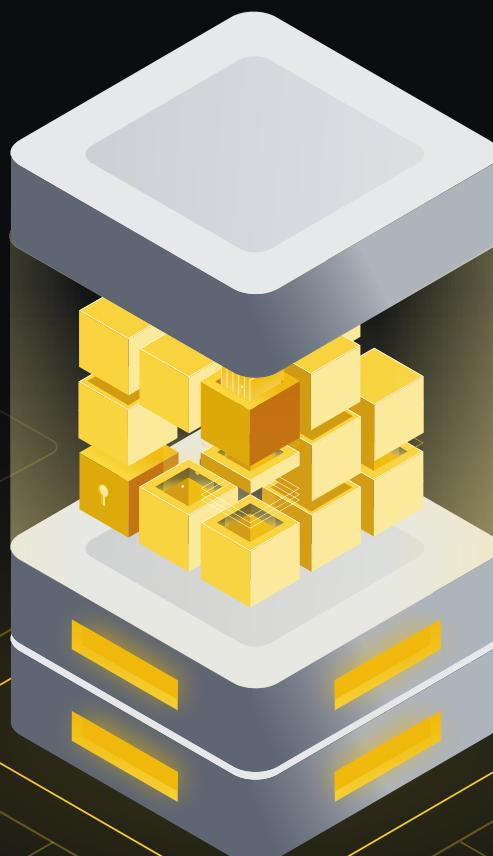


# Decoding Cross-Chain Interoperability



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# Key Takeaways

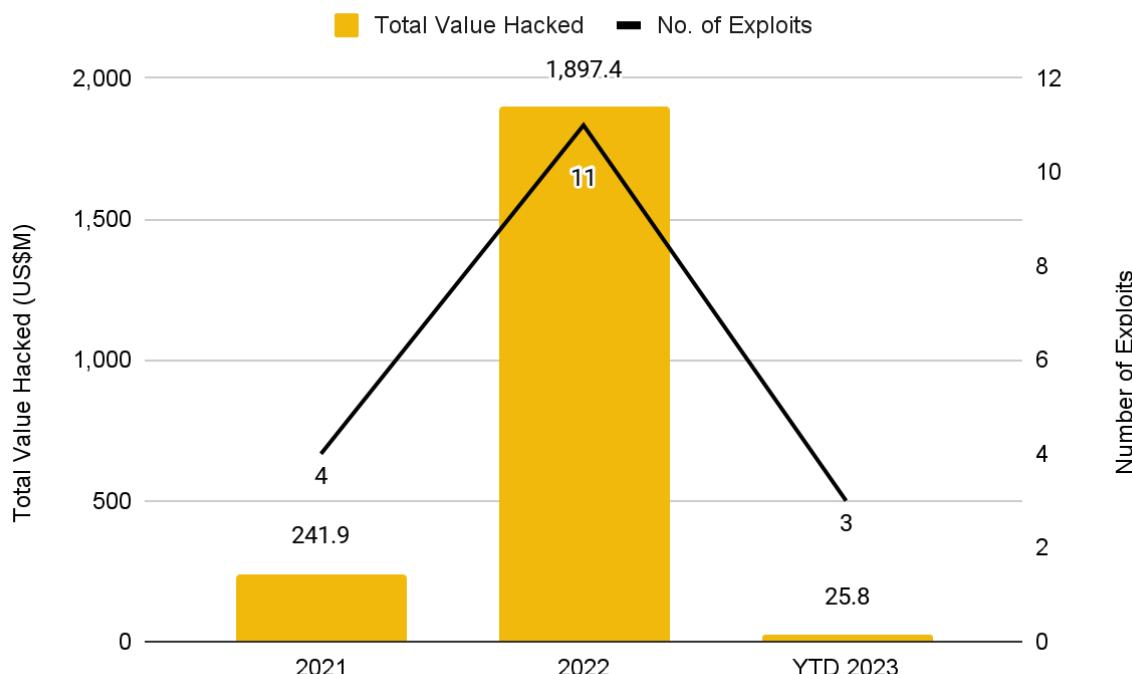
- ◆ In the growing multichain ecosystem, developers face challenges with non-uniform tooling, while users contend with the limitations of chain-specific decentralized applications (“dApps”), resulting in fragmented liquidity and less-than-ideal UI/UX. Cross-chain interoperability emerges as a key solution.
- ◆ First-generation bridges, using the lock-and-mint model, have faced over US\$2B in losses from security breaches, pushing the industry toward more secure, second-generation cross-chain messaging protocols. These newer solutions support native integration and have led to a shift in performance criteria from total value locked (“TVL”) to more transaction- and message-based metrics.
- ◆ Serving as a generalized infrastructure layer for dApps to build on, cross-chain messaging protocols enable the exchange of not only tokens but also arbitrary data. This evolving ecosystem now supports over 60 chains and boasts over 900% year-over-year (“YoY”) growth in aggregate transaction count.
- ◆ CCIP, Chainlink's latest venture into the interoperability domain, utilizes a triple-network architecture to ensure robust verification. With a strong focus on security, CCIP also stands to benefit from Chainlink's established presence to bootstrap initial growth, particularly in connecting TradFi with real-world assets (“RWAs”).
- ◆ LayerZero, having seen a notable uptick in activity in 2023, employs a distinct framework that separates oracle and relayer functions, safeguarding against collusion and misconduct. Its lightweight endpoints, which avoid storing all block headers and transaction proofs, provide significant scalability benefits.
- ◆ Axelar facilitates advanced cross-chain communication between Cosmos and EVM ecosystems via its General Message Passing (“GMP”) feature, a key driver of network activity. Notably, Axelar connects to 53 chains, showcasing extensive network support, and uses quadratic voting and key rotation to improve security.
- ◆ Wormhole distinguishes itself as the sole protocol offering support for specific chains like Solana and non-EVM-compatible ones such as Sui. It also has the highest number of ecosystem partners, totaling 94, with Pyth being a significant contributor to its messaging volume.
- ◆ Looking ahead, factors such as maintaining robust security, improving UI/UX, and capitalizing on network effects remain key themes for the growth of messaging protocols. Simultaneously, the progression toward tokenization and TradFi adoption may catalyze their usage further.

# Why Interoperability Matters

Since Bitcoin, the blockchain ecosystem has expanded to include Ethereum, BNB Chain, Arbitrum, OP Mainnet, and more, each hosting several users and decentralized applications (“dApps”). This growth indicates a clear move toward a multichain future, though it is not without its own set of challenges. Developers often find themselves **without uniform tools and operating processes**. Users, on the other hand, are **constrained by the specific chain** a dApp supports, often having to contend with **fragmented liquidity and less-than-ideal UI/UX**. Ultimately, the current multichain world demonstrates the limitations of any single blockchain in satisfying every requirement. **Interoperability is, therefore, essential for achieving the scalability necessary to meet a broad spectrum of demands in the blockchain space<sup>(1)</sup>**.

The pressing question becomes: how can these separate chains communicate? **Cross-chain bridges serve as channels for value transfer** between different blockchains, addressing the communication gap. Unfortunately, they have also traditionally been **vulnerable to high-value exploits**, with security breaches resulting in the loss of over US\$2B in the last few years. These first-generation bridges, **typically dependent on a lock-and-mint model with wrapped assets, inherently carry greater risks**, underscoring the need for more secure cross-chain methods.

**Figure 1: Traditionally, bridges have been susceptible to security breaches, with over US\$2B compromised due to cross-chain exploits**



Source: De.Fi, Binance Research, as of November 17, 2023

**Layered on top of these issues is the fact that permissionless blockchains, by design, struggle with direct cross-chain communication**, an outcome of their trustless nature requiring verification for every message. In homogenous ecosystems such as Cosmos, where chains are linked to a central hub, cross-chain messages and their verification become relatively straightforward. However, heterogeneous, standalone blockchains, which attract a significant share of user interactions and capital in today's market, pose greater challenges. Each adheres to its own distinct set of rules and security measures, making it virtually impossible without the intervention of a **trusted intermediary able to natively communicate across chains**. As the proliferation of Layer-1s ("L1s"), Layer-2s ("L2s"), and application-specific chains shows no sign of stopping, the industry's concerted **effort toward interoperability becomes even more important**.

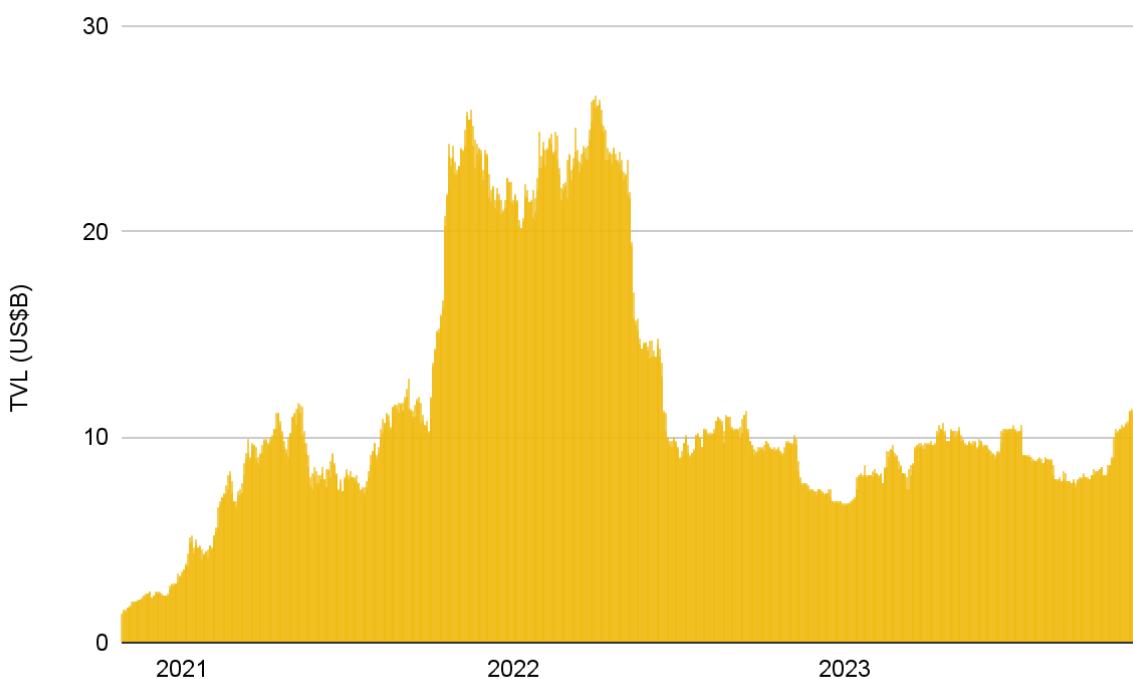
Therefore, for blockchains to fully embrace interoperability, the sector must move past 'chain tribalism' and address the issue of cross-chain hacks. This is where cross-chain messaging protocols come into play. They emerge as a **viable solution to securely connect different networks, mitigating the challenges present in the fragmented blockchain landscape**. Some protocols forge mutual communication frameworks, while others serve as intermediaries, translating messages to suit different chains. Fundamentally, these systems are **designed to enable seamless communication between chains with distinct trust architectures**.

In this report, we explore the state of the cross-chain messaging market, analyze key projects along with their distinct applications, and assess the sector's outlook moving forward.

## State Of The Market

Before the rise of cross-chain messaging protocols, blockchain interoperability was primarily centered around cross-chain bridges. As these bridges predominantly locked tokens on the source chain and minted equivalent wrapped tokens on the destination chain, total value locked (“TVL”) was the key metric for evaluating the performance of these early bridging protocols. In 2021, **against the backdrop of a bullish market and fueled by narratives like ‘ETH Killers’<sup>(2)</sup> and ‘Multichain Future’<sup>(3)</sup>**, there was a significant uptick in the adoption of bridge protocols. This led to a sharp increase in their TVL as numerous alternative L1s emerged. However, 2022 witnessed a major correction in TVL, largely attributed to the bear market. This period also saw **some of the most notorious bridge hacks**, including those affecting Wormhole<sup>(4)</sup> and Nomad<sup>(5)</sup>, which drastically reduced the TVL of bridge protocols. Additionally, **the collapse of Terra Luna<sup>(6)</sup> was another pivotal event**, impacting billions in TVL across several bridges.

