

Insights From the 4th Largest Lightning Network Node

October 2022

Introduction

River Financial is a Bitcoin financial services and technology company that helps people accumulate and use bitcoin. We offer brokerage, hosted mining services, zero-fee dollar-cost averaging, and Lightning Network deposits and withdrawals.

We have been a participant in Bitcoin's Lightning Network since 2019. We were among the many enthusiasts who saw the potential of Lightning as a rapidly-growing scaling solution that allows users to transact in bitcoin in a near-instant and almost free manner.

As of 2022 we have grown into the fourth largest node on Lightning by bitcoin capacity. We now employ a team of four full-time developers who are working on maintaining and upgrading not only our Lightning efforts, but also the Lightning infrastructure for El Salvador's Chivo wallet.

We have learned a lot from our journey with Lightning, and we are excited to share some of our insights with the industry to help the Lightning Network to continue to develop so it can help people around the world to gain financial sovereignty.



River Financial 1 Lightning Node - Source: [Mempool.space's Lightning Explorer](https://mempool.space/lightning-explorer)

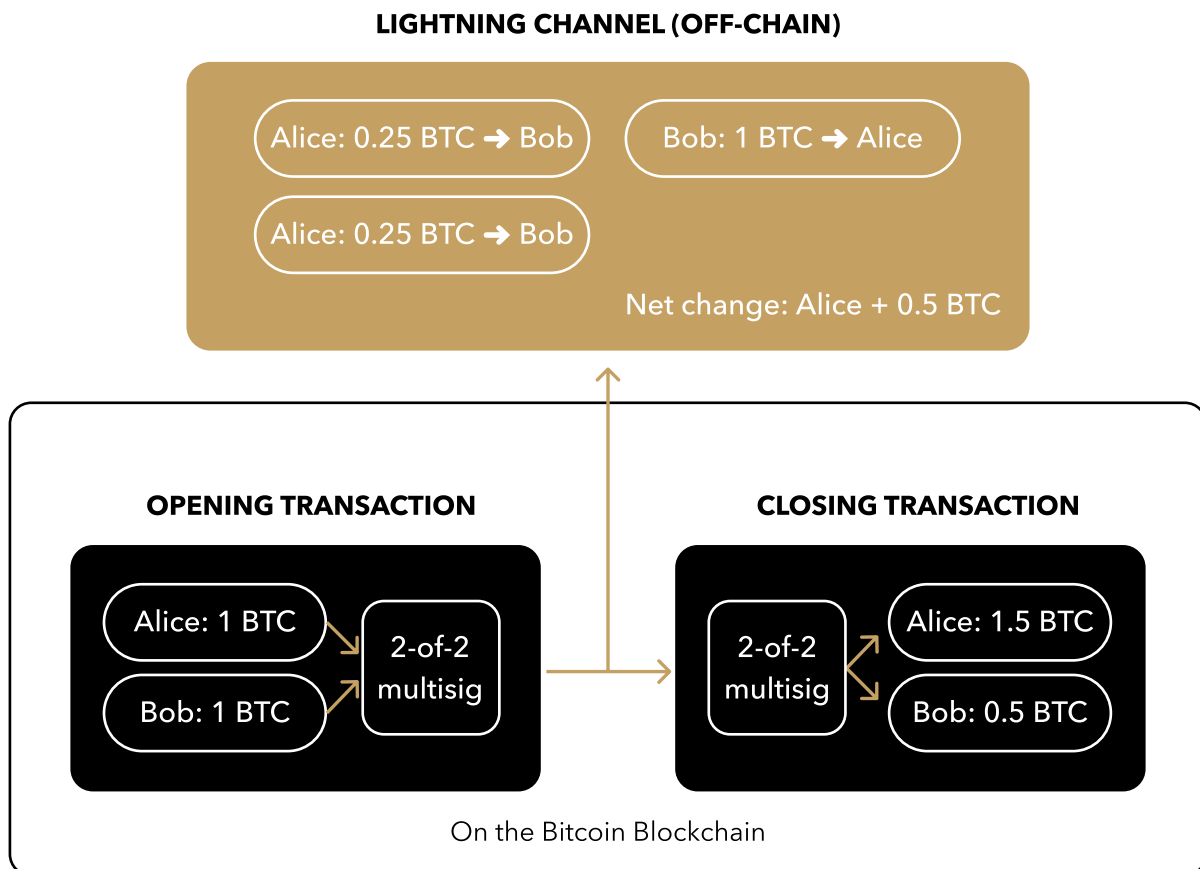
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Context on the Lightning Network

For Bitcoin to become a sufficient medium of exchange, users must be able to transact both quickly and inexpensively. While Bitcoin transaction fees are relatively low now, it may become infeasible to use the base layer for small transactions in the future if fees increase. Bitcoin is optimized for security and decentralization, which has made it an incredibly robust network, but has also created the need for scaling solutions to realize the promise of a peer-to-peer electronic cash system as envisioned by Satoshi in the Bitcoin white paper. This is where Lightning strikes.

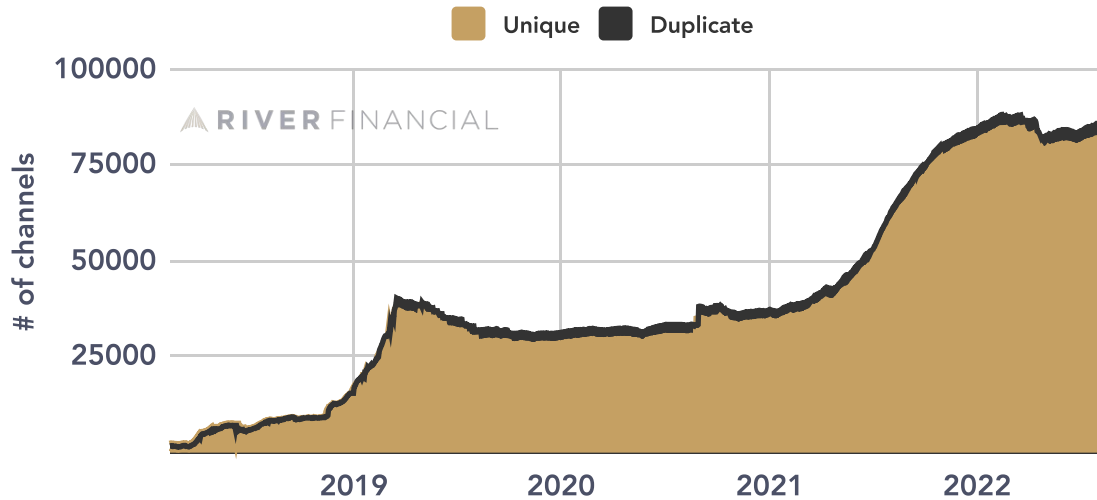
The Lightning Network (“Lightning”) is a second layer built on Bitcoin that allows users to transact in Bitcoin without needing to wait for on-chain settlement. Users create bidirectional payment channels on the Bitcoin blockchain, by depositing bitcoin into a 2-of-2 multisig address, which gives the channel a defined capacity. Once this initial transaction is confirmed on the Bitcoin blockchain, the Lightning channel is opened, and the two parties can now execute a near limitless amount of transactions between themselves, moving capacity from one side of the channel to the other.



