some limitations.

It is also important to note that for the vast majority of Lightning's existence, on-chain transaction fees have been relatively low. If they were significantly higher, node operators would be opening and closing far fewer channels. Until this is the case, minimizing the on-chain footprint is not a high priority for many Lightning node operators. At River, we are first and foremost aiming to achieve the highest degree of reliability, while also maintaining capital efficiency to minimize risk for the company.

The need to close and reopen channels would also be reduced by implementing a relatively new feature called Splicing, which enables node operators to resize existing Lightning channels rather than having to close and reopen them. This still has an on-chain footprint, but one lower than closing and reopening channels.

2.4 Insights from River Lightning Clients and Prospects

To round out this chapter, we want to share what we have learned from speaking to many companies that have an interest in Lightning. Which industries are they in? Why are they interested in Lightning? What are the hurdles to adopting it?

What Kind of Companies Want Access to Lightning?

Thus far most of the interest has been from the following types of companies:

- Wallets
- Exchanges
- Fintechs
- Payment processors
- Gaming
- Streaming
- Rewards and earnings
- eCommerce
- Cross-border payments

We already see companies in each of these verticals on the Lightning Network today, but more are looking to join in.

Why Are They Interested in Lightning?

We see four main reasons why these companies are interested.

1. Having a unique selling point (USP) over competitors

Like in any other industry, companies strive to have great features that their competitors are lacking. Lightning's novelty and unique attributes combined with how well it is known in the industry make it ideal to stand out from the rest.

2. Cost savings

Over the years, on-chain transaction fees can add up to a significant cost for both companies and their users. By integrating Lightning, B2B transfers and deposits, as well as withdrawals become much cheaper.

3. New revenue streams or business models

Businesses are often interested in developing new revenue streams. As established in this report, Lightning extends Bitcoin's utility through small and instant payments that cannot be made on-chain. This enables revenue streams or even business models that were previously not feasible. It will take time and people with interdisciplinary backgrounds and skill sets to uncover many of these new possibilities.

4. To support Bitcoin

During a bear market, many cryptocurrencies that got hyped up tend to fade into irrelevance. It is a good time for companies that diversified into supporting many of these to realize that for their business to be sustainable in the long run, Bitcoin adoption needs to grow. Each company can play its role in supporting Bitcoin, and a great way to do so is by supporting the biggest scaling upgrade for Bitcoin to date. More usage of the Lightning Network gives developers more insights into how to improve it and continue to make Bitcoin scale.

In addition to these four reasons, we believe there is a fifth, underappreciated reason.

5. As an insurance policy against high fees

Historically, many businesses in the industry make a significant portion of their revenue during a small number of days during bull markets. An inability for users to affordably withdraw funds during those times due to high on-chain fees can be a risk factor, as some users may stop recommending these services to personal relations in favor of others who did integrate Lightning. In this sense, integrating Lightning becomes an insurance policy against the risk of high on-chain fees, even if not many clients might use Lightning today.

Waiting until your business is forced to adopt Lightning likely means it will happen at the worst possible timing: while being overloaded with other priorities.

Hurdles to Adoption for Businesses

While there are variations in hurdles across different industries, their main hesitations in adopting Lightning are typically the same.

1. Bitcoin's role as a **Medium of Exchange is still limited** today. While great software exists to support businesses, it does not change the fact that they need to be able to assist or even educate users on using Bitcoin when they have questions. Even with the best documentation, many users will still get in touch with the company, and introduce more effort than just a one-time setup.
2. Businesses have no insight into **how big the Lightning Network is**, and thus if it is worth it to get involved. In this report, we aim to provide some answers to that.

3. How Can Lightning Grow Further?

We have established that Lightning activity has grown significantly over the past 1.5 years. In this chapter, we focus on three themes that could help adoption to grow exponentially.

3.1 Exchange Adoption

For many Bitcoin users, their exchange is their only touchpoint with Bitcoin. When it does not support Lightning deposits and withdrawals, a user may not realize that Lightning exists, or never looked into how they could use it. Exchanges taking a leading role in Lightning onboarding and education would lead to exponential growth in adoption.

Historically, the incentives for exchanges to lead the charge were not there, but this is beginning to change.