**Figure 2: The TVL of bridges experienced sharp increases in 2021, followed by a steep correction in 2022 due to the bear market and several bridge exploits**



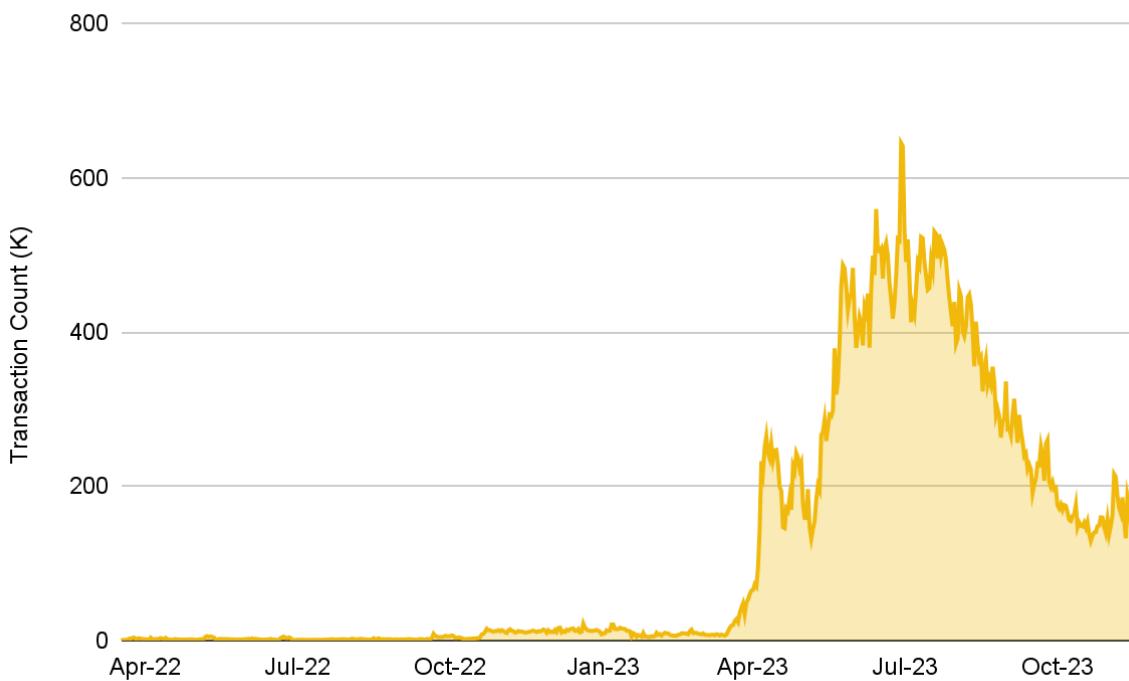
Note: The figures cited are based on the data from the top five bridges

Source: DeFiLlama, Binance Research, as of November 17, 2023

The security vulnerabilities and limitations of traditional cross-chain bridges have steered the blockchain industry toward the adoption of cross-chain messaging protocols. **By late 2022, there was a marked increase in user engagement with these advanced, second-generation solutions, which serve more as an infrastructure layer.** These protocols, in contrast to the first-generation bridges that relied on the lock-and-mint

method, **integrate natively to facilitate use cases such as the exchange of native assets across different chains**. While TVL was the primary method for evaluating the performance of earlier bridges, **the focus has shifted to transaction- and message-based metrics as more relevant measures for assessing the effectiveness of these new protocols**.

**Figure 3: Since late 2022, the transaction counts of cross-chain messaging protocols have experienced significant growth**



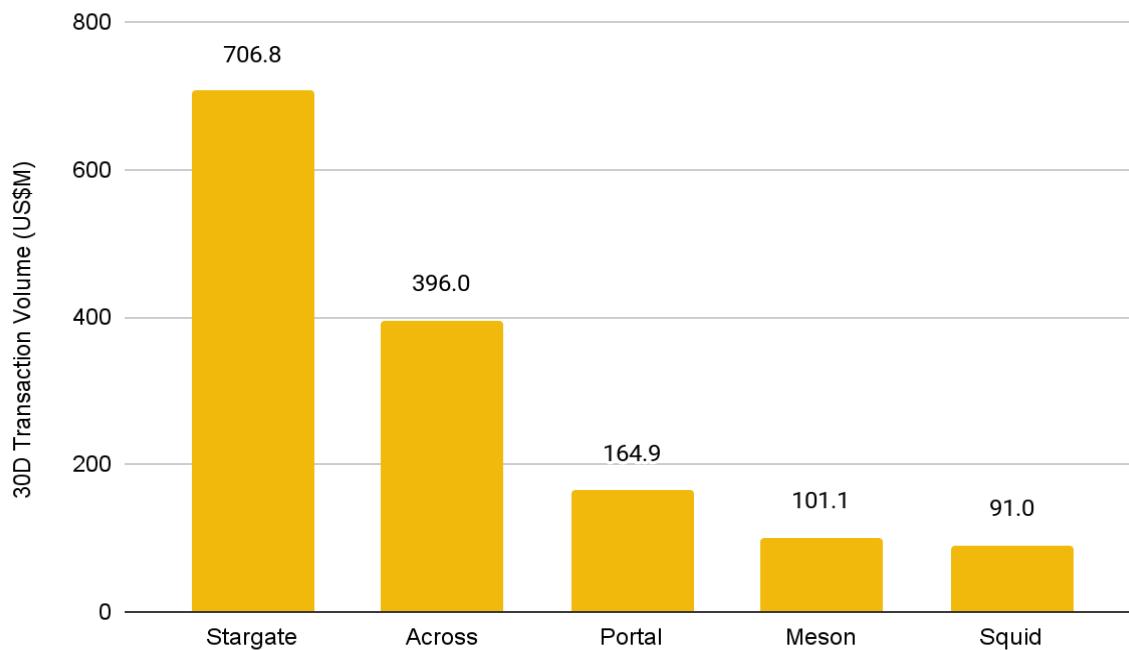
Note: The figures provided are illustrative of the trend rather than exhaustive, as data for some protocols is not available

Source: Dune Analytics (@axelarnetwork, @springzhang, @synthquest), Binance Research, as of November 17, 2023

**Notable projects like Axelar and LayerZero have seen marked increases in transaction counts, a trend that has continued into 2023.** While a portion of LayerZero's activity spike may be attributed to airdrop farming, **the willingness of users to engage in cross-chain activities indicates a broader confidence in cross-chain messaging protocols**. Moreover, the launch of Chainlink's cross-chain interoperability product introduces a well-established player into this evolving market, adding to its momentum.

The growing importance of cross-chain messaging protocols is further emphasized by the success of the applications built on them. Excluding L2-specific bridges, Figure 4 below showcases that **Stargate, Portal, and Squid rank among the top five in terms of 30-day transaction volume**. As cross-chain liquidity solutions from LayerZero, Wormhole, and Axelar, respectively, **their high transaction volumes underscore the expanding adoption of cross-chain messaging protocols** in today's blockchain environment.

**Figure 4: Stargate, Portal, and Squid are in the top five for 30-day transaction volume**

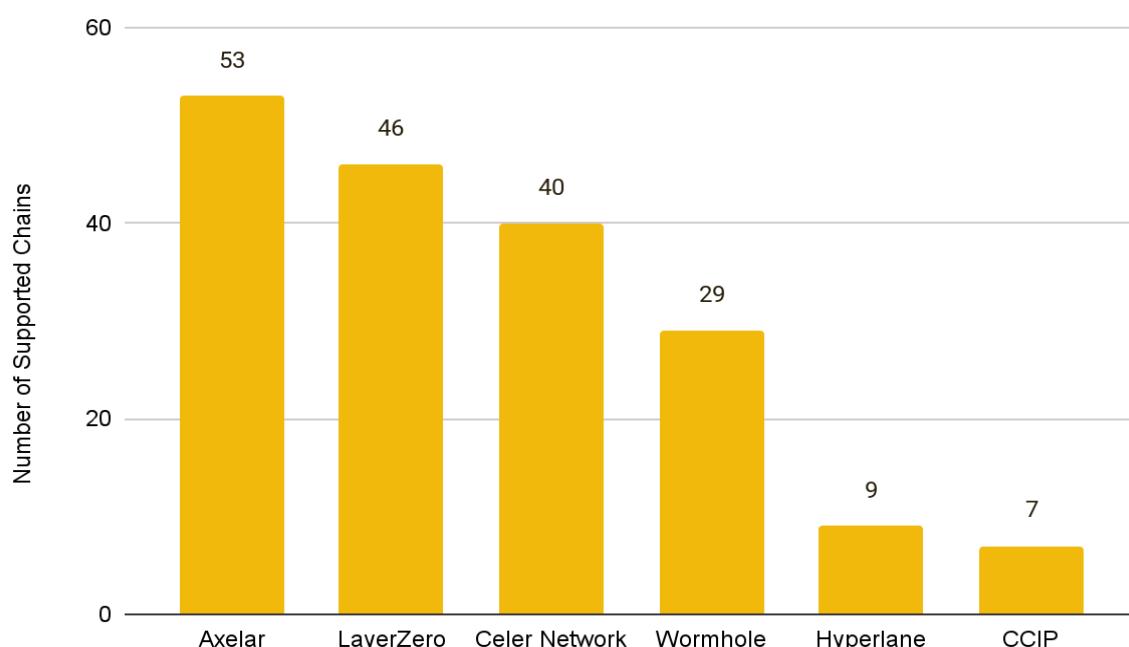


Note that at the time of writing, DeFiLlama does not support all chains. Readers are advised to refer to each protocol's native explorer for a more accurate representation of the figures

Source: DeFiLlama, Binance Research, as of November 17, 2023

The depth of network support is another critical dimension when evaluating cross-chain messaging protocols. Presently, **many of these protocols are connected to a significant number of networks**, underscoring their growth and alignment with a multichain future. For instance, Axelar is now linked to 53 networks, and LayerZero supports 46, with plans to increase these numbers further. **Such widespread support of chains represents a major stride in realizing a completely interconnected blockchain ecosystem.**

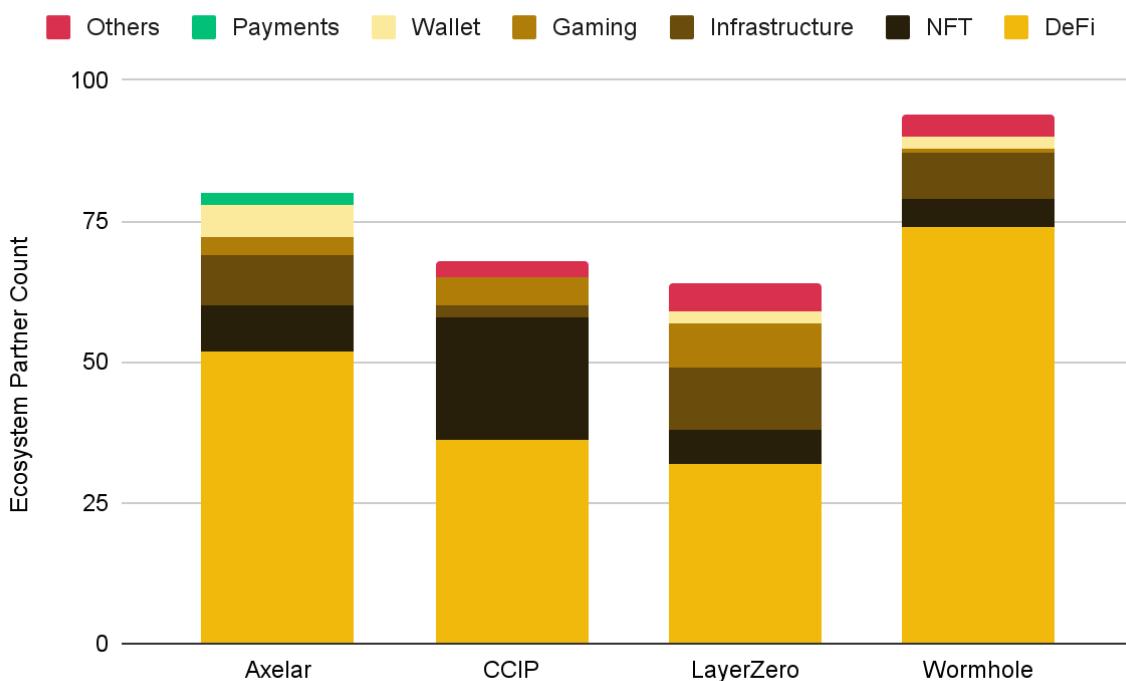
**Figure 5: Today's cross-chain messaging protocols extend support to a notably large number of chains**



Source: Project Websites, Binance Research, as of November 17, 2023

Beyond increased user engagement and expanding network connections, **these protocols also boast thriving ecosystems**. They have a substantial number of ecosystem partners, often exceeding 60; Wormhole, in particular, is nearing 100 partners. **The most common applications we see in these ecosystems are predominantly DeFi, leading by a significant margin with 194 in count**, followed by NFT and infrastructure.