A channel can remain open however long the node connecting the peers remains online, and neither peer chooses to close the channel. To close a channel, another on-chain Bitcoin transaction is broadcast, this time reflecting the net change in both of their balances.

Users can open multiple channels between each other, known as duplicate channels, for different transaction purposes, or to raise the odds of having capacity on their side to route payments to the other party.

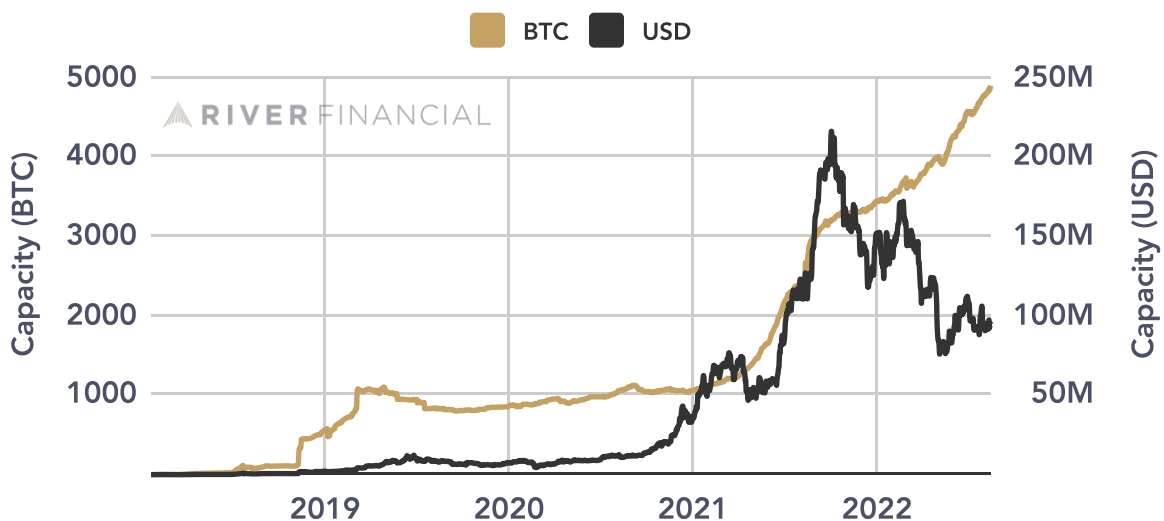
Lightning Network Channels



It would be inefficient if users had to open a channel with everyone they want to transact with. Instead, users can forward payments through common connections for a small fee. This process of routing transactions is the primary function of a Lightning node.

Since the launch of the Lightning Network in 2018, total capacity has grown to nearly 5000 BTC. Capacity represents the amount of bitcoin capable of being transacted with on Lightning, and is a decent metric for measuring the adoption of the network.

Lightning Network Capacity



River's Lightning Backstory

River launched its first Lightning node, River Financial 1, in October 2019. Immediately upon going live, our clients were able to deposit and withdraw funds to/from the Lightning Network.

Ever since, Lightning's adoption and development have grown. The future of the network has become more clear, and thus its potential application to business. Lightning unlocks exciting new opportunities for our mission to help people accumulate more bitcoin.

Today, Lightning helps our clients transact in bitcoin more quickly and cheaply than they could on-chain. Tomorrow, Lightning may enable full financialization of Bitcoin as node operators can put their bitcoin to productive use by properly capitalizing Lightning nodes. This may allow node operators to generate a passive yield on bitcoin with very low counterparty risk. New protocols such as Taro will further this reality as more assets and functionalities are brought to the network.

Becoming a Lightning Infrastructure Provider

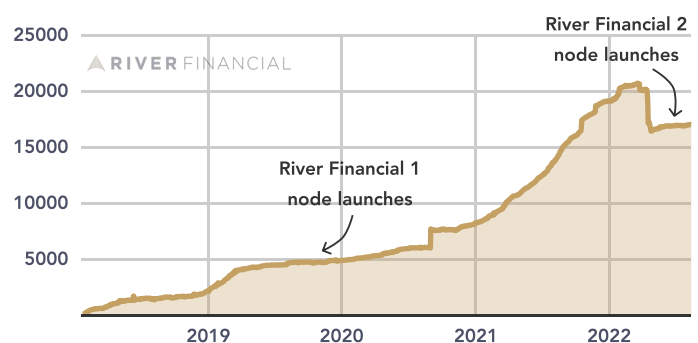
To remain at the forefront of the advancements and new possibilities in Lightning, we have increased our investment accordingly. We have grown our Lightning team from one to four full-time engineers and are working to improve our infrastructure as it becomes a major focus for the company.

We are not the only user of this infrastructure. El Salvador's Chivo wallet uses River's Lightning API for all of its Lightning transactions, which get routed through our nodes. This frees up the Chivo team from needing to focus on liquidity and channel management, and allows El Salvadorans to benefit from the reliability of our infrastructure.

As an infrastructure provider, we have to ensure we can always route payments for clients, while still performing software updates and maintenance. So we launched a second node, River Financial 2.

Our Lightning story is only just beginning, and we are excited to see where it takes us and how we can contribute to the growth of the network.