Exchanges tend to have long backlogs of features they want to implement, which may directly lead to more profit in the short term. This makes Lightning integration difficult to prioritize if the exchange intends to build and maintain its Lightning infrastructure. Solutions such as [River Lightning](#) exist, which make it easy for businesses to integrate with Lightning through an API, and thus lower the resource requirement significantly.

As the crypto industry lost its steam for now while Bitcoin continues to regain market share, exchanges are forced to look towards the future and think carefully about how they will need to contribute to the growing Lightning space or risk losing market share to competitors that build new solutions on top of it.

The incentives go beyond benefits for their users and include benefits for themselves.

How Much Exchanges Can Save on Fees by Using Lightning

Bitcoin exchanges have paid tens of millions of dollars in on-chain fees in 2023, making up a double-digit share of the \$270 million in total fees paid until September this year. Throughout Bitcoin's history, exchanges have paid hundreds of millions of dollars in fees.

These exchange-related fees can be split across:

- Inter-exchange transfers.
- In-house exchange transfers.
- User withdrawals.
- User deposits.

Inter-exchange transfers are the most appealing to switch over to Lightning, as there are fewer parties involved. An estimated \$1.5 million could have been saved in 2022 by moving them to Lightning, and over \$15 million in 2021 due to a higher fee market.

Eventually, inter-exchange transfers over Lightning will likely become standard practice for all exchanges. Whenever fees rise, markets are often heating up and exchanges are less concerned about paying on-chain fees. This is exactly what is happening today, as exchanges can in theory already settle their balances across the Liquid sidechain, but thus far adoption has not taken off. The benefit of using Lightning is that exchanges will want to use Lightning for their user base anyway, and can now reuse the same infrastructure for additional purposes.

If we look at the other categories for exchanges, Lightning is not relevant for in-house transfers, as these are internal accounting practices involving cold storage. Given that Lightning wallets are hot wallets, meaning they are internet-connected at all times, it is not desirable to use Lightning for large sums of user funds today.

Lightning is certainly relevant to reduce fees for the remaining categories of user deposits and withdrawals. Users pay for the deposit fees, however, so why would an exchange care about that? If a user deposits over Lightning, they are also more likely to use it to withdraw, which saves the exchange on fees. Ultimately, the customer decides how they want to deposit or withdraw. Exchanges can take steps to educate users on the potential fee savings and speed benefits when using Lightning. This is in their own best interest too, as only the most efficiently operated exchanges will be able to survive in the long term.

Implications for Miners

Throughout Bitcoin's history, inter-exchange fees have only made up a low percentage of total fees as they can be efficiently batched on a recurring basis. Still, for miners every bit of revenue counts, and they are interested in a healthy fee market as the block subsidy decreases every four years. It is thus worth evaluating the argument as to whether exchanges should move their settlement to Lightning.

Miners are impacted when any Bitcoin users make use of space-saving techniques, such as [transaction batching](#), [signature aggregation](#), or [SegWit](#). These are good practices, as they free up space for more users to affordably self-custody and open Lightning channels.

For some exchanges, it is unlikely that they will move inter-exchange transfers to Lightning until on-chain transaction fees become so significant that they will save substantial amounts. If that is the case, then a healthy fee market is already developing and the argument to not draw fee revenue away from miners is a non-issue.

3.2 Technical upgrades

The Lightning Network is far from finished on a technical level. Like Bitcoin, it is not a unified product that is maintained by a single company, but a decentralized network with many contributors. Evaluating Lightning only based on how it performs today means underestimating what it is becoming. There is no protocol better suited today for native Internet payments, but there is much to be improved before Lightning can become as widespread as the Internet itself.

A range of technical upgrades and new features can significantly improve the user experience on the Lightning Network, and thus make it more appealing for people who are currently not using it.

Specifically, upgrades targeting the following:

- Reducing manual effort to use Lightning.
- Reducing the technical expertise needed to use Lightning.
- Reducing on-chain fees and/or the on-chain footprint of Lightning.
- Eliminating the need for users to be online to receive payments.
- Enabling Lightning usage without price volatility risk.
- Making it easier to identify personal or business relations on Lightning.
- Improving the security of internet-connected wallets.

It is not the purpose of this report to go into detail about the specific technical upgrades that would accomplish these feats. Lightning developers are frequently coming up with new, revised, or better ways to improve the network in a variety of ways and would quickly make our overview go out of date. The key point here is that Lightning is far from finished and improvements are consistently being made across the board.