**Figure 6: DeFi stands out as the largest among the top three application categories in the cross-chain interoperability landscape, followed by NFT and infrastructure**



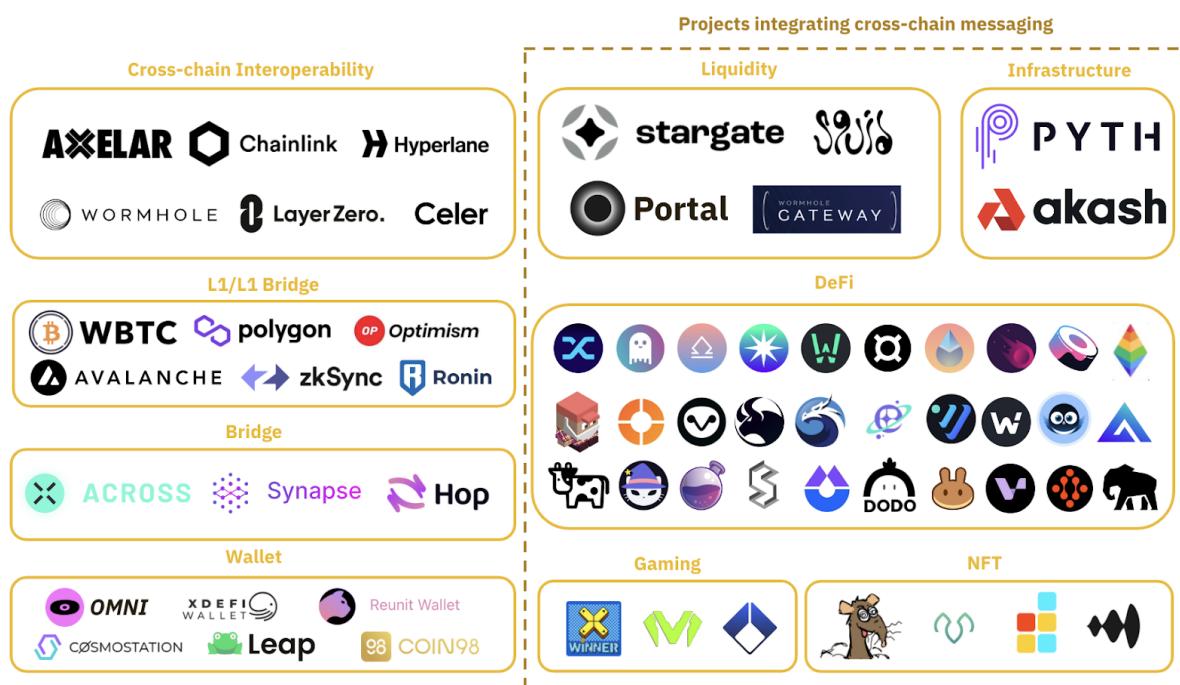
Source: Project Websites, Binance Research, as of November 17, 2023

## Industry Map

Cross-chain messaging serves as a **cornerstone of interoperability**, providing the essential **link that allows developers to focus on building composable applications**. Earlier forms of bridges primarily facilitated token transfers, but cross-chain messaging protocols have **expanded this capability to include the transmission of arbitrary data** across distinct networks. This enables the exchange of not only token details but also generalized information, **unlocking cross-chain execution and a range of new use cases**.

Today's cross-chain landscape can be categorized into distinct segments, each defined by its specific use case. Figure 7 below illustrates key protocols that provide the infrastructure layer as well as the broader ecosystem of projects that support cross-chain capabilities. As cross-chain messaging advances further, users can anticipate benefiting from an expanding suite of use cases.

**Figure 7: Industry map with notable interoperability protocols and broader ecosystem of projects that support cross-chain capabilities**



Source: Project Websites, Binance Research

In the following section, we will primarily explore generalized interoperability solutions, which are important in enabling the **transfer of various data types across independent blockchain networks**. They adeptly **manage a multitude of transactions, from fungible and non-fungible token transfers to cross-chain smart contract interactions**, surpassing the basic functionality of token-only exchanges between blockchains.

Note that the mention of specific projects does not constitute an endorsement or recommendation by Binance. Instead, the projects cited are merely used for the purpose of illustrating the aforementioned concepts. Additional due diligence should be taken to better understand the projects and associated risks.

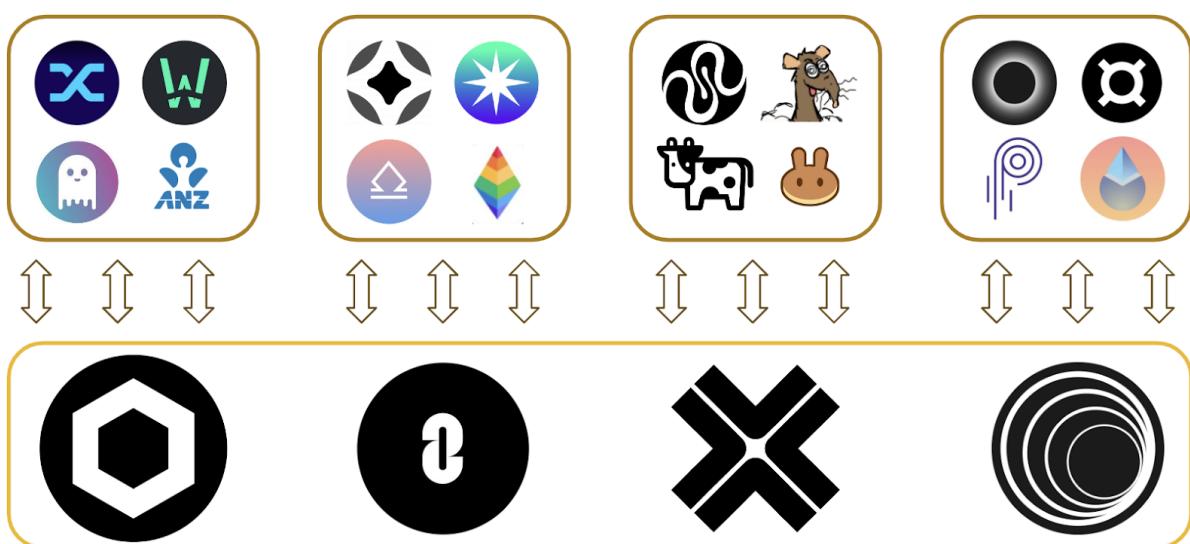
# Industry Projects

At the outset of reviewing the individual mechanics and frameworks of each protocol, it's essential to recognize that cross-chain messaging protocols are fundamental connectors for blockchains. They serve as more than mere bridges, acting as **the underlying infrastructure that enables a spectrum of applications to operate on top of them.**

These protocols facilitate a variety of cross-chain operations such as governance, lending, yield farming, NFT exchanges, and beyond. They play a key role not only in the transference of tokens but also in arbitrary data and programmable transactions. To understand the functioning of these protocols, we analyze them from two perspectives: their messaging process and their implementation.

- ◆ **Messaging Process:** Specifications of how messages, whether tokens or data, are transmitted from the source blockchain to the target blockchain. This includes analyzing the protocol's infrastructure design, security measures, and distinctive components.
- ◆ **Implementation:** The applications and use cases that are built on top of these messaging protocols. Two representative implementations for each protocol are highlighted to showcase their capabilities and differences.

**Figure 8: Cross-chain messaging protocols serve as the generalized infrastructure layer for dApps to build on**



Source: Binance Research

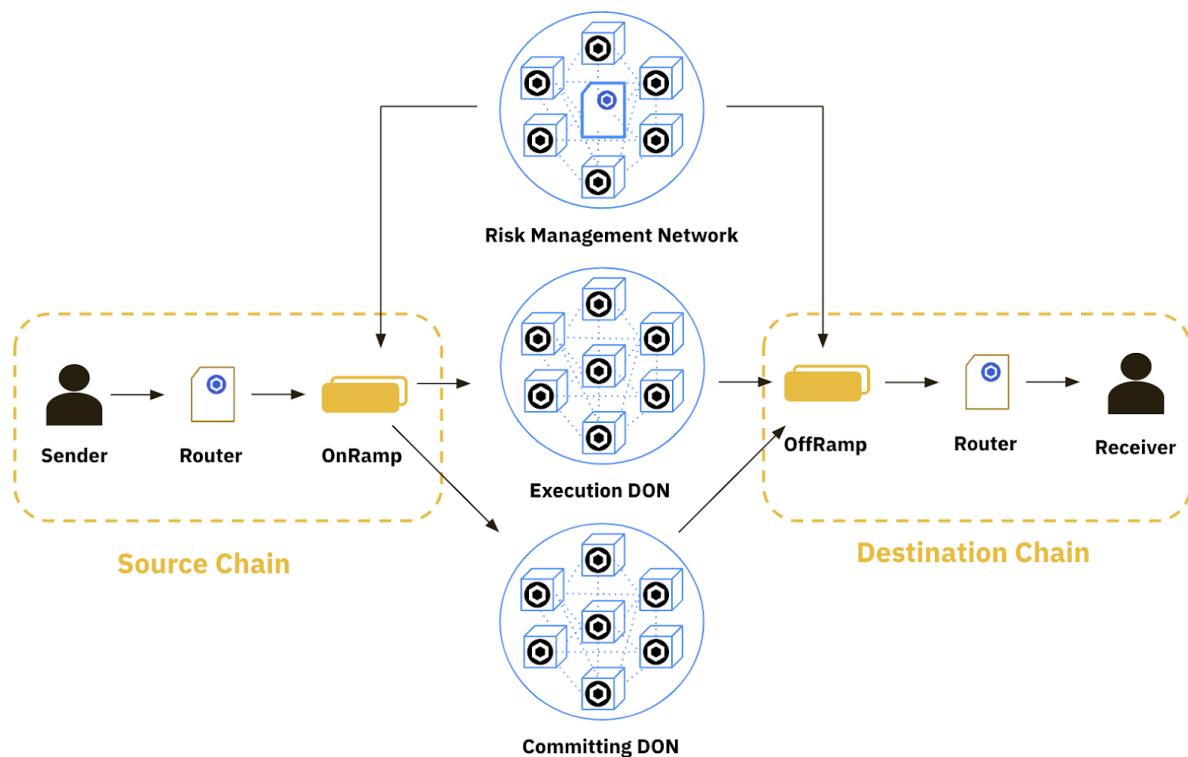
4.1

## Chainlink CCIP

Launched in its Early Access phase in July 2023, the Chainlink Cross-Chain Interoperability Protocol (“CCIP”) is Chainlink’s cross-chain interoperability solution, designed to forge a **unified global liquidity network** by interlinking a diverse range of blockchains, including public chains, private banking chains, and more. CCIP is **powered by Chainlink Decentralized Oracle Networks (“DONs”)**, networks of oracle nodes that perform on- and off-chain computations to expand the functionalities of smart contracts. **CCIP facilitates three types of cross-chain messaging: the transmission of data, tokens, or a combination of both.**

CCIP's core strength lies in **solving the cross-chain security problem** by introducing **additional validation layers, specifically a secondary Risk Management Network**. As per Chainlink documentations, CCIP is the sole messaging protocol to achieve a **level-5 interoperability standard** in the space.

**Figure 9: Visual representation of Chainlink CCIP’s architecture and components**



Source: Chainlink, Binance Research

## CCIP Messaging Process

1. Users interact with the Router contract, which dispatches messages to the OnRamp contract.
2. The OnRamp contract authenticates message details, manages message sequences, oversees billing, executes token lock/burn operations, and emits events to the Committing DON.
3. The Committing DON monitors events emanating from the OnRamp contract, creates the Merkle root of the transactions, and sends the root into the CommitStore contract on the destination chain.
4. Before the Merkle root can be actioned, the Risk Management Network conducts surveillance checks and ‘blesses’ the root if no anomalies are spotted.
5. Concurrently, the Execution DON verifies the transaction consistency with the Merkle root in the CommitStore contract. It then generates another Merkle root and relays it to the OffRamp contract on the destination chain for validation against the previously ‘blessed’ Merkle root.
6. Upon successful validation, the OffRamp contract finalizes the CCIP transaction by dispatching the messages to the Router on the destination chain, which in turn delivers them to the receiver.

CCIP distinguishes itself from existing cross-chain messaging solutions through its multifaceted security architecture<sup>(7)</sup>. In particular, **the integrity and security of the system are underpinned by three independent networks**: the **Risk Management Network**, the **Committing DON**, and the **Execution DON**. **Each network comprises multiple independent nodes, each run by independent operators possessing unique keys**, thereby enhancing decentralization at a foundational level.