Lightning Network Nodes (with channels)



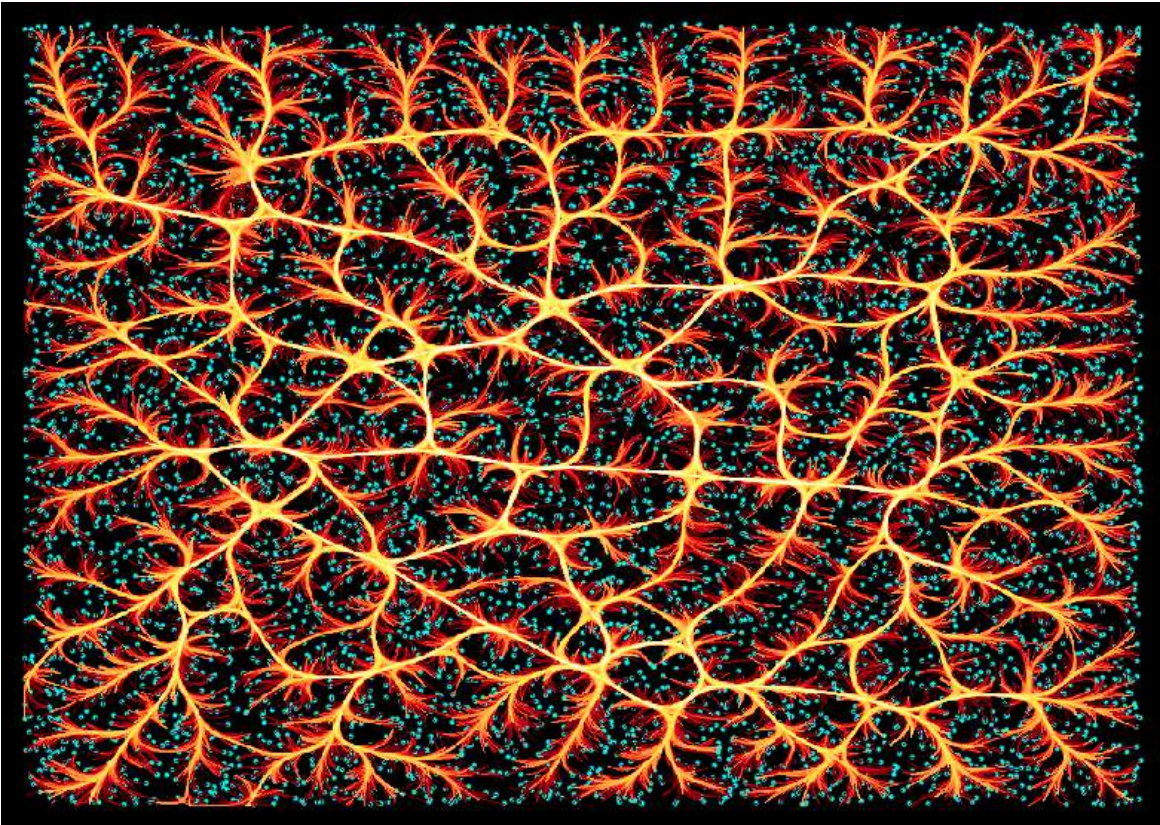
Our Lightning Insights

Running Lightning nodes with a high capacity and hundreds of channels has taught us a lot about Lightning. We have gathered insights on various aspects and grouped them into the following categories:

- Network topology
- Routing activity
- Earnings
- Infrastructure for business

Lightning Network Topology

The Lightning Network consists of nodes run by individual users and businesses. These Lightning nodes form a vast, interconnected web that spans the globe, by connecting to each other through channels.



Visualization of 16k Lightning nodes and their 140k channels by [@pymoment](#) on Twitter

Connecting the “highways” of this network are routing nodes, which forward payments to others for a fee. Anyone can set up such a node, but it takes considerably more time and effort to do so successfully, which we will elaborate on later. The non-routing nodes with few connections (or channels) are at the edges in blue, they belong to users who will primarily send and receive payments for personal reasons.

Similar to using Bitcoin, not everyone uses Lightning for the same reasons. The goals to operate a node vary and can be characterized as the following types of profiles:

Profile Type	Goal
Cost profile	Reducing transaction fees for a user or business
Business profile	Enabling clients to purchase goods and services that benefit from instant global settlement and/or microtransactions
Yield profile	Earning a yield on bitcoin with very low counterparty risk, by routing payments for other users
Trader profile	Enabling traders to engage in arbitrage without using stablecoins

Each of these goals affect the challenges a node operator faces, what their incentives are, and how their node and channels are configured. These goals may answer questions regarding needed capacity, number of channels, connections, fees and rates, and whether they prioritize outbound or inbound traffic. Any node may fit multiple categories.

There Is No Best Profile

Some people may consider the nodes with the highest yield on its capacity to be the “best,” but because of the variety of goals and profile types, there may be other, more important metrics for success. For example, an exchange can make far more profit off trades on its platform than from charging a user routing fees on Lightning, and so may not optimize for the highest yield, while an individual looking for an income stream likely would.

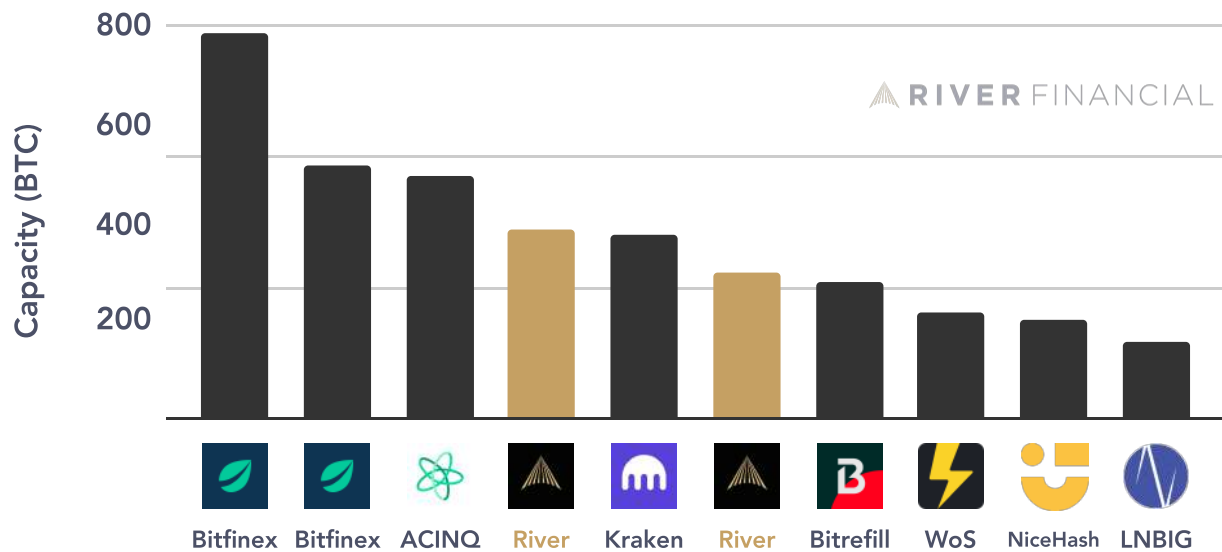
We look into the publicly available metrics around nodes (capacity, channels, fees, and liquidity), and what we have learned about them in relation to the goals.

