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In Search of Interoperability:

An Overview of the Cross-Chain Market

October 2021

Research and Insights

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Executive Summary

- **As cryptocurrencies gain increasing adoption, the demand for cross-chain transactions has grown tremendously. The total value locked (TVL) in the major Ethereum bridge protocols has increased 1.2 times from USD 137B to $302B in May to October 2021.**
    - New smart contract blockchains such as Avalanche, Terra, and Binance Smart Chain (BSC) are gradually thwarting Ethereum's monopoly (Ethereum's market share reduced from 98% in January to 66% in October 2021).
    - BSC showed the highest TVL with $13.7 billion, followed by Polygon, Avalanche, Fantom Anyswap, and Arbitrum at the end of October 2021.
- **Cross-chain solutions are grouped into two different taxonomies:**
    - By their purpose: asset-specific, chain-specific, application-specific, and generalised "Internet of Blockchains" bridges; and by its method of validation: externally verified, natively verified, and locally verified.
    - Based on TVL data for bridges connected to the Ethereum network, chain-specific bridges have historically bridged the lion's share (90-95%) of cryptocurrencies since April 2021. Application-specific bridges have started to gain popularity among users, bridging 27% of TVL in Ethereum in October 2021, skyrocketing four times from September.
- **More comprehensive blockchain solutions (Cosmos, Polkadot, and Avalanche) have emerged to solve the lack of interoperability at a lower infrastructure level and introduce scalability where simple bridges cannot.** Their popularities are also reflected in the changes of their market values:
    - The market capitalisation of their native coins (Cosmos's ATOM, Polkadot's DOT and Avalanche's AVAX) rose by 130%, 31% and 270%, respectively, from May to October 2021.

1. Introduction

As cryptocurrencies gain increasing adoption, the demand for cross-chain transactions has grown tremendously, with buzzwords like "the multichain world" becoming the talk of the town. Although blockchains are still considered novel technology, thousands of public and private blockchains already exist today. Many today, however, are siloed with different technological infrastructures, rules and governance models. A direct transfer of Bitcoin into the Ethereum blockchain to take advantage of its DeFi applications or Ether into a new up and coming blockchain such as Terra or Avalanche is impossible due to incompatible technologies and token standards. The lack of interoperability is an evolving, growing problem. Yet, interoperability is the key to a decentralised blockchain network and a fundamental function in the road towards Web 3.0.

In the context of cross-chain communication, this report uses the terms "interoperability" and "bridge" interchangeably to mean the same thing. Blockchain interoperability is the ability to share information across various blockchain networks. The information can be tokens, smart contracts, and other data stored in blockchain systems. Similarly, a blockchain bridge is a connection that allows the transfer of tokens and arbitrary data from one chain to another.

1.1 Why Does Interoperability Matter?

Interoperability unlocks innovation. As individual ecosystems grow, they develop their own strengths, such as greater security, faster network speed, lower transaction costs, improved privacy, and unique communities. Bridges are important because they enable users to access new platforms, protocols to interoperate, and developers to jointly build new products.

Firstly, interoperability improves productivity and capital efficiency for existing crypto assets. Bridges enable crypto to be transferred to different blockchain networks instead of being isolated in their native ecosystems. For example, the Avalanche-Ethereum bridge allows users to send ETH to the Avalanche blockchain ecosystem to stake or perform yield farming.

Secondly, interoperability opens the doors for developers to a larger target audience. This gives developers an incentive to increase their product

capabilities, develop new features and use-cases and extend their protocol design to other blockchains.

Finally, interoperability spurs innovation toward decentralised technology. Many users in crypto still depend on centralised entities to transfer or convert their assets between ecosystems. While this is inevitable due to the nascency of crypto and blockchain technology, it nonetheless presents a heightened point of failure that is vulnerable to bad actors and regulatory risk.