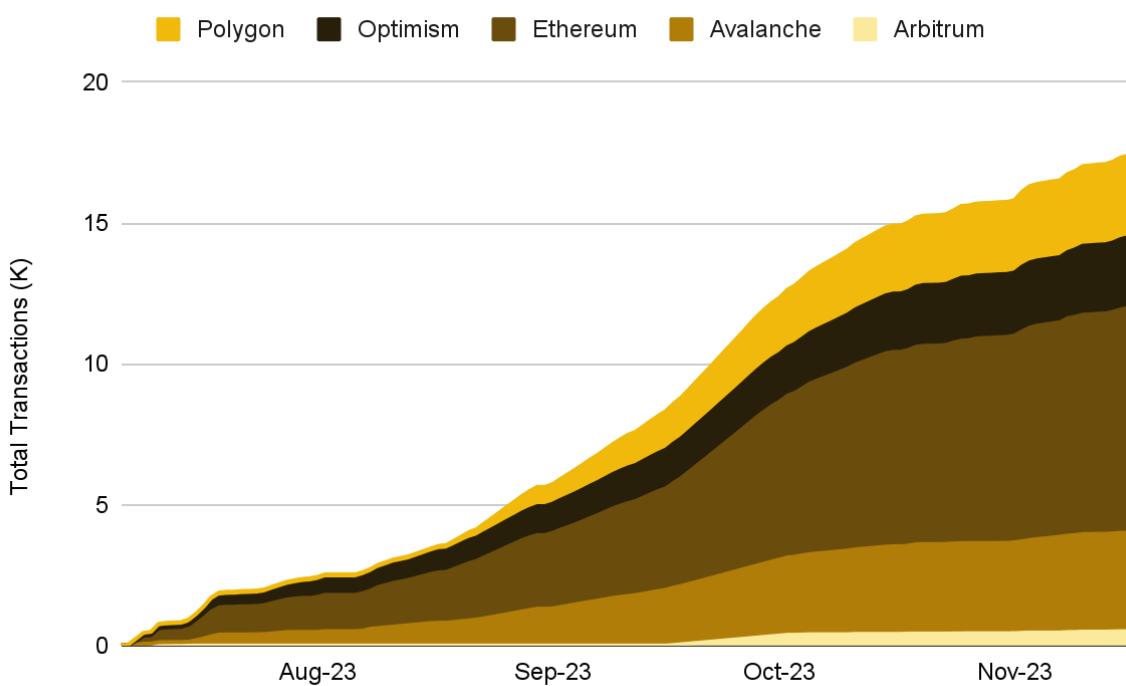
To further promote decentralization, **the software code used for the Risk Management Network differs from that of the other two networks**<sup>(8)</sup>. This design choice **underscores CCIP’s commitment to prioritizing security** in its operations. By **utilizing three separate networks for transaction verification**, CCIP not only **ensures a more robust verification process** but also effectively **mitigates the risk of network overload**. This approach **improves reliability, offering a solution to common performance challenges faced by protocols using a single, monolithic network system**<sup>(9)</sup>.

Additionally, CCIP’s architecture **distinctively separates the commitment of transactions from their execution**, providing **extra time for secondary approvals and anomaly checks** through the Risk Management Network. This separation strengthens the overall integrity and reliability of cross-chain communication. Complementing this architecture is CCIP’s **rate-limiting mechanism for token transfers**, which **sets a limit on the value and volume**

**of tokens that can be transferred** between chains in a given timeframe. This safety mechanism helps mitigate potential losses in adverse scenarios, **adding an extra layer of security to the protocol**.

Given its **innovative architecture and strong ecosystem partnerships**, it's not surprising that CCIP has been relatively successful in bootstrapping and attracting users during its Early Access phase. This is particularly true for dApps already using Chainlink for price feeds, as incorporating CCIP for cross-chain interactions would be a natural extension of their existing infrastructure. Since its introduction in July, CCIP has shown significant growth in usage. Starting from a cumulative transaction count of 2,389 in July, **CCIP experienced an average monthly growth rate of over 90%**, bringing total transactions to approximately 17,400. In terms of transaction distribution, **Ethereum leads the way, accounting for nearly half of CCIP's transactions**, followed by Avalanche and Polygon, which account for 20% and 16.7%, respectively<sup>(10)</sup>.

**Figure 10: Since the Early Access launch, CCIP has experienced a steady increase in transactions, with Ethereum leading the count, followed by Avalanche and Polygon**



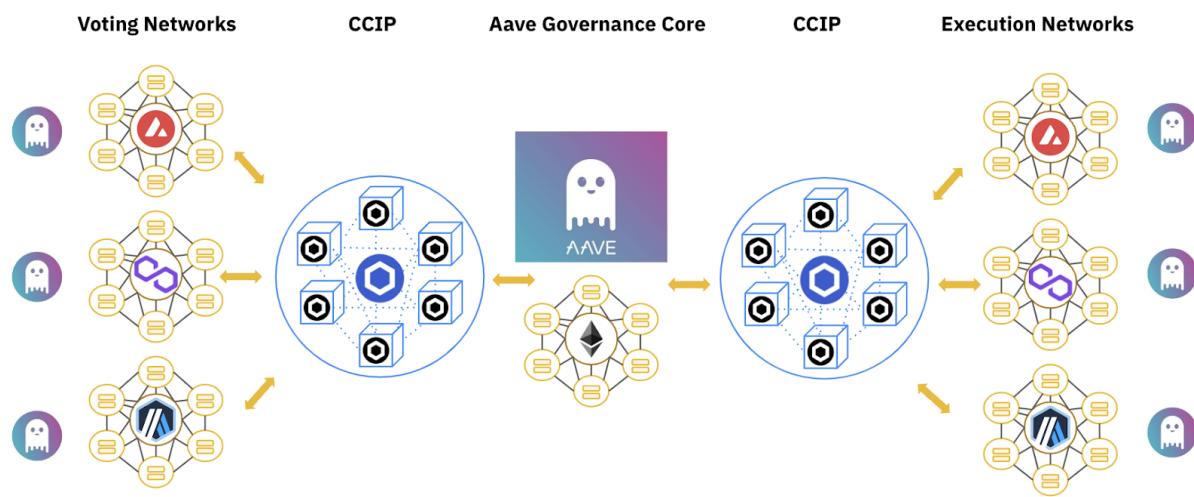
Source: Dune Analytics (@synthquest), Binance Research, as of November 17, 2023

## Governance: Aave

Aave, a multichain liquidity protocol, has integrated CCIP to enhance its security and operational efficiency. Aave's governance, which is spread across multiple chains, faced challenges like dependence on native bridges, limited network expansion, and high cross-chain voting expenses. CCIP helps enable the Aave community to refine the Aave Governance V3 workflow and improve scalability. This integration **creates a link between Aave's main governance contract on Ethereum and its deployments on other networks**,

helping ensure the smooth transfer of proposal details, voting results, and execution directives.

**Figure 11: Aave's integration with CCIP streamlines the transfer of proposal details, voting results, and execution directives, helping ensure a smooth governance process**



Source: Chainlink, Binance Research

## Settlement: ANZ

Australia and New Zealand Banking Group Limited (“ANZ”), a leading institutional bank in Oceania, has collaborated with Chainlink Labs to [explore a cross-chain settlement solution utilizing CCIP](#). Their **focus was on validating the feasibility of on-chain Delivery versus Payment (“DvP”)**<sup>(11)</sup>, a settlement method ensuring securities are exchanged for payment either simultaneously or after the payment.

The trial, executed in a testnet environment using CCIP as the backend infrastructure, yielded a notable result. It successfully demonstrated that a customer could use an ANZ-issued New Zealand dollar stablecoin to buy tokenized Australian asset NFTs, priced in a different stablecoin on another blockchain. **CCIP's role was pivotal in helping ensure both the buyer and seller simultaneously received their payment and NFTs in one blockchain transaction**, effectively achieving atomic cross-chain settlement.

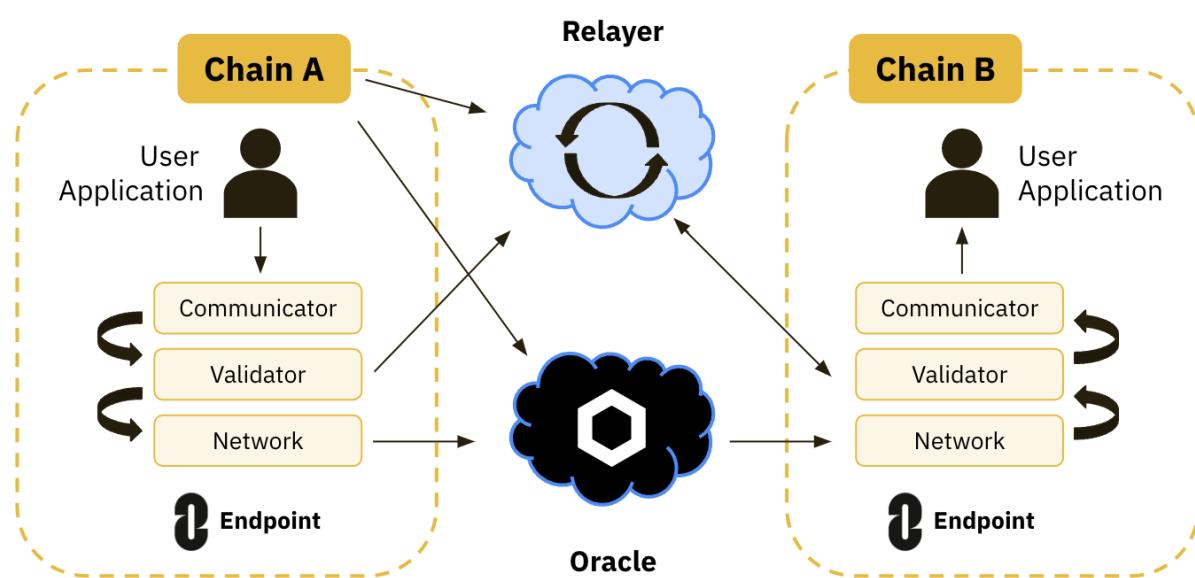
Ultimately, CCIP is able to **facilitate the transfer of value from banks to public chains**, thereby streamlining TradFi's integration process. By **allowing the connection of existing systems to CCIP**, it enables organizations to **leverage their familiar APIs and messaging services** for setting goals and carrying out on-chain transactions. **Serving as a single point of integration**, CCIP grants access to multiple blockchains and DeFi-based dApps, and helps enable protocols and institutions to tap into an additional pool of liquidity and users. Looking ahead, **CCIP is anticipated to take on an increasingly vital role in connecting TradFi with various blockchain networks**.

4.2

## LayerZero

LayerZero, a creation of LayerZero Labs, is an omnichain interoperability protocol engineered for secure and reliable transfer between its supported networks. It aims to **mitigate the risks associated with using centralized exchanges (“CEXes”) for bridging and the inefficiencies found in certain cross-chain approaches requiring intermediaries**. Furthermore, LayerZero has introduced the **Omnichain Fungible Token (“OFT”)** standard, which enables tokens to be natively burned or minted across different chains, establishing a **cohesive standard for multichain fungible tokens**.

**Figure 12: Messaging on LayerZero is facilitated by the Endpoints, the Relayer, and the Oracle**



Source: LayerZero, Binance Research

### LayerZero Messaging Process

At the heart of LayerZero's messaging system is the LayerZero Endpoint, comprising a suite of smart contracts: the Communicator, Validator, Network, and Libraries. Each network that integrates with LayerZero has its own Endpoint.

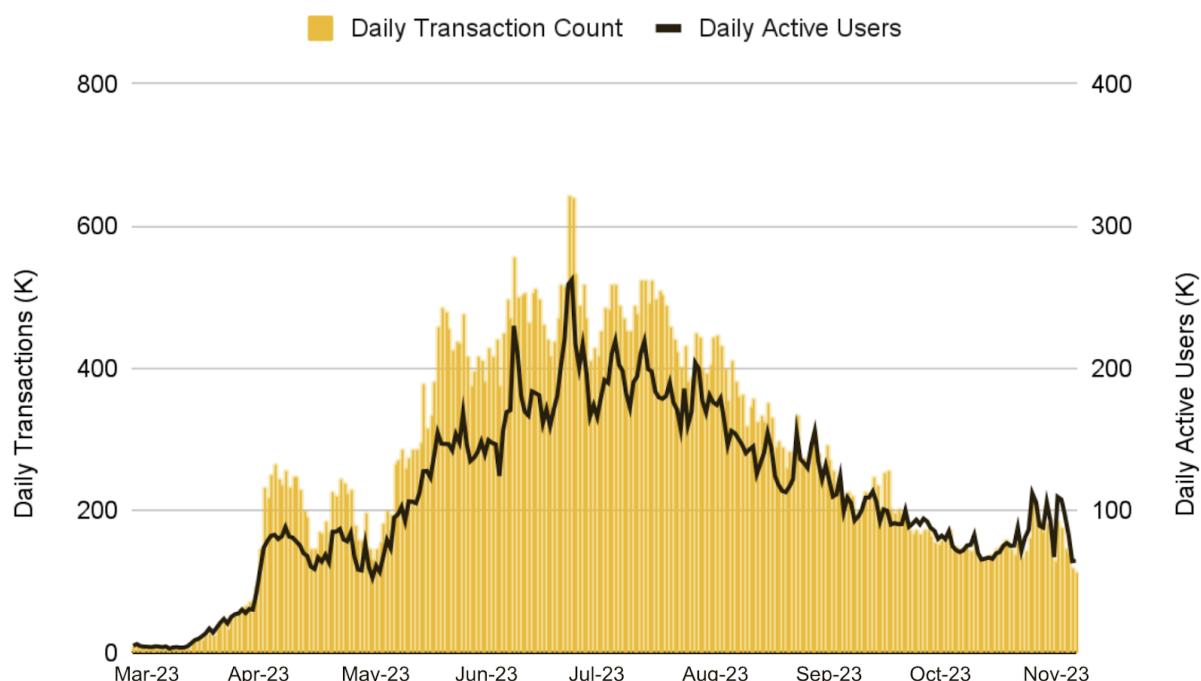
1. An application on Chain A sends key details – transaction and destination chain identifiers, payload, and payment information – to the Communicator contract.
2. The Communicator contract compiles the destination chain identifier and payload into a packet, forwarding it, along with the remaining data, to the Validator contract.
3. The Validator coordinates with the Network contract to initiate the transfer of Chain A's current block header to Chain B while simultaneously cueing the Relayer to retrieve the transaction proof in advance.