Capacity Is Not King, It Is a Signal

As of 2022, our River Financial 1 node has grown into the fourth largest Lightning node by capacity, with our second node following closely. As an initial matter, River does not use any client funds to support our Lightning capacity. No bitcoin is used that cannot be made whole on our balance sheet.

We find ourselves among a group of innovative peers that are eager to help the Lightning Network grow and want to be at the forefront of this financial breakthrough.

Top Lightning Nodes by Capacity



Capacity on a node is not the metric that necessarily shows the best nodes in the network to connect to. Having a lot of capital is great, but it should be used constructively. A high capacity is no guarantee that a node will route payments with the highest success rate and for the most competitive fees. For example, a node with high capacity could belong to a hobbyist who accumulated a lot of bitcoin in the early days, but then puts in relatively little effort to manage their liquidity and channels.

High capacity does increase the odds that a node is a business node. Unlike users, businesses have much stronger incentives to use their funds efficiently, and that is less likely to happen by devoting capital to a channel with an individual user without a track record. Beyond that opportunity cost, there is also a security cost for keeping capital out of cold storage, as is the case when using Lightning.

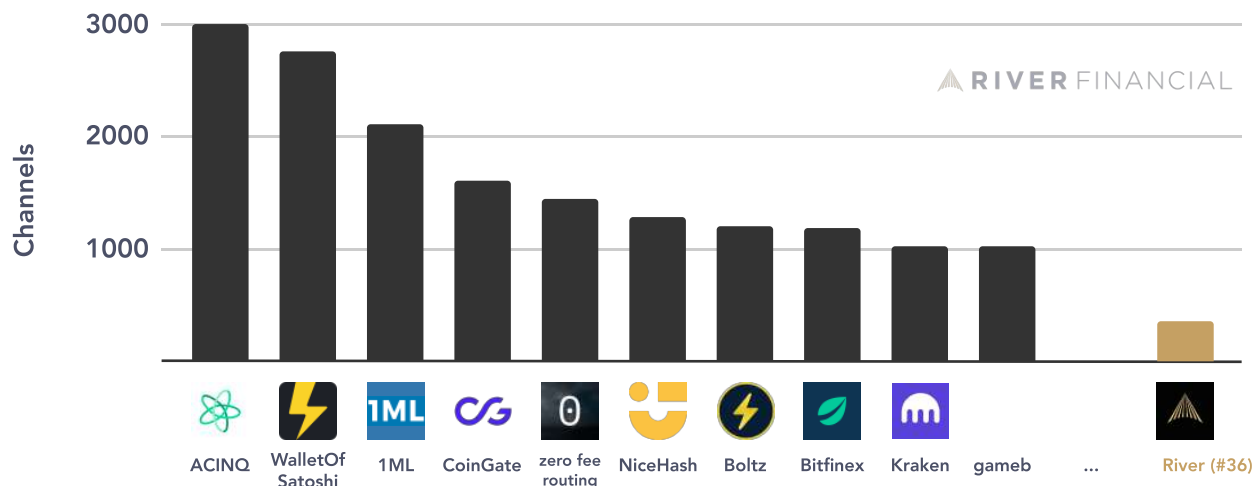
Individual node operators, however, can more easily gain access to much of the network by having a channel with a business node. The easiest way to connect to a business node is to open a channel with them and buy something from them with part of the funds.

Channel Count as a Signal

Looking at how many open channels a node has can be another signal pointing to helpful nodes. Although there is no guarantee that such a node is performing well, the incentives align for someone who pays fees to open many channels, or get many channels opened to them, to be “nodeworthy.”

In terms of open channels, our River Financial node is not close to the top 10. We rank in the thirties.

Top Lightning Nodes by Channels



Our relatively lower number of channels is by design. We are not aiming to be the most connected node in the network. We are trying to ensure all our connections are highly reliable for clients. More on this later when we dive into analysis of our routing activity.

The Cost of Opening Channels

A bitcoin transaction fee must be paid to open each channel. Throughout 2022, the median fee for a bitcoin transaction was around 7728 satoshis, or around \$1.54. Since a transaction to open a channel takes up slightly more block space, the fee to open or close a Lightning channel is typically a little higher than the average, unless an operator waits longer to get their transactions in at a lower fee. Across thousands of on-chain transactions for Lightning channels, we have paid an average fee of 3905 satoshis, or ~\$0.78 at today’s prices.

If the goal is to become a node that earns a yield, then opening dozens or hundreds of channels will quickly rack up costs that may be difficult to recover if the channels turn out to have little activity. In the future, if bitcoin transaction fees rise, it could become more expensive to create new successful routing nodes.

Channel Quality Over Quantity

Each node operator wants good peers. This is a big challenge for operators looking to earn a yield by routing payments for others, and for users who want to save costs by using Lightning for payments. Node operators need to convince other operators to allocate capital to a channel with them so they have inbound liquidity. If the node is new, then there is no insight into the benefits for those locking up the capital.

As a result, marketplaces to buy and sell inbound Lightning liquidity have emerged. These are not a perfect solution, because buying inbound liquidity does not always result in routing activity, so the process may need to be repeated many times. These marketplaces do provide people with options, which has been a useful development.

Node operators looking to earn a yield will often close long-term inactive outbound channels and reallocate that capital. Since 2022, we have started to manage our channels much more actively, to a point where we are currently opening and closing dozens of channels each day.

Channel Count on River's Lightning Nodes



We fully expect activities such as setting fees after opening channels or closing inactive channels to become automated, which would make running a node more manageable for operators. Even if these activities are automated, we expect building out a successful routing node will still require a significant time investment.

Fees and Liquidity

The concepts of inbound and outbound liquidity can be confusing, so we review them here:

Inbound liquidity is the amount of bitcoin a node can receive, or the value sitting on the other side of the channels connected to it. The node has no control over the fees charged for inbound liquidity, and doesn't earn any fees on inbound transactions either.

According to Lightning Engineer Joost Jager, the lack of inbound routing fees could be a potential limiting factor for the efficiency of Lightning.

Example: Alice uses her node to open channels with Bob, and Carol for 1 BTC each. The inbound liquidity is 0 BTC, until she sends 0.5 BTC to Bob and 0.2 BTC to Carol. The inbound liquidity is now 0.7 BTC, which is the sum of the value sitting on the other side of each channel.