It is worth noting that there are also self-imposed upgrades by Bitcoiners, which would not necessarily drive significant adoption, but are critical for the long-term decentralization and success of the network.

These are upgrades targeting:

- Making it easier to use Lightning non-custodially.
- Improving privacy on the Lightning network.

The reasons these upgrades do not hold back widespread adoption are that the average user today does not care much about non-custodial usage, as is evident by far more people holding Bitcoin on exchanges than in self-custody, and they also do not care about privacy, until it starts becoming a problem in their daily lives.

3.3 Building on Lightning

The more needs users can fulfill on Lightning, the faster adoption will grow. There are different approaches to fulfilling these needs, which range from what kind of business provides them, to whether the user even realizes that Lightning is being used. We describe the different approaches below.

Lightning-native Businesses

If you look back at the industry overview we shared in chapter 1.4, it is clear that there are many Lightning-native companies. This is a logical consequence of Lightning enthusiasts being at the front lines of the technology, and being first to recreate existing solutions and adding Lightning to them.

Many of these Lightning-native companies have emerged in the past two years. A lot of them are still looking for product-market fit and do not have a profitable business model at the moment. Becoming profitable is their primary concern, and they have to build traction from scratch. This process can take years, especially given that their user base is often limited to a subset of people who hold Bitcoin. As a result, their success is often tied to Bitcoin adoption increasing, which is a risky position to be in as a business.

In general, existing businesses that adopt Lightning have a higher probability of sticking around in the long term. These can be companies that already succeeded in the Bitcoin space or non-Bitcoin companies.

Bitcoin Businesses Adopting Lightning

When successful Bitcoin businesses integrate Lightning in their products or services instead, it allows these solutions to reach a larger user base sooner. We already covered exchange adoption earlier in this chapter, but there are still many other Bitcoin businesses that could be using Lightning. We expect that if fee pressure returns, most Bitcoin businesses will be forced to integrate Lightning if they haven't already done so.

Non-Bitcoin Businesses Adopting Lightning

The real acceleration in Lightning adoption comes from non-Bitcoin businesses that integrate it. When they do, it saves years of work to expose a large number of people to Lightning. Cash App is a prime example of this, completely overshadowing all other Lightning wallets in terms of users. This doesn't mean Cash App necessarily has the most active Lightning users out of all wallets, but they do have tremendous potential to expose many new people to Bitcoin and Lightning, and arguably the highest odds of survival due to already being a profitable business.