4. The Oracle retrieves the block header from Chain A, followed by the Relayer obtaining the transaction proof. Subsequently, the Oracle forwards the block header to Chain B's Network contract, which then relays the block hash to the Validator.
5. After the Validator receives both the packets and transaction proofs from the Relayer, it performs the validation and forwards the message to the Communicator.
6. The Communicator finalizes the message delivery by conveying the message to the user application on Chain B.

**The independent operation of the Oracle and Relayer in LayerZero's framework ensures protection against collusion and misconduct**, safeguarding the integrity of message delivery. This separation, coupled with the **strategy of not duplicating and storing all block headers and proofs<sup>(12)</sup>**, makes the LayerZero Endpoints both efficient and economical, particularly on resource-heavy chains like Ethereum. Additionally, the Libraries contract within the Endpoint specifies the communication details for each chain, enabling LayerZero to rapidly expand and support additional networks.

In terms of traction, LayerZero has experienced a significant uptick in activity throughout 2023, marked by consistent increases in daily transactions and active users. The protocol has achieved several noteworthy milestones, including an expansion of its user base to over 3.3M, a cumulative transaction count exceeding 71.6M, and the total value of assets bridged reaching approximately US\$23.9B<sup>(13)</sup>. **While the role of airdrop farming cannot be overlooked as a significant catalyst for this growth**, LayerZero's overall performance remains commendable, indicating its strong capability to attract both users and capital.

**Figure 13: LayerZero has seen a significant uptick in activity throughout 2023, with both daily transactions and active users continuing to rise**



Source: Dune Analytics (@springzhang), Binance Research, as of November 17, 2023

LayerZero's [recent partnership with Google Cloud](#), making it the default oracle provider for dApps requiring plug-and-play cross-chain solutions, is also notable as it showcases Google's confidence in LayerZero's technology. This strategy of outsourcing infrastructure development enables LayerZero to **focus on onboarding dApps and forming strategic partnerships**, all while maintaining the reliability of its services. While this partnership is significant, **LayerZero continues to offer a modular approach**, allowing dApps the flexibility to choose other providers or combine various configurations for enhanced verification. This means that the security of each LayerZero protocol may vary, depending on the combination of relayer and oracle chosen.

## Liquidity: Stargate

Stargate, developed atop LayerZero, is an **omnichain liquidity transport protocol** that facilitates the transfer of native assets across different blockchains. **It offers a novel approach compared to conventional bridging solutions dependent on wrapped tokens**, which frequently result in fragmented liquidity and suboptimal user experiences.

Stargate's design revolves around its Delta Bridge and Delta Algorithm<sup>(14)</sup>. The Delta Bridge leverages a **unified liquidity pool shared across all supported networks**, offering a scalable solution compared to the fractured pools seen in other systems. The Delta Algorithm acts as a rebalancing mechanism, preserving the equilibrium of liquidity in this unified pool to **avert depletion and potential transaction reversals**. These components facilitate smooth liquidity flow within Stargate, with LayerZero providing the essential cross-chain communication infrastructure.

**Figure 14: Visual representation of fractured liquidity versus unified liquidity**



Source: Stargate, Binance Research

## Lending: Radiant Capital

Radiant Capital functions as an omnichain money market, leveraging LayerZero's infrastructure for cross-chain borrowing and lending. **The platform takes advantage of two distinct LayerZero offerings: OFT and Stargate**. In its v2 iteration, Radiant Capital transitioned its native token \$RDNT from a standard ERC-20 to an OFT, significantly improving its interoperability and enabling more complex yield strategies<sup>(15)</sup> for \$RDNT holders. Moreover, Radiant Capital incorporates the Stargate router to expand its borrowing capabilities, permitting users to deposit on one chain and borrow on another, thereby removing the necessity for bridging collateral.

4.3

## Axelar

Axelar, developed using the Cosmos SDK, is a Proof-of-Stake (“PoS”) network that acts as a **communication layer for dApps to interact across both the EVM and Cosmos ecosystems**. It enables the transfer of tokens, smart contract calls, and general messaging, all overseen by a network of validators. These validators operate nodes to monitor the state of the network, authenticate transactions, and manage cross-chain communication.

**Figure 15: Axelar's messaging process relies heavily on the important roles of Axelar Gateways and network validators**



Source: Axelar, Binance Research

### Axelar Messaging Process

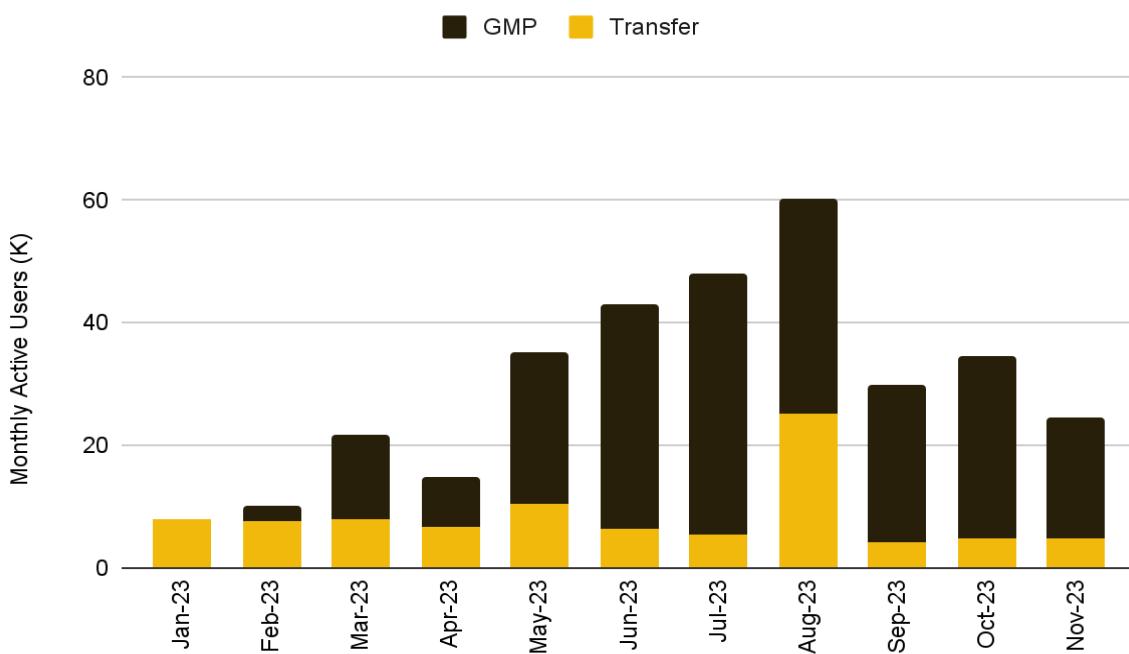
1. A dApp user initiates a cross-chain message via the Axelar Gateway on the source chain. This action triggers an event, which is then propagated by a relayer to Axelar's validators for processing.
2. Validators verify the event's authenticity by confirming that their nodes on the source chain have observed it.
3. Once validated, a requisite number of validators who hold a share of cryptographic keys must authorize the message.
4. Following authorization, the message is relayed to the destination chain, where it is ready for execution.

To enhance security, Axelar incorporates measures such as **quadratic voting** and **key rotation**<sup>(16)</sup>. Unlike traditional PoS systems, where weight delegation can centralize power due to stake concentration, **quadratic voting naturally disincentivizes the concentration of voting power**, fostering greater decentralization. **Validators also periodically rotate their key shares**, adding another layer of security against potential vulnerabilities. Additionally, Axelar Gateways employs **rate limiting to restrict the volume of assets that can be transferred within certain intervals**. Together, these measures work in concert to ensure the integrity and safety of the network's operation.

Since 2023, Axelar has experienced a surge in adoption, evident in the rise of both transaction numbers and active users. This increase is largely attributed to the implementation of its General Message Passing (“GMP”) feature, which enables **sophisticated cross-chain function calls and state synchronization**. Moreover, GMP began supporting interactions between Cosmos and EVM chains in May<sup>(17)</sup>, representing a major enhancement for Axelar.

Prior to GMP, **the interoperability between these ecosystems was largely confined to asset bridging**, offering limited composability. The **introduction of GMP introduced more complex interchain communication**, catalyzing Axelar's increased use. The impact of GMP is clear in the 2023 data: approximately 72% of transactions involve GMP messaging, and roughly 93% of active users are engaging with GMP<sup>(18)</sup>, **highlighting the integral contribution of GMP and its importance to Axelar's growth**.

**Figure 16: Axelar has experienced a significant increase in usage this year, largely driven by its GMP feature**



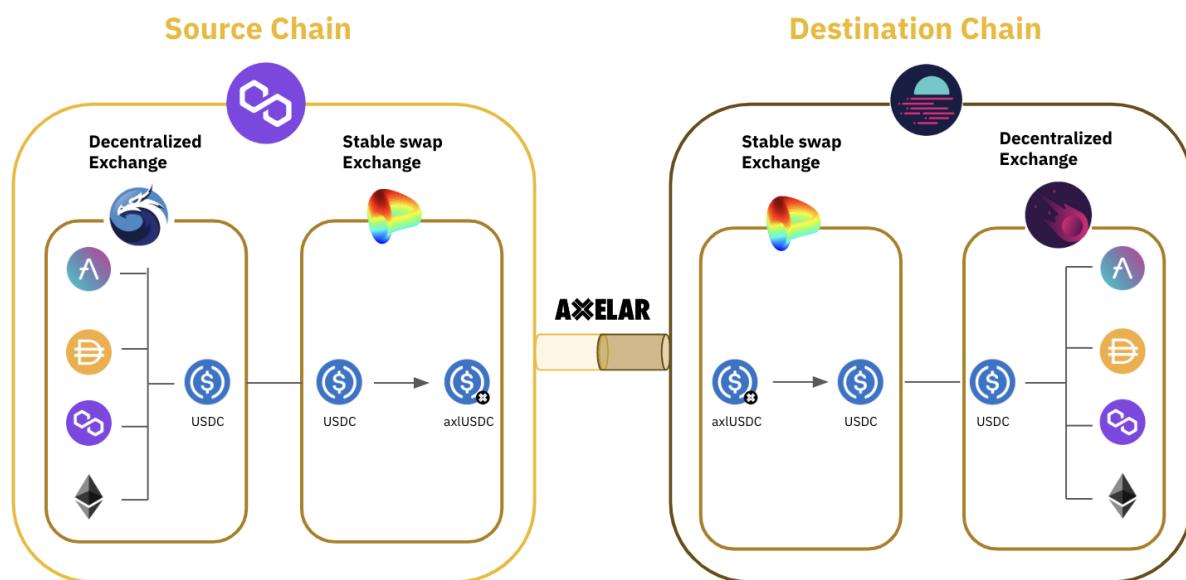
Source: [axelarscan.io](https://axelarscan.io), Binance Research, as of November 17, 2023

A notable example to demonstrate the utility of GMP is the [integration with Ondo Finance](#), a leading issuer of on-chain U.S. T-Bills. **Ondo Finance leverages GMP for Ondo bridge, fostering a unified on-chain USDY liquidity**. Axelar is also not short of enterprise partnerships, evident by its recent [collaboration with Microsoft](#), marking Axelar's entry into the Azure Marketplace. **This partnership makes tools like AxelarJS SDK and GMP available to developers, offering advanced hybrid blockchain solutions**. Given the extensive use of Azure worldwide, this partnership could significantly fuel Axelar's growth and expansion.