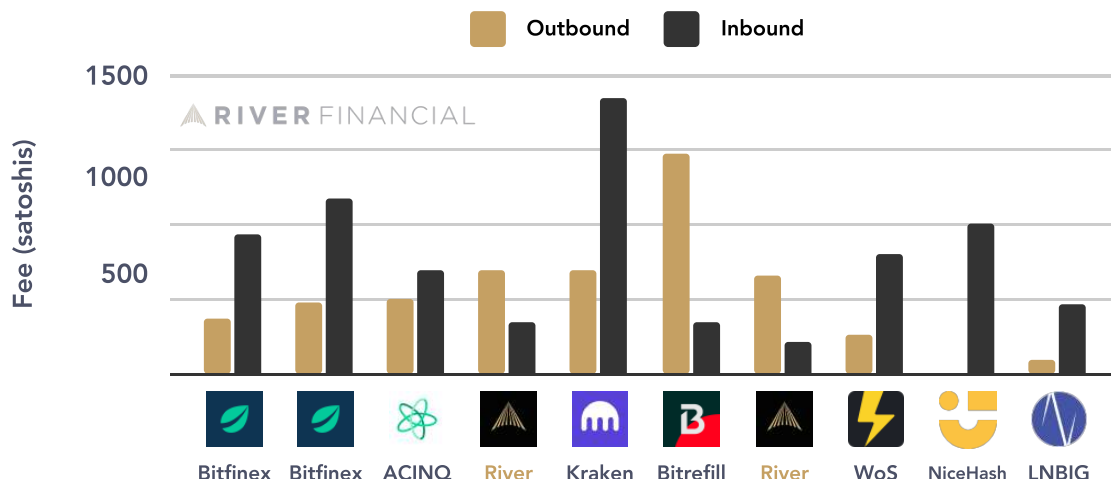
Outbound liquidity is the amount of bitcoin a node can send, as it is value sitting on their side of the channels connected to them. The node controls the fees charged for outbound liquidity.

Example: Using the previous example, Alice starts with 2 BTC in outbound liquidity. After sending 0.5 BTC to Bob and 0.2 BTC to Carol she now has 1.3 BTC left in outbound liquidity, of which 0.5 is to Bob and 0.8 is to Carol.

We also briefly review fees, as there are two types of fees on Lightning: A base fee, which is a flat fee that is charged for every transaction, and a fee rate, which is a rate dependent upon the size of the transaction. There is an ongoing effort to set base fees to zero across the network which we are supporting, as it makes payments that use multiple routes to increase success rates more efficient.

Below we look at the fee rates charged on the liquidity for the top 10 nodes by capacity.

Average Fee Rates by Top 10 Capacity Nodes



As previously mentioned, getting inbound liquidity is the hard part for many participants. Looking at Bitfinex’s nodes for example, their peers are charging relatively higher fees to send bitcoin to Bitfinex, while sending bitcoin from Bitfinex’s node has a similar cost to other nodes.

Each node deals with its individual liquidity challenges. A user who mostly uses the Lightning Network to spend needs to frequently replenish outbound liquidity. A business that receives payments needs to replenish inbound liquidity, or each customer would be required to open a channel directly with them.

Routing nodes want as little capacity in inactive channels as possible. A formula could be constructed to measure the percentage of actively contributing capacity and thus how effective a routing node is. Only the node operator could calculate it as the activity is not public information. An example:

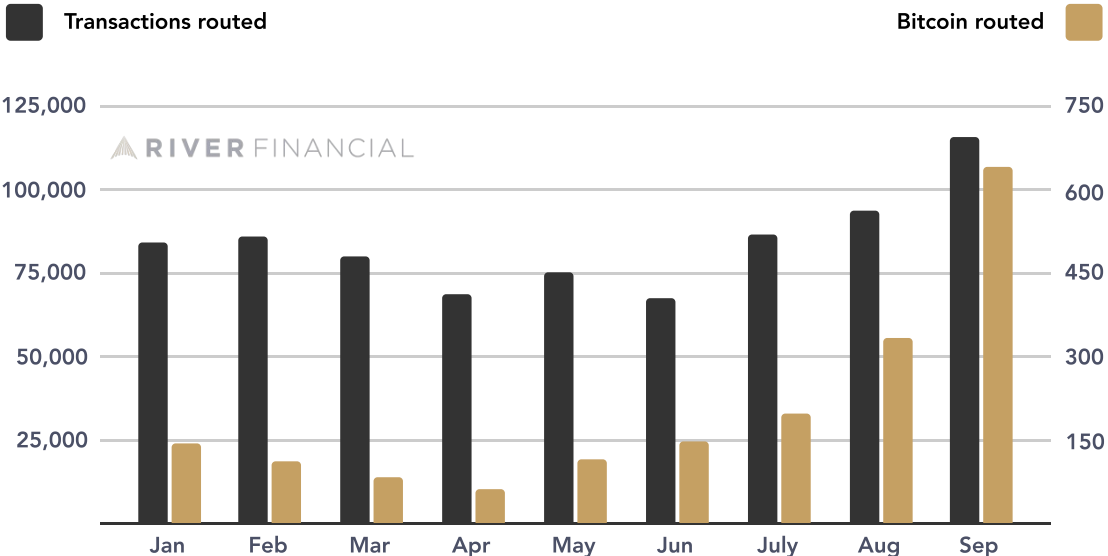
$$\frac{\text{Capacity in channels with X fees earned in the last Y days}}{\text{Total Capacity}} = \text{Capacity efficiency}$$

In time, as more data becomes available, it could be aggregated across many operators to analyze the range of expected activity on Lightning channels. We take a first look below.

Lightning Routing Activity

The number of transactions we have been routing over Lightning this year is growing ~5% per month, or 20% per month in Q3. Note that this is not representative of the growth in the Lightning Network as a whole. As previously mentioned, our goal has not been to try to be as connected as possible, nor to route as much traffic as possible. We are aiming for high reliability to route transactions.