2. Classification of Bridges

The multichain world is still far from reality. However, the potential of Web 3.0 has already driven practitioners to innovate a variety of working bridge solutions to enable interoperability. Many of these solutions have gained significant traction during the NFT boom this year to enable these unique digital assets to move between blockchains.

For an overview of existing bridging solutions, we group cross-chain solutions into two different taxonomies: By purpose and by the design of the mechanism of validating the cross-chain transactions.

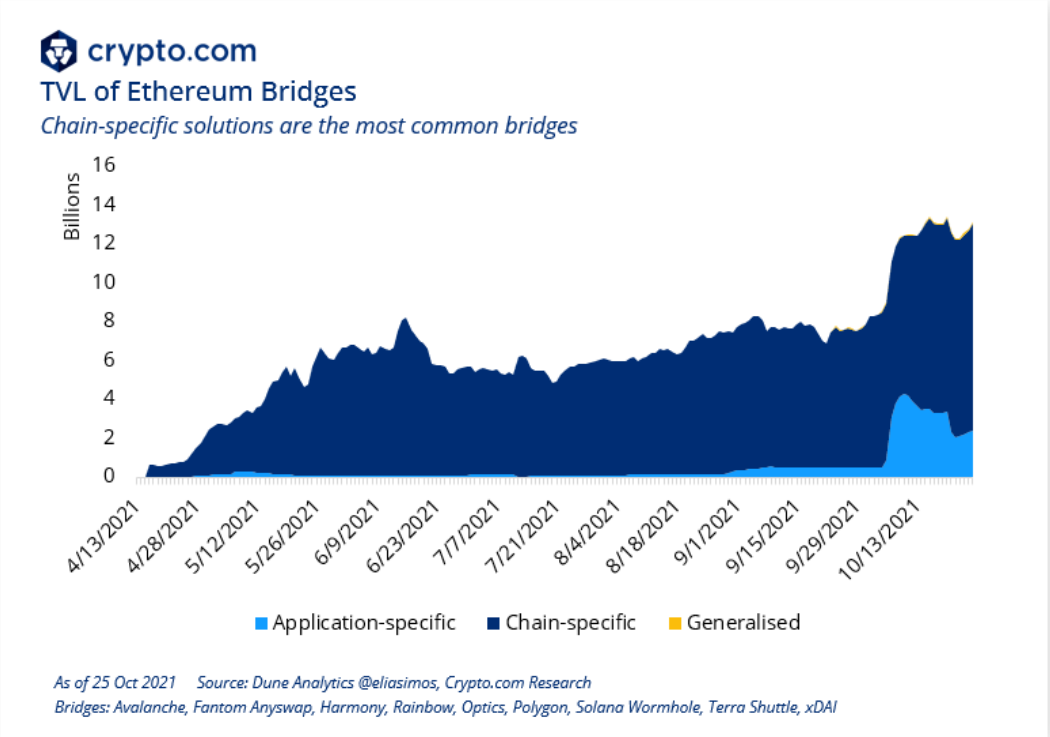
2.1 Classification by Purpose

We can categorise bridges by their targets: asset-specific, chain-specific, application-specific, and generalised bridges. The following table displays the taxonomy of bridges of this classification method and examples:

Asset-Specific	Chain-Specific	Application-Specific	Generalised
Interlay	Avalanche Bridge	AnySwap	Chainlink
WBTC	Binance Bridge	cBridge	Cosmos IBC
tBTC	Harmony Bridge	Celer Network	Polkadot
WRAPPED	Polygon Bridge	Thorchain	
	Rainbow Bridge	Wanchain	
	Terra Shuttle		
	Solana Wormhole		

As of October 2021 Sources: 1kxnetwork, Connext

Based on the data of the major bridge solutions, chain-specific bridges dominated the market before September 2021. However, representatives of application-specific bridges were under the spotlight recently as its TVL skyrocketed 4 times in October.