## Swaps: Squid

**Squid acts as a cross-chain liquidity router on the Axelar network**, interfacing with decentralized exchanges (“DEXes”) such as Uniswap and Curve to facilitate token swaps across its interconnected chains. It functions by deploying contracts on each chain in the Axelar network. When users conduct transactions via Squid on a source chain, the Axelar infrastructure manages the cross-chain communication with the target chain.

**Figure 17: Squid facilitates token swaps via axlUSDC / USDC pools across its network of interconnected chains**



Source: Squid, Binance Research

For end-users, **Squid improves UI/UX**, removing the need to manually sign the transactions for each chain they interact with, thereby **simplifying the cross-chain swap process**. Moreover, for developers seeking to integrate cross-chain functionalities, **Squid provides a Javascript SDK**. This toolkit enables easy and quick integration, **offering developers effortless access to cross-chain liquidity routing** without extensive backend development. Additionally, **Squid is integrated with major wallet providers such as Metamask, Trust Wallet, and Blockchain.com**, uniquely positioning Axelar as the sole messaging protocol to be adopted by these platforms.

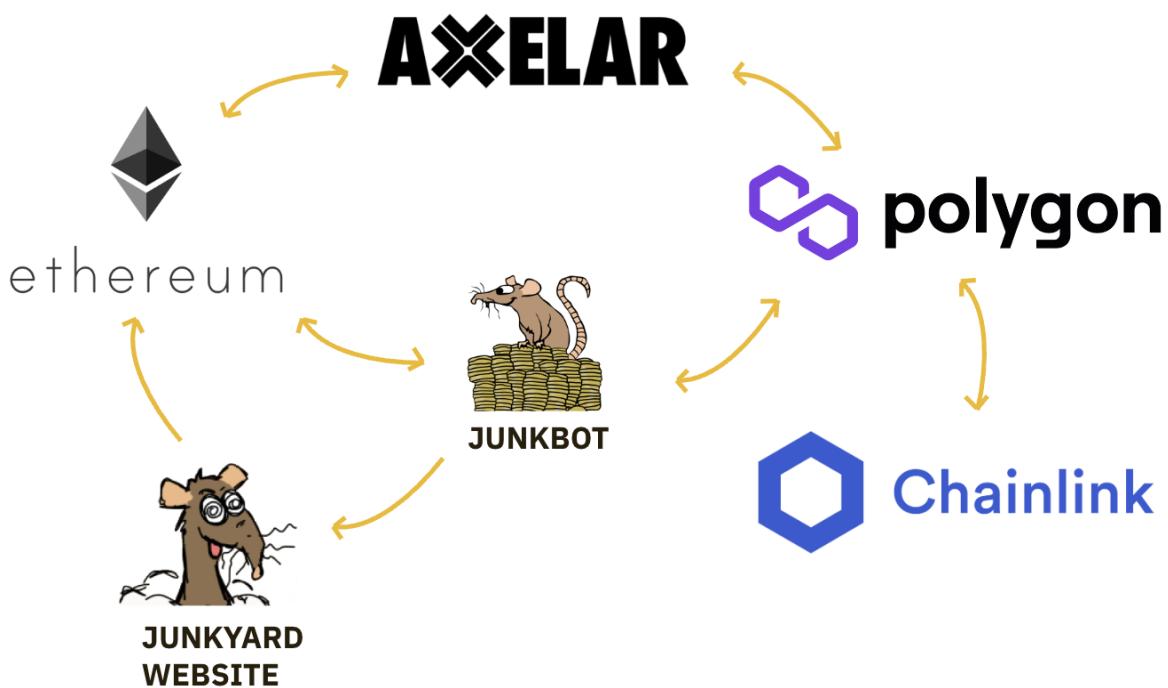
## NFTs: Junkyard

Junkyard, a cross-chain NFT lottery platform, leverages Axelar for its core functionality. It offers users the opportunity to offload their unwanted NFTs and, in exchange, receive credits to participate in ‘fishing’, a lottery-style game with chances to win valuable NFTs.

The operational framework of Junkyard has three key components: **the Junkyard contract on Ethereum to lock in NFTs**, a corresponding **Junkyard contract on Polygon to maintain the data of these locked NFTs**, and **Chainlink to facilitate random selection of NFTs for ‘fishing’ participants**<sup>(19)</sup>. When users discard an NFT, it is securely stored in the Ethereum contract, while its data is replicated to the Polygon contract via Axelar. During fishing, when a user opts to claim a selected NFT, Axelar facilitates communication between the Ethereum and Polygon contracts by synchronizing the network state; the Ethereum contract delivers the NFT while the Polygon contract updates the data records accordingly.

Axelar’s integration enables Junkyard to **benefit from Polygon’s low-cost environment**, providing a cost-effective operation. This setup ensures users enjoy a streamlined cross-chain experience, **free from the complexities of wrapped NFTs or navigating multiple networks**.

**Figure 18: Axelar serves as the communication hub between the Junkyard contracts on Ethereum and Polygon**



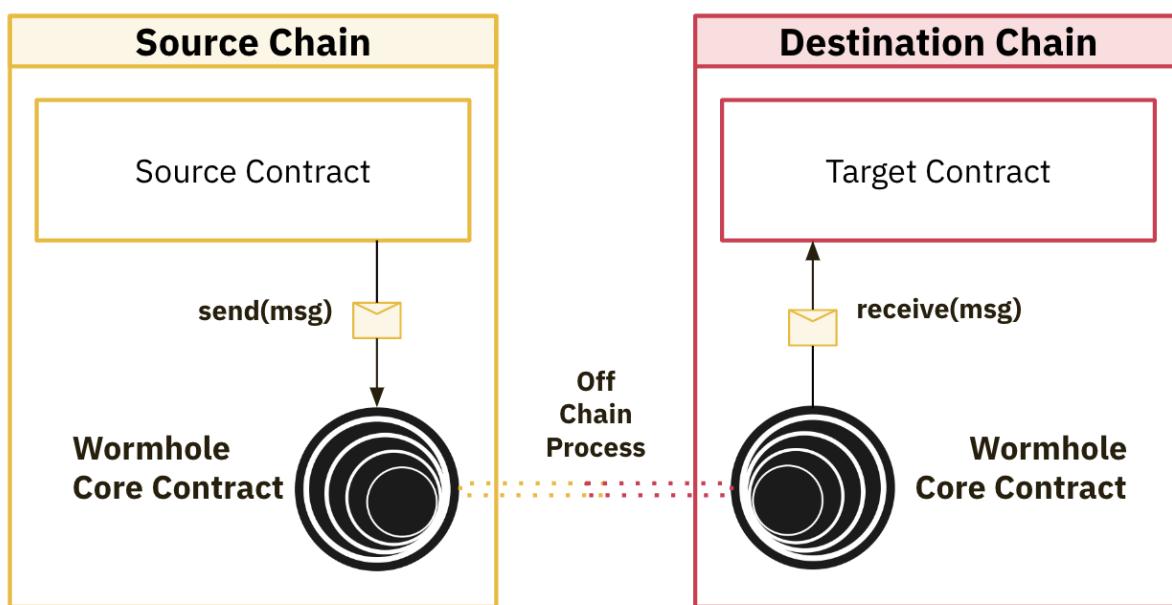
Source: Junkyard, Binance Research

4.4

## Wormhole

Wormhole is a generic message-passing protocol that facilitates interconnectivity for applications across multiple blockchain ecosystems. **It stands out due to its support for less connected chains such as Solana and non-EVM-compatible chains such as Sui**, positioning it as a uniquely capable protocol in the cross-chain messaging domain. The security of Wormhole is upheld by a network of 19 Guardians<sup>(20)</sup>, which are nodes that monitor chain activities and validate messages.

**Figure 19: High-level overview of the Wormhole cross-chain framework**



Source: Wormhole, Binance Research

### Wormhole Messaging Process

Each connected blockchain has a Wormhole core contract that serves as the main interface for cross-chain applications.

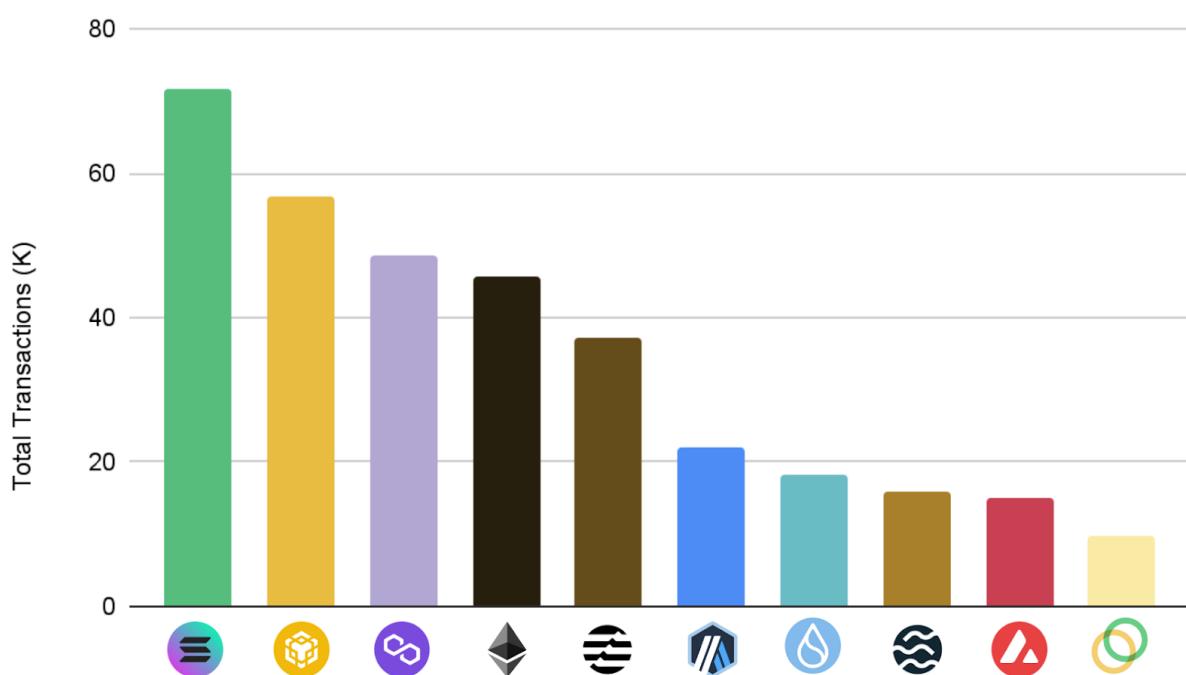
1. Messages sent through the Wormhole core contracts are forwarded to the Guardians, who independently verify and approve the messages' authenticity.
2. Once a supermajority (two-thirds) of Guardians have validated a message, it is encapsulated into a structure called Verified Action Approvals (“VAAs”).
3. A relayer will then transmit the VAAs to the target chain for execution.

**Guardian nodes are operated by reputable entities in the crypto industry<sup>(21)</sup>**, such as Jump Crypto, ensuring a high level of trust and operational integrity due to their public accountability. The likelihood of these well-established firms engaging in malicious activities is minimal, considering the significant reputational stakes involved. Wormhole

further enhances its security with its Governor feature, which allows Guardians to temporarily halt messages from registered token bridges if the transaction value is exceptionally large. This additional layer of security helps protect against potential misuse of the system.

Solana emerged as the top source chain in transaction count over the past year across networks supported by Wormhole. This dominance is likely because major cross-chain messaging protocols such as LayerZero and Axelar have yet to extend support to Solana, rendering Wormhole the primary option for users seeking interoperability with this chain. BNB Chain follows next, accounting for 15% of Wormhole's source chain transactions in the same time period. Interestingly, Sui also ranks in the top ten, making up 4.85% of the source chain transactions over the past 365 days<sup>(22)</sup>. This is likely because, similar to Solana, other competitors are yet to extend support to Sui, thereby positioning Wormhole as the favored option for users in the Sui ecosystem.