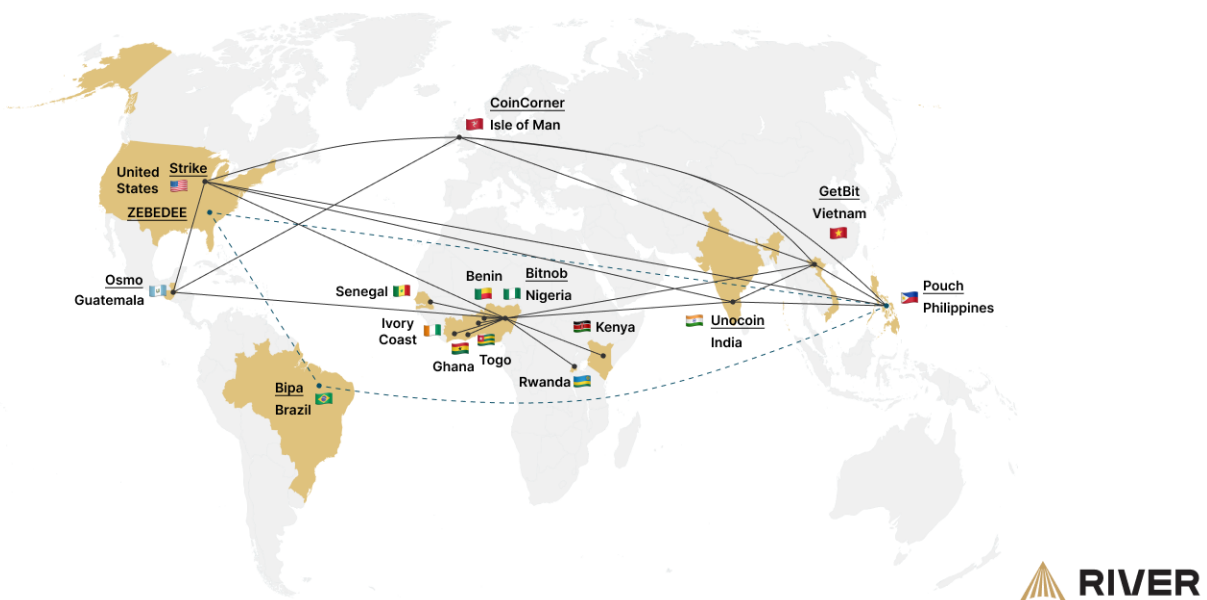
Lightning As a Backend Solution

Increased Lightning adoption does not necessarily require consumers to use it directly. We are already seeing solutions built on Lightning that do not require the end user to be aware of how it works or that it is even being used. They only know value is being exchanged instantly and at a global scale, which is enough. It drastically reduces the effort to onboard new users, while they still reap the benefits of Lightning. People often don't know how technologies such as the Internet or credit cards work, they just know that it works.

The strongest example of such a solution is payment networks that are being built on Lightning, which we covered in our previous report on [Bitcoin vs. the \\$156 Trillion Global Payments Industry](#). Exchanges in over a dozen countries are already connected through the Lightning Network today to enable remittances with automated local currency conversion, without the user having to know about Lightning. Beyond these networks, almost every human can access an exchange that integrates with Lightning.

Exchanges Using Lightning to Process Cross-Border Payments

With automated conversion to local currencies, no user knowledge of Lightning needed.



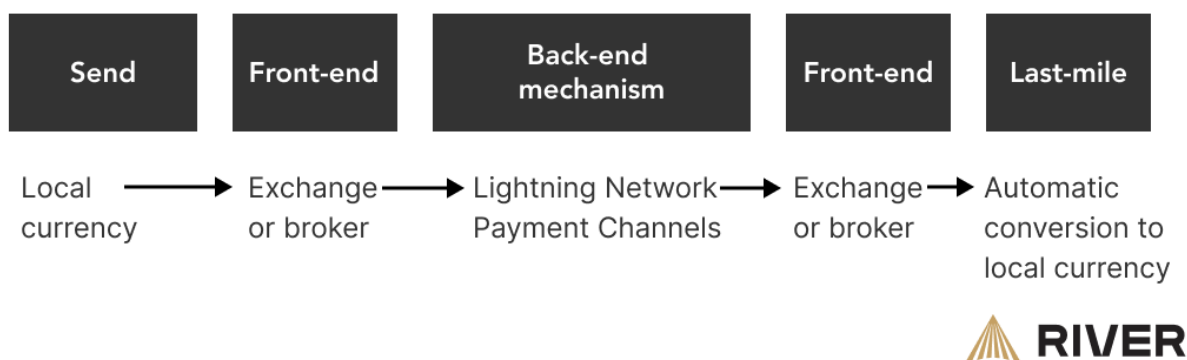
How the Lightning Model Beats Fintechs

Fintech companies use banks in various countries to do slow internal settlements while fronting the cash to consumers for a seemingly faster user experience than traditional remittance companies.

Lightning-powered businesses can effectively transfer value instantly, with better capital efficiency, at a global scale, and with partners that all speak one common language.

Like with Fintechs, users do not realize how the internal accounting happens, and as a result, need to have no understanding of the technology that is being used. They do need to (temporarily) trust the companies involved. Better yet, the consumer does not need to hold any Bitcoin in this model and is thus never exposed to price volatility if they do not want to be.

Bitcoin's Custodial Cross-Border Payments Flow



The tradeoff this model makes is that price drops now fall upon the exchanges. If they do not use a service like River Lightning, they must hold significant amounts of Bitcoin in their Lightning payment channels to satisfy user demand at all times. They can offset risk by charging small fees for payments, but it is a business challenge to ensure the exchange is long-term profitable. However, exchanges are likely better equipped than individual users to protect themselves against price drops.

A major risk of the model is that it is vulnerable to regulatory changes aimed at undermining Bitcoin. The companies involved rely on the banking system to operate and could have their access cut off, as we have historically seen in some countries. In addition, the model does not eliminate costs to move money into and out of these services.