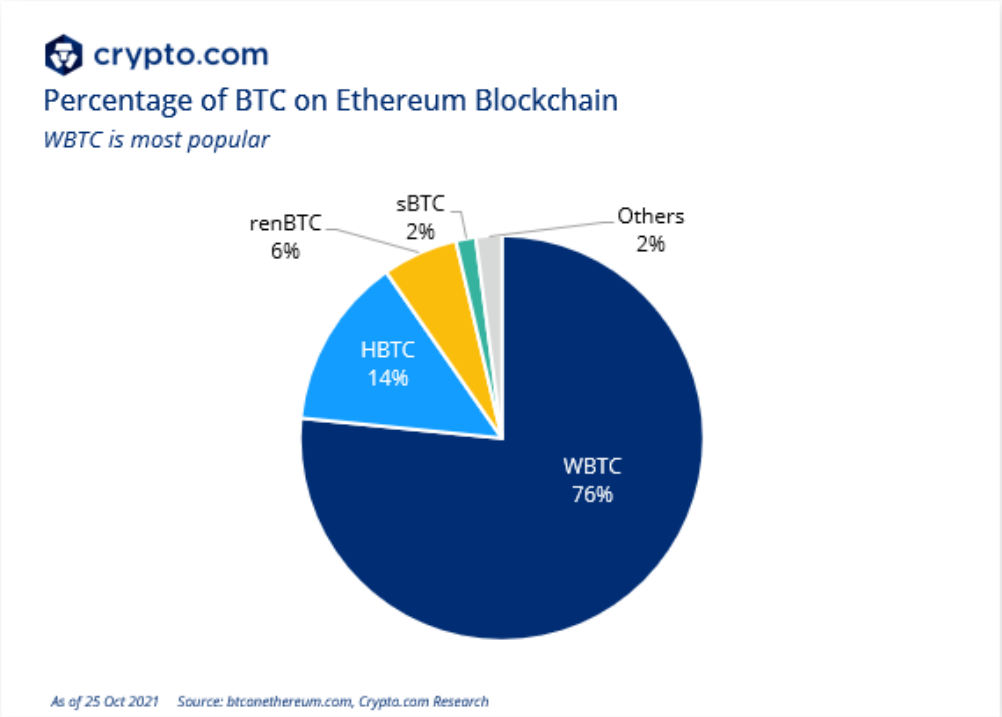


Asset-Specific Bridges

Asset-specific bridges are built to transfer specific cryptocurrencies.

The most popularly known example is the Wrapped Bitcoin (WBTC) operated by BitGo. WBTC is an ERC-20 token that matches equally the value of Bitcoin by 1:1 backing of Bitcoin. WBTC allows users to unlock the equity potential of their previously dormant capital in the Bitcoin network to participate in DeFi. Minting WBTC in the wrapped framework is initiated by a merchant and performed by a custodian without involving users.

According to data from BTC on Ethereum, among other bridged BTC assets, WBTC is the most popular. As of October 2021, there are a total of 283,839 mimic Bitcoins existing on the Ethereum network as ERC-20 tokens. 76% of these tokens are in the form of WBTC, while the other 24% are composed of HBTC, renBTC, and others.



A common criticism of wrapped assets is that they are fundamentally managed by a centralised entity that oversees the gateway and rules by which assets are locked and minted like WBTC and HBTC. Although alternatives like renBTC use decentralised ways to create mapping assets on different platforms, the technology is still too limited in scalability to achieve mass cross-chain communication.

Chain-Specific Bridges

A bridge between two blockchains usually supports simple operations around locking and unlocking tokens on the source chain and minting new assets on the destination chain. One good example is Polygon, a protocol and a framework for building and connecting Ethereum compatible blockchain networks. Although such a bridge can be scalable and faster in transaction speed, the limited blockchains access is the main bottleneck.

Application-Specific Bridges

As its name suggests, these bridges focus on specific applications. For example, THORChain is a blockchain that aggregates liquidity across multiple chains through its multichain THORSwap DEX. Like most application-specific bridges, it only supports a limited transfer of 20+ coins across five different blockchains.