**Figure 20: Solana, with over 70.1K transactions, stands as Wormhole's most active source chain in terms of transaction count over the past 365 days, followed by BNB Chain**



Source: wormholescan.io, Binance Research, as of November 17, 2023

## Bridge: Portal

Portal functions as a cross-chain bridge, leveraging Wormhole's capabilities to enable asset transfers across multiple networks. As the third-largest cross-chain bridge by TVL, Portal oversees assets worth US\$593M<sup>(23)</sup>. It uses the conventional lock-and-mint bridging approach, wherein original tokens are locked in a smart contract on the source chain and equivalent wrapped tokens are minted on the destination chain. Users can then directly

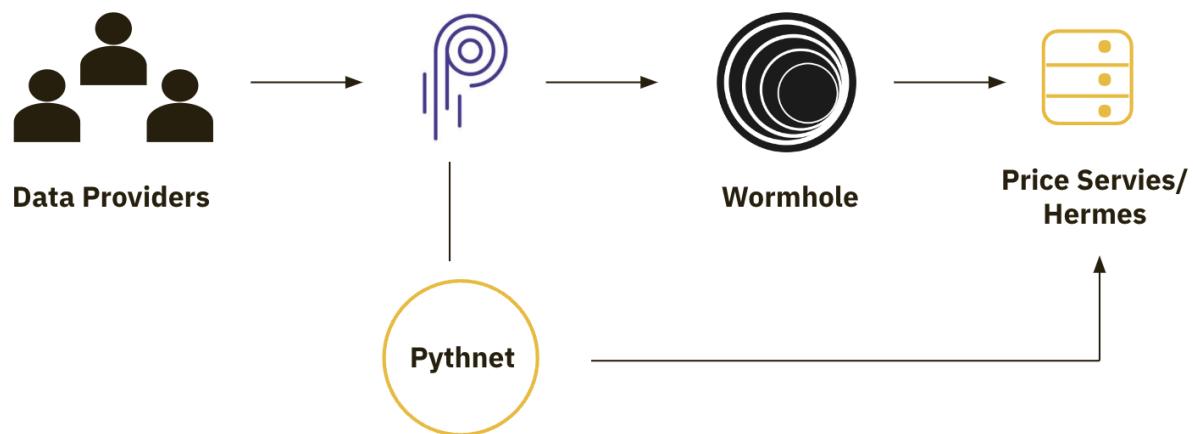
utilize these wrapped tokens in DeFi applications or opt to trade them in the liquidity markets of the destination chain.

## Data: Pyth Network

Pyth Network is an oracle service that utilizes Wormhole to broadcast financial market data across multiple blockchains, drawing from a variety of sources, including CEXes and market makers. This data is consolidated into reliable price feeds. Central to Pyth Network's operation is Pythnet, an application-specific chain that aggregates price feeds from these data providers.

Validators on Pythnet are responsible for relaying data to Hermes, a web service that monitors both Pythnet and Wormhole. Hermes acts as a repository for the latest price data, ensuring users have access to the most up-to-date information. This data passes through the Wormhole contract, undergoing a validation process by the Guardians. End-users looking to utilize Pyth Network's price data interact with Hermes to retrieve the most recent pricing information, which they can then incorporate into their applications and transactional activities.

**Figure 21: Wormhole transmits Pyth Network's price feeds across a multitude of blockchains**



Source: Wormhole, Binance Research

# Outlook

The landscape of blockchain interoperability is undergoing a significant transformation as **the older model of wrapped asset bridges is gradually being supplanted by more advanced cross-chain messaging mechanisms**. In this evolving space, the performance of bridge protocols is increasingly being measured not by their TVL but by metrics such as transaction counts, volume, and frequency of cross-chain messages sent.

As the multichain ecosystem expands, the need for seamless interoperability becomes increasingly imperative. Established bridge protocols have been quick to pivot, with initiatives like Multichain's Anycall, Celer's Interchain Message, and Synapse Chain laying the groundwork for cross-chain communication. However, **it's the newer protocols such as LayerZero and Chainlink's CCIP that have been gaining traction**.

## Market Comparison

The race is certainly on in the market for cross-chain messaging, with competition sharply rising. LayerZero, currently leading with the highest number of cross-chain messaging transactions, **distinguishes itself by integrating a wide range of tokens with its OFT standards and supporting popular cross-chain dApps** such as Stargate and Radiant Capital. While Wormhole may have fewer transactions compared to LayerZero, it still generates notable volume, primarily through the Pyth oracle. Its integration with Pythnet has been particularly successful, contributing significantly to message volume and emerging as a key component for the protocol's future growth. Wormhole is also aiming to **broaden its reach in the Cosmos ecosystem with the launch of Gateway**, its dedicated chain.

Axelar stands as a key player within the Cosmos ecosystem, functioning as the primary bridge for Osmosis and facilitating the spread of wrapped staked Ethereum (wstETH) into Neutron. Having just launched its **interchain token service with notable partners such as Sushi**, Axelar is positioning itself to gain broader influence. What's more, its **integration with major wallets like TrustWallet and MetaMask** reinforces its unique standing in the market. Chainlink's CCIP may be the latest entrant, yet the protocol has the **advantage of leveraging its robust oracle network to secure partnerships** with platforms like Aave for governance and Synthetix for sUSD usage. Its **integration with SWIFT could be a game-changer**, potentially enabling Chainlink to **outpace its competitors by bridging enterprise chains with real-world assets ("RWAs")**, carving out a niche for itself in this sector.

**Figure 22: Comparative snapshot highlighting key details and metrics of cross-chain messaging protocols**

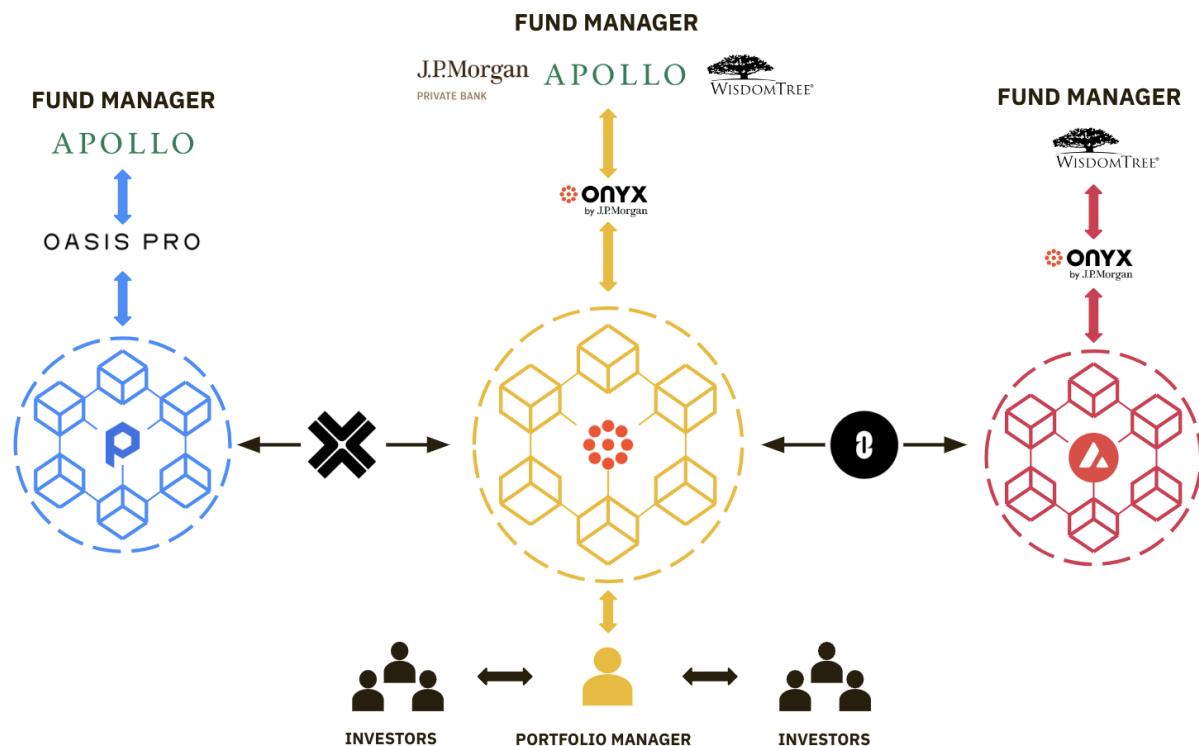
				
	Chainlink CCIP	LayerZero	Axelar	Wormhole
<b>Protocol Details</b>				
Launch	<a href="#">Jul 2023</a>	<a href="#">Mar 2022</a>	<a href="#">Jan 2022</a>	<a href="#">Aug 2021</a>
Supported Products	Oracle and Cross-chain Messaging	Cross-chain Messaging	Bridge and Cross-chain Messaging	Bridge and Cross-chain Messaging
Connected Chains	<a href="#">7</a>	<a href="#">46</a>	<a href="#">53</a>	<a href="#">29</a>
Most Active Chain (365D)	Ethereum	BNB Chain	Polygon	Solana
Example Projects	Aave, ANZ, SWIFT	Stargate, Radian Capital, Rage Trade	dYdX, Ondo Finance, MasterCard	Portal, Pyth, Aptoswap
Token	LINK	-	AXL	-
<b>Key Metrics</b>				
Valuation (US\$b)*	7.7	3.0	0.3	2.5
30D Transaction Volume (US\$bM)	-	975.8M	261.1M	431.7M
30D Transaction Count	10.2K	4.5M	80.9K	37.3K
30D Average Daily Users	-	81,672	1,310	-

\*For projects that don't have a token, the figures are derived from their most recent private market valuation.  
Source: Project Websites, Dune Analytics (@synthquest, @springzhang), axerlarscan.io, wormholescan.io, Binance Research, as of November 17, 2023

Beyond their respective implementations, factors like the **number of supported networks, degree of decentralization, security, scalability, and integration costs** are equally crucial in evaluating cross-chain messaging protocols. Their **ability to execute effectively in business development and secure partnerships** also plays a vital role. Given the varied designs of cross-chain messaging protocols, their performance is likely to differ based on such parameters.

A case in point is the recent [collaboration](#) between Onyx by J.P. Morgan and Apollo Asset Management. This partnership aims to explore the **feasibility of cross-chain portfolio management using on-chain tokenized funds and smart contracts**. For this initiative, Axelar and LayerZero were selected as the interoperability infrastructure providers, **indicating recognition from respected TradFi institutions**. This case study sends a strong signal, underscoring the important role cross-chain messaging protocols are set to play in future growth.

**Figure 23: Axelar and LayerZero provide the necessary infrastructure for asset managers to transfer funds and manage tokenized asset positions across multiple interconnected chains**



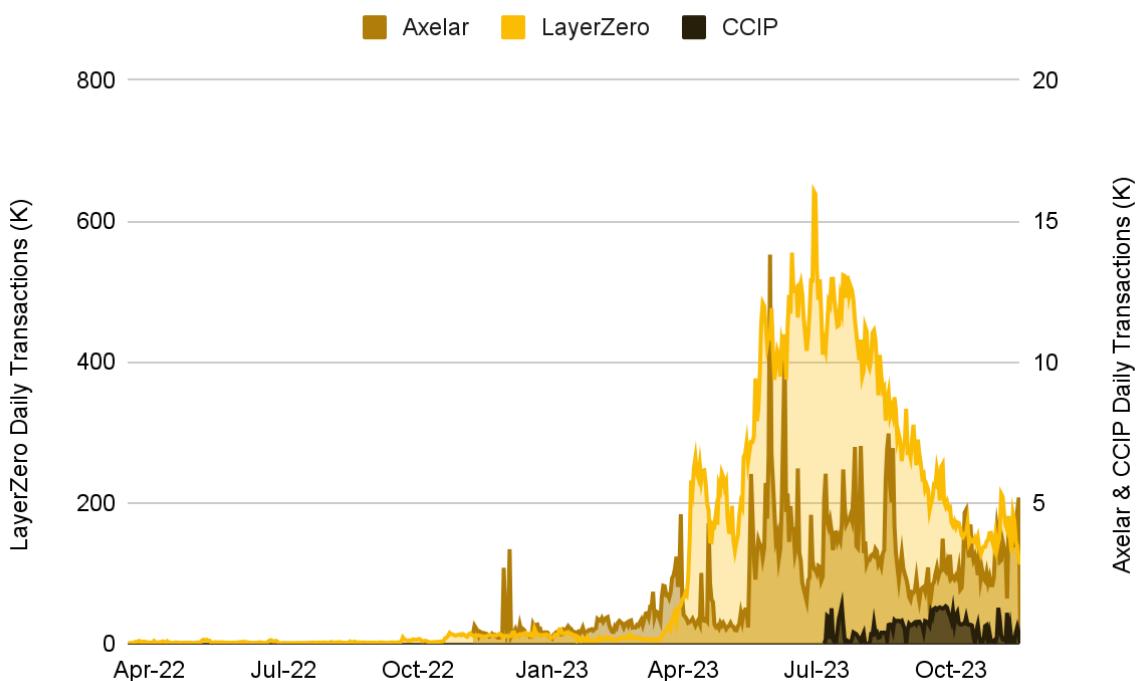
Source: Onyx by J.P. Morgan, Binance Research

While the project's documentation doesn't explicitly detail the reasoning behind protocol selection, it does indicate that the decision was influenced by some of the factors previously mentioned. Axelar and LayerZero support a more extensive network with 53 and 46 connections, respectively, compared to Wormhole's 29 and CCIP's 7. **LayerZero's scalability is also advantageous, as its endpoints avoid storing all the block headers and transaction proofs, making it an economically efficient choice.** Axelar's architecture offers flexibility, enabling **ease of integration while accommodating necessary configuration modifications** to align with the project's scope. The decentralization and security of both protocols are not too bad either. Axelar, for instance, boasts a high level of decentralization with 75 validators<sup>(24)</sup>, and its improved PoS system, which includes features like quadratic voting and key rotation, adds notable benefits.