If this model scales well, it is likely that in the long run, the financial services that are part of this network would turn into major banking players, as people would increasingly want to hold their balance on these platforms for convenience and make use of additional services. As a result, all kinds of financial institutions will attempt to join in, especially to service businesses that send orders of magnitude more value globally. However, these businesses won't have in-house Lightning Network expertise and will likely outsource this part of the operation to accelerate their go-to-market and manage costs, as talent will be scarce. River has built [River Lightning](#) to make it easy for companies to participate in the Lightning Network through an API service.

Conclusion

While critics get hung up on the plateau or slump in network metrics around nodes, channels, and capacity, the underlying trend of activity is crystal clear: Over the past two years, Lightning has been growing tremendously in transaction count (1,212%), volume (546%), and solutions built on top of it. The “nobody is using Lightning” meme is dead.

The real discussion is around non-custodial versus custodial usage, which refers to whether users hold their funds or not. Making non-custodial usage as appealing as custodial wallets is a tough challenge, one that may require orders of magnitude more developers, companies, and capital to help figure out. The best way to draw these resources in is through user growth, and thus any user, custodial or non-custodial, is contributing to the mission of improving Lightning so that it can continue to grow and be a trust-minimized scalability solution for Bitcoin.

Lightning shares many of Bitcoin's challenges. It is complex to understand, and many users prefer to trust custodial solutions to offload the responsibilities that come with owning your money. Bitcoin itself is also largely used custodially, as the majority of users hold their Bitcoin on exchanges. This does not mean that Bitcoin or Lightning has failed, nor that the situation won't change in the future. New solutions may emerge, and until then, Bitcoin can be used non-custodially by those who want self-sovereignty, and it can be a more transparent alternative to the opaque traditional financial industry for custodial users.

Meanwhile, Lightning will continue to be under steady development, [the user experience will improve significantly](#) over the next few years, and gradually more businesses will be integrating with it.

River Lightning

If you are interested in taking action and getting your business involved, check out River Lightning at rfs.dev for seamless integration of Lightning payments into your business.

Credits

Report created by: [Sam Wouters](#)

Review by: [Alex Leishman](#), [Reid Paulson](#), [Julia Duzon](#), [Josh Fix](#), [Phil Pfeffer](#)

Cover design by: [Jason Benjamin](#)

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Appendix

Methodology to Determine Transactions and Volume

Due to the architecture of the Lightning Network, an outside observer can't determine exactly how many transactions are happening on the network.

The only way to get estimations is by aggregating data from many large nodes in the network and extrapolating those insights, which is how we arrived at our estimation. As time progresses, gathering enough data for this methodology will become increasingly more difficult. Competition on the network may begin to increase if usage continues to grow and more nodes become focused on earning routing fees.

Lightning Transaction Data Collection

As mentioned in the report introduction, we were fortunate enough to collect data on routed transactions from a range of large nodes in the network, which allowed us to establish a lower bound of the total number of transactions in the network.

The reason this is a lower bound is that traffic on the Lightning Network happens across four categories, some of which cannot be reasonably estimated.

1. **Routed transactions:** For these transactions, the data provider has a record of taking a transaction in from one node, and passing it on to another.
2. **Direct transactions:** These are transactions directly between two nodes without any other nodes in between. For privacy reasons, these are not always disclosed.
3. **Private transactions:** Not all of the Lightning Network is public. An unknown amount of traffic happens over private channels, or even between private nodes that do not make themselves available to external connections.
4. **Internal transactions:** If both the sender and recipient of a Lightning payment use the same custodial service, the transaction is settled in the database of that service, without ever touching the Lightning Network. When companies publish data on their Lightning transactions, they may not always exclude internal transactions.

In our dataset, we mostly have transactions in the first category, with some transactions in the second category, and potentially some in the fourth category.

We did not gather any private transaction data, nor attempt to map out transaction flows across the routed transaction datasets. The goal of this data collection was not to deanonymize users, nor to use data from other nodes to improve our position.

Problems to Solve to Estimate Transactions and Volume

There are five major problems to solve to estimate the number of transactions:

1. **The number of direct transactions** can be significantly higher than routed transactions since, in theory, two parties could transact more between them than the rest of the network combined.
2. **The number of private transactions** cannot be deducted in any way.