Generalised Bridges

Protocols in this category design a large-scale completed solution to facilitate general data transfer across multiple blockchains. The data can be tokens, smart contracts, network states, and so on. The representatives are Cosmos IBC and Polkadot, which we elaborate on in Section 3 of this report.

2.2 Classification by Validation Mechanism

An alternative way of looking at bridges is to group them by the parties who will verify the cross-chain transactions. Broadly speaking, there are three ways that transactions can be verified: externally verified, natively verified (light clients), and locally verified.

The following table displays the taxonomy of bridges of this classification method and examples:

Mechanism	Externally Verified	Natively Verified	Locally Verified
Examples	AnySwap Terra Shuttle Wanchain Ren Synapse PolyNetwork	Cosmos IBC Near Rainbowbridge Optics	Celer Connext Hop Liquality
Advantages	(1) Greater connectivity (2) Easier implementation	More trustless form of bridging	High extensibility, security, and trustless
Drawbacks	(1) Trust model is less secure as it relies on external validators (2) Capital-inefficient	(1) Developers must build light clients and smart contracts (2) Resource-intensive, higher gas fees	Limited in ability to transfer assets

As of October 2021 Sources: 1kxnetwork, Connext

Externally Verified

Relying on external validators to secure the bridge is the most common form of protocol design for bridges. As its name suggests, asset transfer between chains is verified by a set of external, third-party validators. These validators monitor events on the source chain and perform an action on the destination chain. An asset transfer is typically done by locking up the asset on the source chain and minting the equivalent amount of that asset on the destination chain. The external validators work like a federation and it requires users to meet certain criteria or demands set by the federation, such as staking a number of tokens, to be part of the bridge.

The advantage of relying on external validators is that it allows for greater connectivity to most domains in the blockchain, and it is easier to implement. The drawback is that users have to trust the external verifiers with their funds/data, making it fundamentally less secure.

Natively Verified

This second method validates cross-chain transactions natively by relying on the underlying blockchain's own validators. This is done by running a light client of one chain in the virtual machine (VM) of another chain.

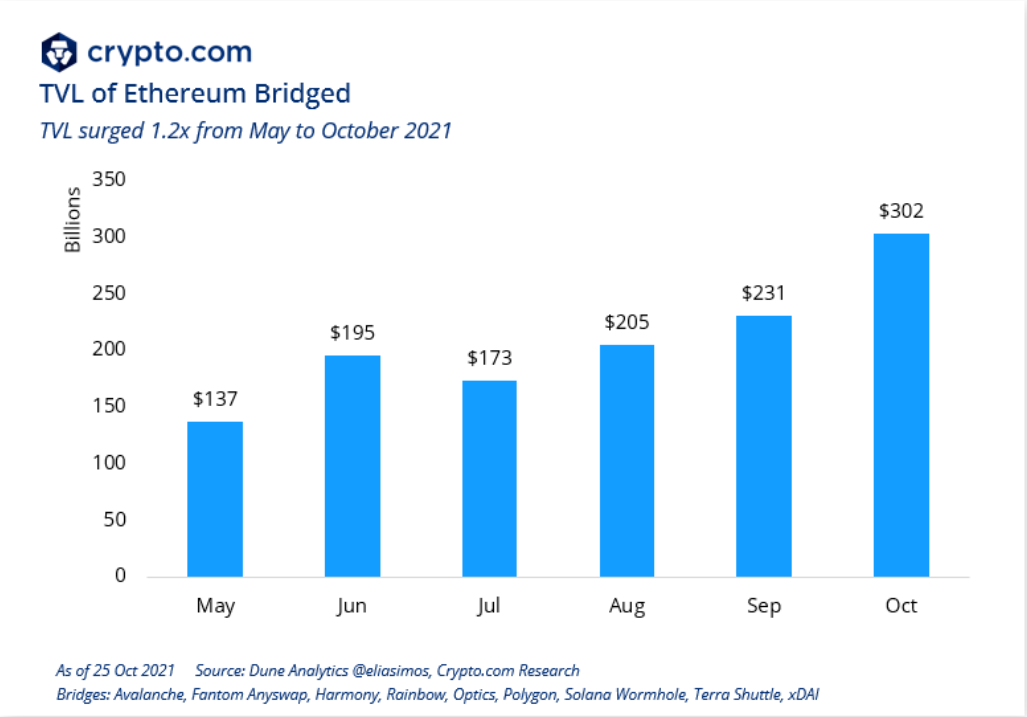
The advantage of this method is superior capital efficiency. It also reduces the complications of the trust model. It achieves interoperability in a more trustless manner since users do not have to trust a relayer in the bridge. However, developers have to build light clients for each customised blockchain. The validation is also more resource-intensive in the form of gas fees.