River’s Lightning Routing Activity in 2022



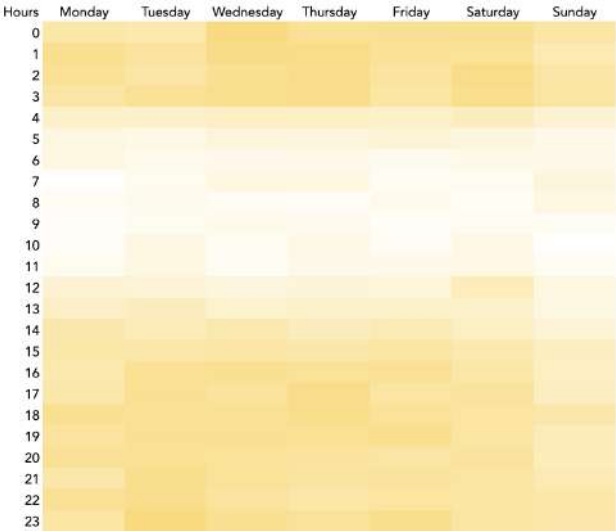
What has changed significantly as a result is the amount of bitcoin we have been routing over Lightning. Our relatively high success rate has increased the odds of peers routing larger transactions through our Lightning nodes.

We cannot do analysis on the final destination of these transactions and how this has evolved. Thanks to the use of Onion routing, or encapsulated layers of encryption, a node cannot tell its position in the payment unless it is the final recipient. Its software can only peel off a layer to find instructions on which channel to send the payment through next.

When Lightning Transactions Happen

What can be analyzed, for example, are the timestamps of the transactions routed. If we put the timestamps for the 115,648 transactions we routed in September 2022 with our Lightning nodes in a weekly heatmap, we get the following overview in Coordinated Universal Time (UTC).

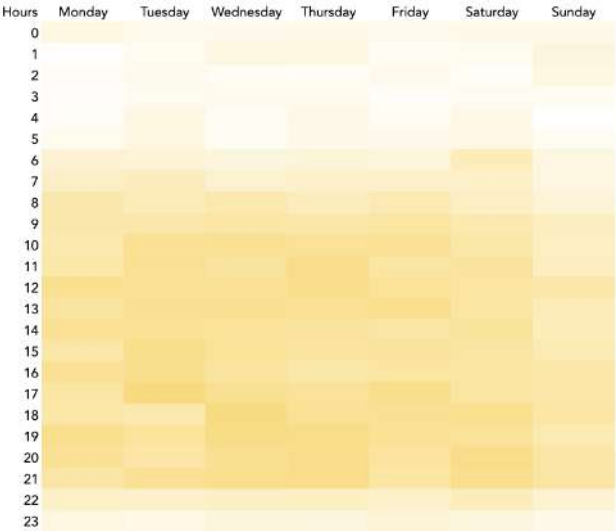
Lightning Transaction Heatmap Sep 2022 (UTC)



Source: River's Lightning nodes

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Lightning Transaction Heatmap Sep 2022 (UTC-6)



Source: River's Lightning nodes

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It immediately becomes apparent that our routed traffic is significantly influenced by activity in American time zones, as average American sleeping hours represent a significant drop in routing activity. This influence is not surprising, given that we have many US-based Lightning channels and are the Lightning service provider for El Salvador's Chivo wallet.

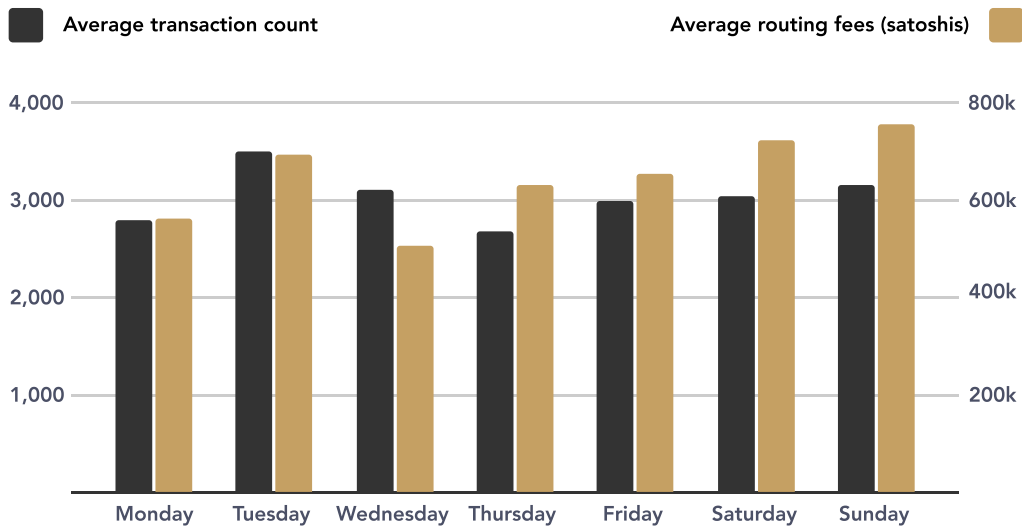
If we adjust the heatmap for UTC-6, which is Central Standard Time and also the time zone for El Salvador, we get the overview on the right. It shows clear US-based sleeping hours, and besides Sunday, there is rather evenly spread activity on the network.

If we were able to aggregate data from other major routing nodes in the network, we may see variance in the activity and get a better understanding of the activity across the entire network.

A Discrepancy Between Activity and Profitability

The most popular days in terms of transaction count are not always the most profitable days for fees earned. The graphs below for August and September 2022 show rather different results (after adjusting the data for the occurrences of each day in those months). The second half of the week tends to be relatively more profitable.

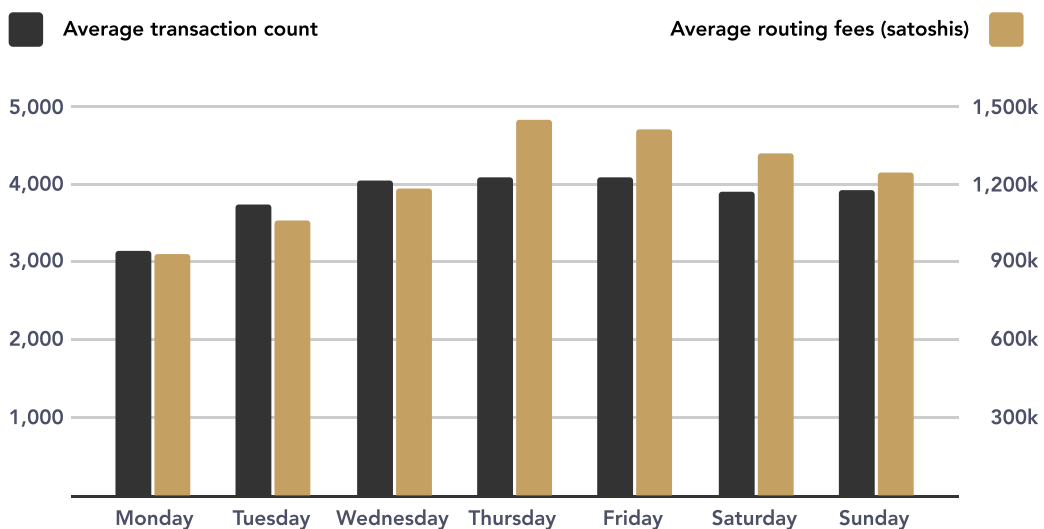
Lightning Transactions Routed vs Fees Earned (Aug 2022)