Without companies involved in these transactions specifically disclosing them, it is not possible to estimate an upper bound of transactions on the Lightning Network.

3. **Eliminating transaction overlap.** Without access to the data of many nodes, it is very difficult to estimate the number of unique transactions, and when we are identifying the same transaction at different points across its route.

To solve this problem for our dataset, we used Wallet of Satoshi as the main node, given that most other data providers had connections to them, and then found or requested the overlapping transactions to their node from other providers.

We found that in August 2023:

- Wallet of Satoshi processed 669,000 Lightning payments.
- Alby users made 1,019,040 Lightning payments, with an 8.5% overlap with Wallet of Satoshi, leaving 932,470 non-WoS payments.
- THNDR Games processed 267,397 Lightning payments, with a 60% overlap with Wallet of Satoshi, leaving 106,959 non-WoS payments.
- River processed 307,581 Lightning payments, with a 50% overlap with Wallet of Satoshi, leaving 153,791 non-WoS payments.

When we include another 252,500 non-overlapping transactions from other data providers, these add up to 2,515,518 Lightning transactions.

4. **Determining how much of the total network traffic we have gathered.** When we add up all of the data providers, there is no definitive way to determine how much of the total network traffic we managed to gather. In other words: we may be counting an unknown number of overlapping transactions, but we also don't know how many transactions we are missing to determine an upper bound.
5. **All of this data is self-reported.** We cannot guarantee the validity of the data that was shared. At the same time it is important to realize that even if a few companies overstated their numbers by 100%, this accomplishes very little at Lightning's current stage as it is still small compared to traditional payment networks.

Methodology

Our estimation is based on data from River's Lightning nodes and the companies that shared data with us. Our findings were then extrapolated across the rest of the network.

In aggregate, our dataset consisted of 2.515 million transactions, of which 402k were overlapping. To go beyond this number and estimate the transaction count on the entire network, we need to look at a few additional metrics.

The nodes in our dataset represent 29% of all the capacity on the network and 10% of the channels. There are still many major nodes whose transaction counts are unknown to us. The big question is how much of the network share we have.

If we extrapolate 2.1 million transactions for 29% of the total capacity across the other 71%, we would arrive at a total of 7.3 million transactions in August 2023. This is an interesting benchmark for our actual methodology below.

Extrapolating the performance of our dataset across the entire network is tricky, as not all nodes are routing the same number of transactions across the same capacity. Some nodes in our dataset routed 16% of their capacity in a month, while others routed up to 196%. The average capacity performance in our dataset was 79%, but it is unlikely that this is representative of the entire network. Our dataset has many professionally run nodes in it with multi-person teams behind them, which is not how most nodes are operated.

A few additional benchmarks are:

- LNBiG, which represents 927.5 BTC or 18.6% of the total network capacity across their 25 nodes. We derived a 35% capacity performance from their [published data](#).
- ACINQ, which runs the biggest and most connected node on the network. Their capacity performance is 43% at [150 BTC routed on 350 BTC](#) capacity.

When we add them to our dataset, we cover 52% of the total network capacity, and the weighted average capacity performance is 59%. By extrapolating this performance across the network we arrive at 2,950 BTC routed in August 2023 using 5,000 BTC in capacity.

Given that we have a decent estimation of total volume at 2,950 BTC and an estimation of the average transaction size on the network of 44.7k sats, we can determine a lower bound of transactions on the network of 6,599,553. This is about 10% below the benchmark above, which is expected given that we cover more professionally run nodes.

The average node performance and/or the average Lightning transaction size could be lower, which would produce a range of different outcomes in the single to lower double-digit millions of transactions.

Our Methodology to Estimate Lightning Users

To estimate the number of Lightning users, we started by looking into the number of installs for popular Lightning wallets.

We categorized these wallets based on their likeliness to be downloaded for Lightning usage. This allows us to better distinguish which numbers we should evaluate to estimate Lightning user counts. This categorization does not judge the usefulness of these wallets, nor their Lightning user experience. We realize this methodology is up for debate.