Locally Verified

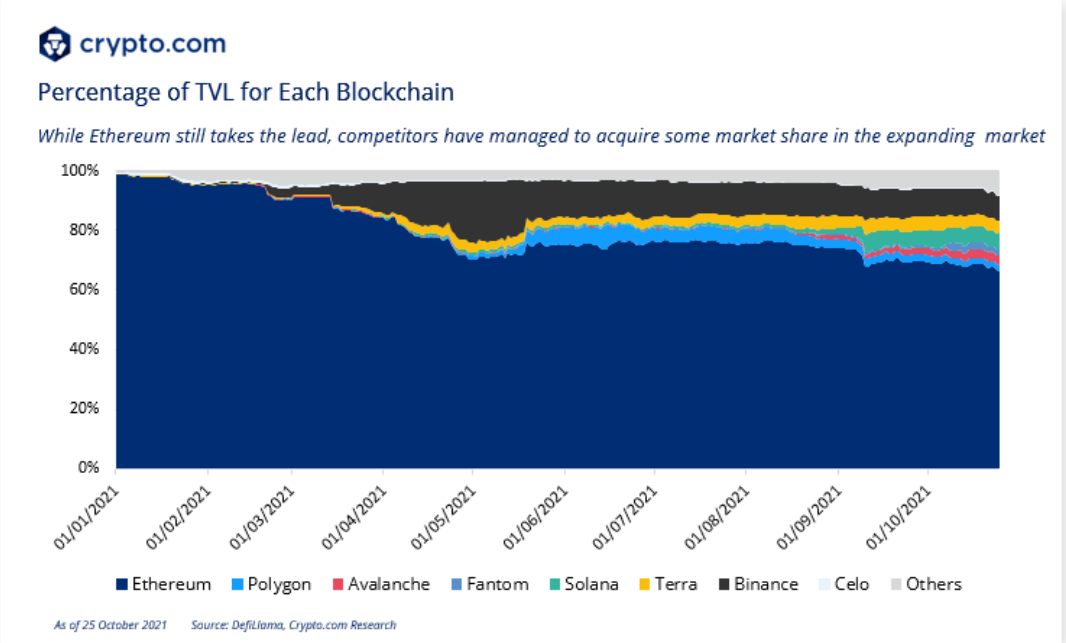
Locally verified protocols are ones where only the parties involved in a given cross-chain interaction verify the interaction. Locally verified protocols turn the complex n-party verification problem into a much simpler set of 2-party interactions where each party verifies only their counterparty. This model works so long as both parties are economically adversarial — i.e. there are no means for both parties to collude to take funds from the broader chain.

2.3 Market Share

Over time, the TVL of major Ethereum bridge protocols has increased 1.2 times from May to October 2021. The majority of bridge solutions that are already working to mitigate crypto's interoperability problem lead to Ethereum because of its significant DeFi presence.