However, it's important to note that the selection by Onyx and Apollo Asset Management doesn't necessarily reflect the absolute strengths and weaknesses of these protocols. Their choice could be influenced by undisclosed factors, and each protocol's suitability may differ based on the specific needs of the project. For example, **CCIP might be more fitting for projects already integrated with Chainlink's oracle solution, whereas Wormhole may be better suited for projects involving non-EVM-compatible networks**. While this case study offers insightful perspectives, it should not be viewed as an absolute evaluation or considered in isolation.

As for performance, 2023 has seen remarkable progress across these protocols. LayerZero and Axelar have both shown significant spikes in usage, while new entrants such as CCIP have quickly garnered notable adoption post-launch. Meanwhile, Wormhole is showing signs of recovery from its previous exploit, a trend visible in the revitalization of Portal's TVL. Looking ahead, it will be essential to closely track various factors to gauge the continued growth and evolution of these protocols.

**Figure 24: 2023 has seen a noticeable uptick in transaction activity across cross-chain messaging protocols**



Source: Dune Analytics (@axelarnetwork, @springzhang, @synthquest), Binance Research, as of November 17, 2023

**For LayerZero, monitoring its metrics post-airdrop will be crucial**, given that the speculation of an airdrop has played a role in its increased activity. The **recent partnership with Google Cloud is also a significant indicator of market confidence** in its offerings. The rising prominence of Injective and Kujira has brought the Cosmos ecosystem into the spotlight, suggesting Axelar might see broader adoption in the future. **Given that the GMP has been instrumental in Axelar's recent successes, keeping a close eye on its adoption rate will also be crucial**. Key metrics to watch are the **pace of partnership growth** and the

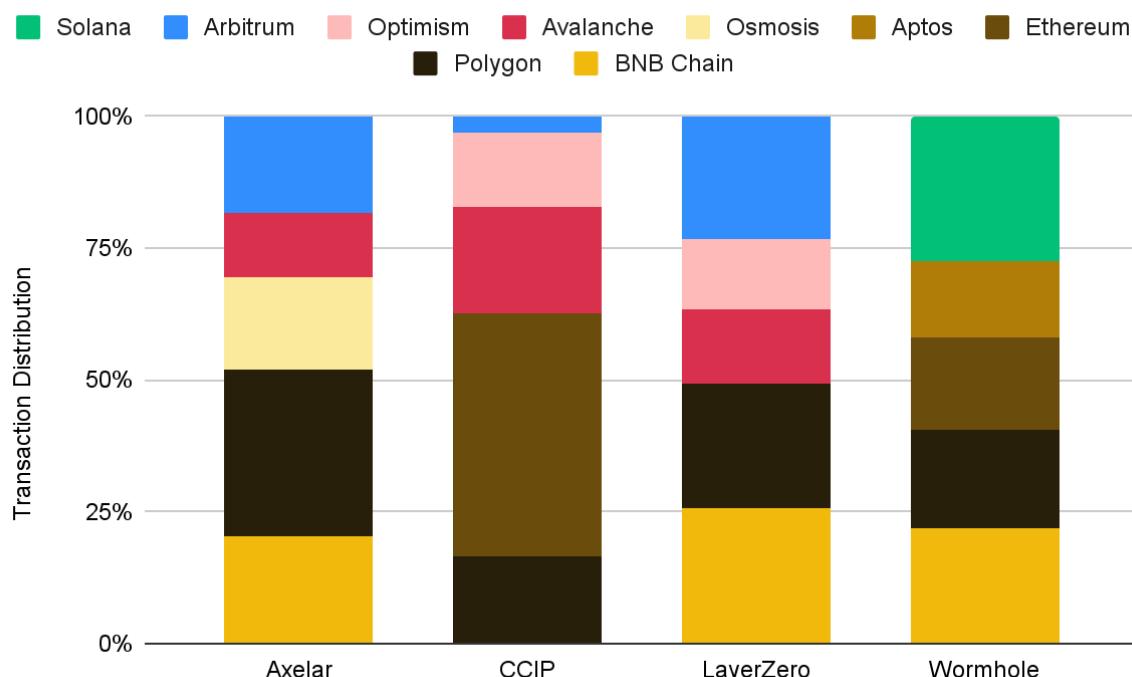
**integration of GMP by top-tier projects.** Additionally, **the renewed community confidence in Solana**, evidenced by the increase in on-chain activity and its ecosystem's TVL, **may bode well for Wormhole's continued growth.**

Despite being a relatively new contender, CCIP has demonstrated impressive potential for growth in both on- and off-chain sectors. **Its successful collaborations with SWIFT and other financial institutions in tokenized asset transfers suggest a path toward mass adoption**, particularly given the scope of tokenized assets and the capital in TradFi. The **widespread use of Chainlink's oracle is also expected to boost CCIP's network reach** and foster more protocol partnerships, highlighting its potential for further expansion.

Additionally, as the scale of cross-chain messaging grows further, **CCIP's unique triple-network structure positions it as a particularly appealing choice**, especially over those protocols dependent on a singular network system.

Analyzing the 365-day transaction distribution across the top five source chains for each protocol in Figure 25 below, it's evident that **prominent chains such as BNB Chain, Polygon, Avalanche, and Arbitrum are major contributors to cross-chain messaging transaction volumes**. While activities on these chains are expected to maintain their growth, the rising engagement and currently smaller transaction share of Cosmos, non-EVM, and newly emerging chains indicate their potential to drive the future expansion of cross-chain messaging protocols. Ultimately, the long-term success of these protocols depends on the chains they support and the activity of the underlying networks. **Protocols that uniquely support chains with potential for growth may gain strategic advantages**, particularly if they are able to capture a significant portion of the transactional value.

**Figure 25: BNB Chain, Polygon, Avalanche, and Arbitrum contribute significantly to transaction counts for cross-chain messaging protocols**



Source: Dune Analytics (@synthquest, @springzhang), axerlarscan.io, wormholescan.io, Binance Research, as of November 17, 2023

# Key Themes

## Theme 1: Increasing Recognition of Cross-Chain Messaging

The value of cross-chain messaging is increasingly being recognized. Several blockchain networks are already enhancing their domain-specific cross-chain interoperability; for example, **AWM for Avalanche and IBC for Cosmos**. Ethereum itself is in the process of confirming [EIP-5164](#) to **define standards for cross-chain EVM messaging**. This upgrade enables Ethereum protocols to coordinate state changes amongst various EVM-compatible blockchains. As technology progresses, the trajectory suggests that **cross-chain interoperability will likely shift from an optional luxury to a fundamental necessity** for users of both L1 and L2 networks.

## Theme 2: Potential Catalysts for the Growth of Cross-Chain Applications

Today, the application layer is multichain but not entirely cross-chain, with many projects still largely confined to operating within their respective ecosystems. The growth of cross-chain messaging serves as a catalyst for the emergence of truly interconnected cross-chain dApps. This may occur through the following value drivers:

- ◆ **UI/UX Improvements:** Previously, users relied on third-party bridges to transfer assets between chains. Now, with improved infrastructure, **cross-chain transactions can be directly incorporated at the application layer**. Developers are supported by an **expanding collection of SDKs and APIs** that offer **streamlined access to cross-chain networks**. This means that **dApps can now own the entire cross-chain interaction and retain the user within their UI/UX**.
- ◆ **Accelerating Network Effects:** Universal interoperability solutions have the **potential to create synergistic effects**, leveraging the fact that many notable projects are already dependent on them for other use cases.

For instance, as seen with Aave and Synthetix, projects may be more inclined to **adopt Chainlink's CCIP for cross-chain communication given their existing reliance on it for price feeds**. LayerZero enjoys a comparable advantage with SushiSwap's Stargate integration and Rage Trade's **selection of LayerZero for its cross-chain derivative trading functionalities**. Axelar extends this with its support for IBC, emerging as a key player in the Cosmos network by facilitating direct connections between Ethereum and Cosmos appchains. As the designated bridge for Osmosis and a leader in IBC traffic, **Axelar stands to gain significantly from wider Cosmos adoption**. Ultimately, these synergies enable cross-chain messaging protocols to **amplify their network effects and reinforce their role in driving cross-chain applications**.

- ◆ **More Chains, More Growth: The value of interoperability protocols is set to grow with the number of connected chains.** Generally, the more networks they link and

the more users that depend on them for cross-chain messaging, the more valuable these solutions become.

The continuous emergence of L1 and L2 blockchains acts as a **natural propellant for the expansion of interoperability networks**. Previously, the blockchain sector experienced a surge in L1 networks, but the current trend has shifted toward L2 networks becoming increasingly prominent. In particular, 2023 marked a significant uptick in the growth of L2s, as evidenced by the substantial user adoption of platforms such as OP Mainnet and Arbitrum and the debut of several ZK-based L2s.

The growing influx of businesses venturing into their own L2s, combined with upcoming developments like Ethereum's Dencun upgrade, is poised to further catalyze this growth. Therefore, as the landscape becomes more fragmented, the **demand for connecting these chains will increasingly be sought after** by both users and developers.

### **Theme 3: Tokenization and TradFi Adoption**

Cross-chain messaging is becoming increasingly important for TradFi institutions, as demonstrated by the recent collaboration between Onyx by J.P. Morgan and Apollo Asset Management. This partnership not only showcases the versatility of cross-chain messaging but also its potential to **unlock diverse applications for TradFi**.

**There is significant merit in facilitating inter-chain dialogue among networks with distinct native tokens, protocols, and characteristics.** This becomes even more pertinent as heavyweight TradFi institutions like Citigroup, Goldman Sachs, J.P. Morgan, and others **actively tokenize RWAs** on multiple blockchain networks. A shortfall in interoperability can create substantial obstacles to these efforts. Hence, cross-chain messaging emerges as a key component in boosting TradFi adoption.

### **Theme 4: Multichain Fragmentation Solutions and Security**

Solving multichain fragmentation should not come at the cost of security. Cross-chain protocols are a contentious debate in the industry due to their history of exploits; some argue that a multichain world of separate blockchains is safer than one with interconnected networks. Even Vitalik Buterin, Ethereum's co-founder, has suggested that different blockchain communities might be better off operating independently. This is because **the safety of cross-chain operations is inversely related to their scale; minimal activity carries lower risk, but this risk escalates with increased cross-chain interactions**.

However, linking distinct networks may well be critical for the mainstream adoption and value capture of blockchains. Sustained investments in **third-party audits**, a concerted push for **greater decentralization**, and **maintaining robust liquidity** are some key measures that will help mitigate the risks associated with cross-chain transactions. Hence, **striking the correct equilibrium between cross-chain interoperability and robust security** is essential.

## **Theme 5: Ensuring Adequate Tools for Developer Adoption**

Cross-chain development can be complex due to the different programming environments and languages specific to each blockchain. Solidity, for instance, is the primary language for Ethereum applications, while Rust is preferred on Solana. Given that this sector is still developing, **prioritizing education, streamlining onboarding, and developing intuitive tools with easy-to-use interfaces** will be critical. The key to advancing developer adoption of interoperability protocols resides in abstracting these complexities.

# Closing Thoughts

As we continue to move toward a multichain ecosystem, **the importance of effective cross-chain messaging becomes clear**. Cross-chain interoperability solutions are progressively developing and actively seeking the right product-market alignment. **With varied security and governance across networks, a robust approach to cross-chain communication is essential, be it through direct frameworks or intermediary systems.**

Protocols such as Chainlink CCIP, LayerZero, Axelar, and Wormhole are rising to meet this demand, offering practical solutions to the challenges of trust in cross-chain communications. Beyond their operational metrics, some of the key factors differentiating them include **the number of supported networks, decentralization, security, scalability, integration costs, and ecosystem partnerships**. Ultimately, these cross-chain messaging solutions are not just important for the present but **lay the groundwork for the future of composable application development**, with several key themes emerging to catalyze their growth further.

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## Moulik Nagesh

### Macro Researcher

Moulik is a Macro Researcher at Binance, having been involved in the cryptocurrency space since 2017. Prior to joining Binance, he had experience spanning cross-functional roles in Web3 and Silicon Valley-based tech companies. With a background in co-founding start-ups and a BSc in Economics from the London School of Economics & Political Science (“LSE”), Moulik brings a comprehensive perspective to the industry.



## Brian Chen

### Macro Research Intern

Brian is currently working for Binance as a Macro Research intern. Prior to joining Binance, he worked as a DeFi researcher at a financial service startup and a Web3 education organization. He holds a Master of Finance degree from the University of California, Irvine (“UCI”), and has been involved in the cryptocurrency space since 2021.

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