	Likeliness to be downloaded to use Lightning	Custodial or non-custodial	New Android installs in August 2023 (Estimates based on SimilarWeb)	Minimum installs (Based on Google Play and Chrome Web stores. Unknown for iOS)
Cash App	Low	Custodial	1.8M	50M+
Exodus	Low	Custodial	138.2k	1M+
Chivo	Medium	Custodial	40.1k	1M+
Strike	Medium	Custodial	6.3k	500k+
ZBD	High	Custodial	43k	500k+
Wallet of Satoshi	High	Custodial	32.4k	500k+
Muun Wallet	High	Non-custodial	20.4k	100k+
Blink	High	Custodial	Unknown	100k+
Phoenix	High	Non-custodial	3k	50k+
Breez	High	Non-custodial	1.2k	40k+
Alby	High	Custodial	Unknown	20k+
Zeus	High	Non-custodial	7.3k	10k+

When we add up all of these wallets, we arrive at a minimum of 54 million wallet installs on Android. The real number could be higher, given that the Google Play Store reports user counts in the lower bound of various brackets, rather than using absolute numbers. (e.g. 98k installs is rounded down to 50k)

To estimate the number of iOS Lightning wallet installs we can look at a few numbers:

- Globally, Android has a mobile operating system market share of 70%, iOS has 28%.
- Cash App is almost entirely US-based, where iOS has a [57% market share](#), so their ratio of Android to iOS installs is significantly different from all the other wallets.
- Chivo Wallet is mostly El Salvador-based, where iOS has a [15% market share](#).

Based on these numbers, we estimate that there are roughly 68 million Lightning wallets installed on iOS, with the bulk of that coming from Cash App.

Adding up the minimum install number for Android and the derived estimate on iOS, we estimate a minimum of 122 million Lightning wallets installed globally.

However, there are two major caveats:

1. **Users can install multiple wallets** and often won't uninstall older ones even when they stop using them. There is thus an unknown overlap among the installs, which could be the case for 5% of users, or even 25% for example.
2. The earlier mentioned **purpose of the app installation**. Cash App is very popular in the U.S., but most of its users downloaded the app for its traditional financial use cases, not to interact with Lightning.

In an attempt to estimate the "Lightning installs", we can run the same numbers as we did above, but only for the "high" and "medium" categories. We then arrive at 2.8 million wallet installs on Android and 900k million on iOS for a total of 3.7 million Lightning wallet installs.

If we want to narrow it down further to only the "high" category, we arrive at 1.3 million wallet installs on Android and 520k on iOS, for a total of ~1.8 million Lightning wallet installs.

Wallets in the "low" and "medium" categories certainly have active Lightning users, but perhaps these numbers offset the overlap in multiple wallet installs. The final count would not be far removed from 1.8-3.7 million wallets installed for the purpose of using Lightning.

Major wallets could survey their users to get estimations of how much wallet overlap there is, but this simultaneously makes their users aware of other wallets, which may not be in their best interest. Any other online surveys would likely be skewed towards power users.

Custodial vs. Non-custodial Wallet Installs

We can look at the ratio between wallet installs for custodial and non-custodial Lightning wallets across the "high" and "medium" categories in the previous table. On Android, we then see at least 170k non-custodial wallet installs and at least 1.5 million custodial wallet installs. We have left Chivo out of the latter group, as the campaign by the El Salvador government to install the wallet in return for \$30 in Bitcoin skews the numbers.

An app install is of course not the same as being an active user, so we attempt to adjust these numbers based on publicly and privately shared monthly active user estimates.

Accounting for Retention

Globally, the user retention rate for apps is [around 6%](#), with Finance apps estimated around this mark as well across various sources.

However, when we look at public data points from Lightning wallets, we see higher percentages. Both [Cash App](#) and [Muun Wallet](#) have publicly shared their monthly active user counts, at 45.5 million and 100k respectively. In Cash App's case, this is roughly 39% of their minimum install count, while for Muun Wallet it is 71% of their minimum install count. The actual percentages will be lower, depending on how many more installs than the lower bounds they have, but not as low as 6%.

We can create estimations for various retention rates to arrive at a range of monthly active user counts for the "high" and "medium" categories:

Retention rate	Estimated Monthly Active Users
10%	279k
15%	419k
20%	558k
25%	698k
30%	838k
35%	977k
40%	1116k

279-1,116k is still a wide range of monthly active users, but without more accurate data from the wallets themselves, we won't be able to narrow it down further.



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NMLS ID#1906809