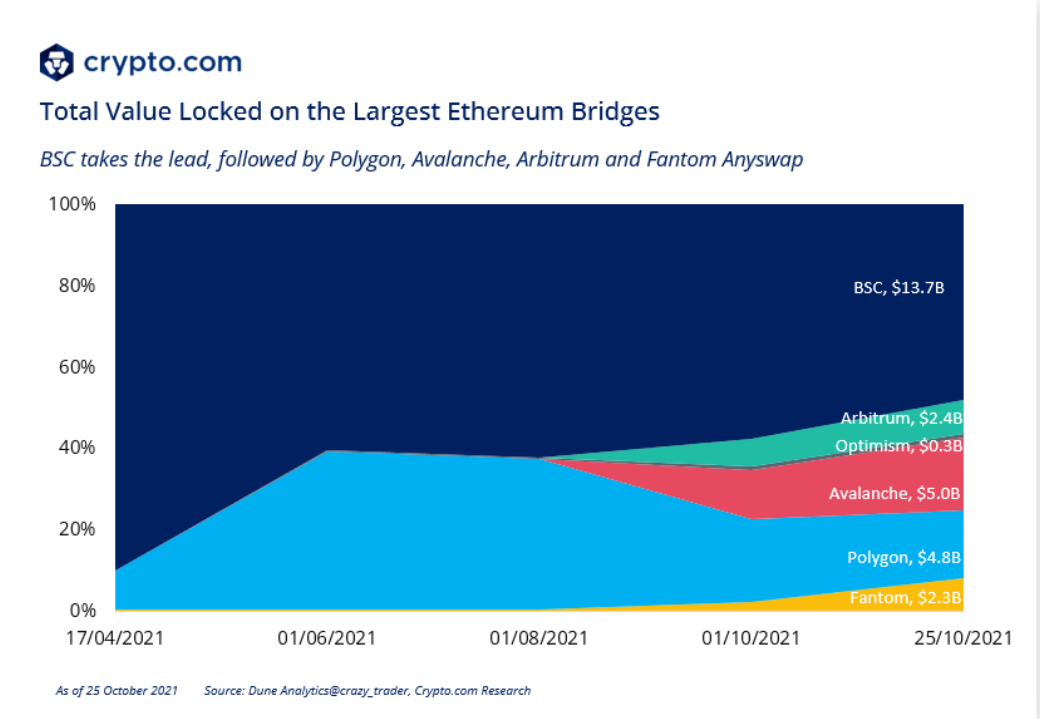


At the same time, Ethereum's market share has been slowly reduced over time as new smart contract blockchains such as BSC, Solana, and Terra enter the fray. Data shows that while Ethereum maintained a near-monopoly of the DeFi market in late 2020, it now only holds closer to two-thirds of the market in late 2021 (Ethereum dominance reduced from 98% in January to 66% in late October 2021 according to DeFi Llama).



This could be due to two factors. First, we are nearing the multichain future as bridge and cross-chain solutions facilitate quicker transfers across blockchains where they previously were siloed. Second, the absolute share of the DeFi market is growing as crypto receives increasing attention from mainstream investors. In terms of TVL, the DeFi market has grown from $10.5 billion in October 2020 to an astounding $93 billion in October 2021.

Based on data from Dune Analytics, a further breakdown of TVL data on all Ethereum bridges over time shows a clear lead by BSC bridge, followed by Polygon.



While most of the aforementioned bridges offer token transferring between blockchains, their interoperability capabilities are limited in terms of scalability. In the next section, we look at three larger-scale cross-chain solutions – Cosmos, Polkadot, Avalanche – that solves the interoperability problem at a more infrastructural level.