Source: River's Lightning nodes

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Lightning Transactions Routed vs Fees Earned (Sep 2022)



Source: River's Lightning nodes

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Why Lightning Payments Can Fail

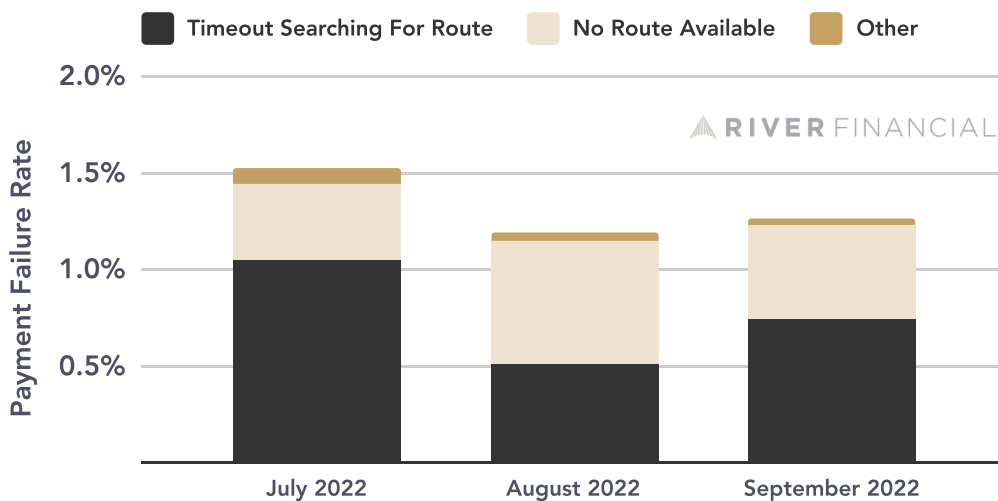
There is no guarantee for Lightning payments to succeed today. There are various technical reasons why payments can fail, such as an inability for nodes to find a successful route because none are available at the time, or taking too long to find a route and timing out after a minute. There are many ongoing engineering efforts in the Lightning development community that aim to improve these problems.

Funds are not lost when payments fail, but it creates a bad user experience. To mitigate this, we primarily focus on the quality of our channels as previously mentioned. The results of this focus are promising so far: our payment success rate in September is 98.7%, across thousands of daily transactions, at an average transaction size of 230k satoshis (~\$46), and a median transaction size of 24.4k sats (~\$5).

This is significantly better than the [earliest publicly available data](#) we could find (which is from the early days of Lightning in 2018), when people were failing \$5 transactions ~48% of the time.

We can look into the September data to understand why payments are failing. Out of the 1467 payments we failed to route in this month, 866 of these were due to timeouts, and 558 due to no route being available at the time. Other, less common reasons for payments to fail were server outages for nodes (1 occurrence), incorrect payment details being provided (14 occurrences), or an insufficient balance being available as liquidity was depleted between the time a node calculated a route and the payment was sent (28 occurrences).

Why Lightning Payments Fail, For Now



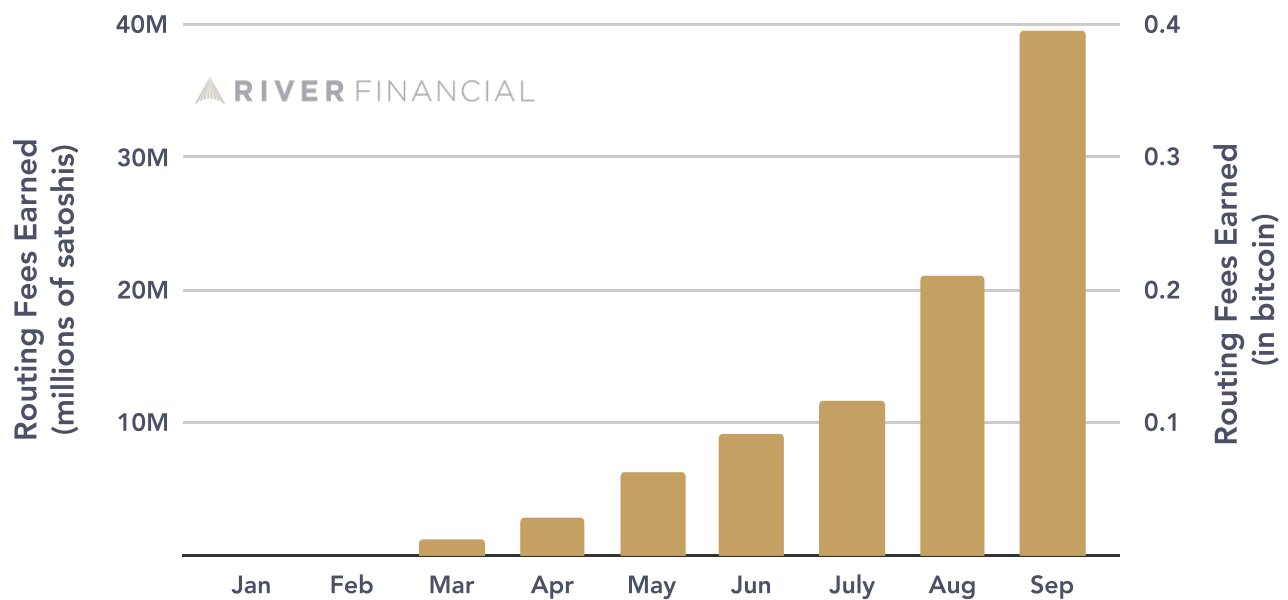
Source: River's Lightning nodes

As time progresses, we expect this payment failure rate to continue to decrease, as the reliability of the Lightning Network improves through many engineering efforts.

Lightning Earnings

Since March 2022, we have started to earn routing fees in the millions of satoshis as we started actively managing our fee rates and expanding our number of peers. Growth has been incredibly fast.

River's Routing Fees Earned in 2022



In September 2022, we had an average capacity of roughly ~420 btc across our Lightning nodes, and earned roughly 40 million satoshis in routing fees. This is a yield of 0.095%, which is ~1.15% APY (Annual Percentage Yield). That is relatively low for now, but growing rapidly.

For context, [@cold_sats](#) on Twitter is a Lightning enthusiast running a top 100 node with a total capacity of ~19.8 btc. He discloses his earnings and most of his strategies, which is commendable and makes his data useful for comparison. In March he estimated his yield for 2022 to be 1.44% per year, but using [September 2022 data](#), this number is 0.55% per month, or 6.8% on a yearly basis. This is significantly higher than our performance, with the caveat that we have been primarily focused on building out our infrastructure.

There is also a plateau where additional capacity may not convert linearly into returns anymore, depending on the current activity on the network and its size. Using the data input from many node operators would enable us to visualize this plateau, and how it progresses over time.

While a return of a few percent sounds great, it comes with a caveat: high effort.

Lightning Infrastructure

Running a Lightning node to send and receive payments on Lightning is relatively easy. Setting up a successful routing node from scratch or integrating a node with business systems is more labor intensive and comes with a steep learning curve. Each are multi-month projects to get up and running due to the trial and error involved. There is a great guide by the @cold_sats Lightning node operator that gives an idea of [all the tasks involved in setting up a node](#) from scratch.

It takes at least several hours per week to run a large Lightning node. The main tasks are managing channels and liquidity. Some time savings can be introduced through automation, but for now this automation is custom-built and not widely available in standard software. We expect that future updates to Lightning will continue to make it easier to manage nodes.

Even after such updates, we expect that the average user will not be able to run a highly profitable routing node. This is not a problem for the smooth functionality of the Lightning Network itself, as the number of profitable nodes is a self-balancing mechanism. If there are too many operators trying to run profitable nodes, some will drop off over time and raise profits for the others. If there are too few profitable nodes, people will learn how to run them. In a similar way, most content creators on platforms such as YouTube or TikTok do not earn a significant amount, but the experience for both content creators and viewers is still good.

Similarly, we do not expect the average business, in or outside the Bitcoin industry, to want to employ people to run Lightning infrastructure. There are significantly more considerations when running Lightning as a business.

Lightning Infrastructure for Business

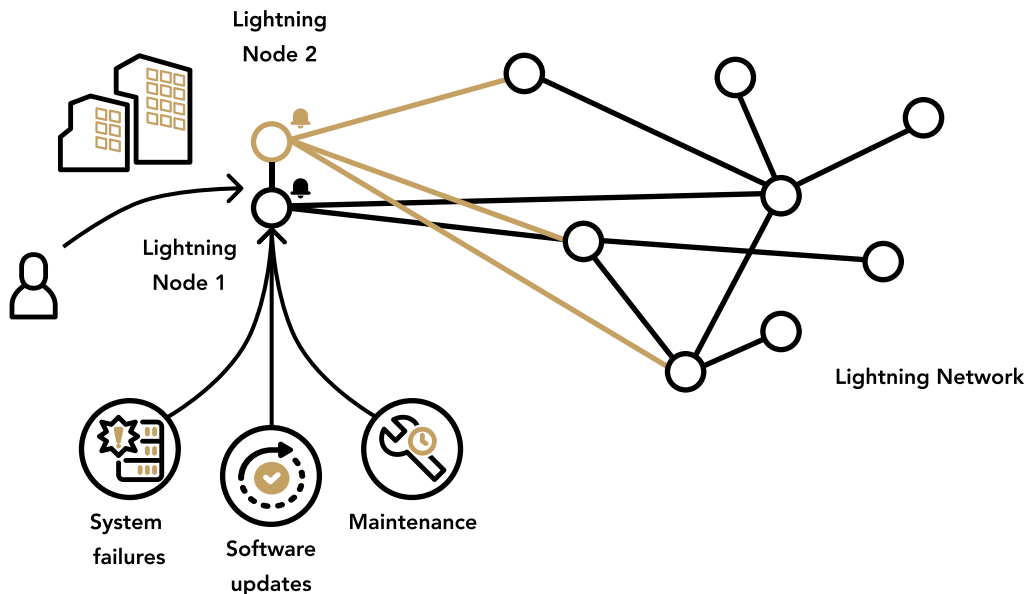
As a service provider of Lightning infrastructure to other companies, our responsibilities are much more extensive than those of the average node operator.

Like any node operator, we need to update our node software. When clients are counting on a system for their payments, however, it can never go offline. This means that we (and any business that would want to run its own Lightning infrastructure) must build out and run multiple nodes, to account for unexpected system failures, software updates, and maintenance. A business also needs alerting systems to replenish inbound liquidity to ensure users can always use Lightning to pay.

Business Lightning Infrastructure

When clients are counting on a system for payments, it can never go offline.

An always-live Lightning infrastructure requires redundancy, alerting systems,...



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There are also many accounting considerations and required integrations with business systems to have accurate reporting. And then there is the critical matter of security, as Lightning capacity is stored in a live system and no more secure than a hot wallet.

Ensuring the system always works is one aspect, but when it does not, a user needs to be properly informed on what happened and what action they can take. Sometimes Lightning payments can still fail or get stuck as liquidity is unexpectedly drained. As previously mentioned, we currently route payments with a 98.7% success rate, but this still means users may experience some form of error and may need to try again. That is a high failure rate compared to other consumer payment systems, but Lightning is a relatively new network and we expect our success rate to continue to rise in the coming years.

We have learned a lot by dealing with these challenges and have developed expertise that lets us help other companies to leverage the Lightning network without having to go through these hurdles themselves. We are launching [River Lightning Services](#) to help more companies integrate Lightning into their business operations.

Conclusion

Running Lightning continues to be both challenging and exciting. With the advent of [Taro](#), we envision a bright future for Lightning as it transforms what is possible on Bitcoin.

With that said, we have grown to believe it will not make sense for many businesses to bring the competencies to run Lightning nodes in-house. There are many unique challenges for a business to work through to use Lightning at scale, especially related to accounting, security and maintenance. As a result, many businesses may benefit from outsourcing such responsibilities.

As for River, our Lightning mission is simple: to be the single best peer on the network. To further this mission, we are excited to be at the cutting edge and continue to develop novel financial products made possible by Lightning. As Lightning adoption grows and client demand grows with it, River is excited to scale alongside the network while providing the same customer experience clients have grown accustomed to with our brokerage and mining products. [River Lightning Services](#) is one important step in that process.

If you are interested in what we will be developing, sign up to our newsletter on our website or follow us on Twitter [@River](#)

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