3. Interoperability-Focused Internet of Blockchains

More comprehensive blockchain solutions have emerged to solve the lack of interoperability at a lower infrastructure level and introduce scalability where simple bridges cannot. This report focuses on three major projects working to facilitate interoperability cross-chain communication: Cosmos, Polkadot, and Avalanche. The following table summarises their features:

Feature	Avalanche	Cosmos	Polkadot
Genesis Block Date	21 Sep 2020	13 Mar 2019	27 May 2020
Consensus	Proof-of-Stake	Proof-of-Stake	Nominated Proof-of-Stake
Validation Mechanism	Externally Verified	Natively Verified	Natively Verified
Number of Projects	~343	~255	~499
Token MC	AVAX $13.6 billion	ATOM $12.0 billion	DOT $41.4 billion
Transactions per Second	4,500 - 10,000 per Subnet	1,000 TPS per Hub/Spoke	1,500 per Parachain
Time-to-Finality	<2 seconds	6 seconds	60 seconds

As of 27 October 2021 Sources: 1kx, Connext, Avalanche, Cosmos Hub, Seq, Polkadot Wiki

3.1 Cosmos

Cosmos' key protocol that bridges together its ecosystem is the Inter-blockchain Communication (IBC) that is built with a Hub & Spoke design architecture. Perhaps the most prominent project name that comes up in any discussion of interoperability in crypto right now is Cosmos, whose mainnet went live in 2019 after an ICO that raised $17 million. **Marketing itself as the "Internet of Blockchains", Cosmos is a decentralised network of independent blockchains that aims to bridge blockchains in a trustless and permissionless manner that does not require the trusting of an intermediary like Wrapped assets or chain-specific bridges.** To date, there are at least 255 projects that have been built on Cosmos.

Heterogeneous blockchains in Cosmos – known as Zones – can transfer tokens or data between each other through hubs on IBC without having to connect directly to every other Zone directly. Cosmos Hub is the first hub (and one of many) to be set up on Cosmos, a Proof-of-Stake blockchain with its own token ATOM. Node validators can participate in governance through the Cosmos Hub by earning voting rights through staking ATOM for block rewards. Cosmos Hub will start with 125 validators and is scheduled to increase to a maximum of 300 validators over time.

3.2 Polkadot

Compared to Cosmos, Polkadot's institutional setup is slightly more centralised. This is due to its mandated "shared-security" federation model that revolves around a common set of shared validators on its central "Relay Chain". Polkadot was founded by computer scientist Gavin James Wood, most famously a co-founder of Ethereum. It launched a successful ICO in 2017. **Although commonly mistaken for a Layer-1 blockchain, Polkadot is closer to a "Layer-0" meta-protocol that serves to connect Layer-1 blockchains.** As of October 2021, Polkadot has a grand total of 499 projects built on its infrastructure.

Developers on Polkadot can launch their own side-blockchains (known as "parachains") at a much faster speed that connects to the Relay Chain. Its first parachain auctions, which grants developers rights to develop a chain integrated to its main Relay Chain, are set to begin on 11 November 2021, marking the project's very first steps towards multichain interoperability.

The Relay Chain is capable of supporting up to 1000 validators, with fewer on the parachains. Unlike traditional blockchains, developers can upgrade their blockchains through automated node upgrades without going through the traditional process of seeking consensus and forking. Failure to upgrade notes is met with the penalty of being kicked off the network.

Polkadot's backward compatibility – sometimes referred to as a "consensus enforcer" – makes blockchain upgrades by orders of magnitude faster, offering developers an unprecedented element of flexibility to add their own features and have more control over their roadmaps in a way that was more constrained on networks like Bitcoin or Ethereum.

3.3 Avalanche

Avalanche is a "platform of platforms" network where thousands of heterogeneous, interconnected individual blockchains (known as subnets) can be built on top of it. Avalanche is the newest of our three featured blockchains, having launched slightly more than a year ago in September 2020 after its ICO in July 2020. Avalanche's growth has been exponential thanks to a significant $180 million grant by the Avalanche Foundation in liquidity mining incentives. As of October 2021, Avalanche stands as the fifth-largest blockchain in terms of TVL at $7.81 billion according to DefiLlama, and hosts a total of 343 projects.

Anyone can create their own customised applications on a subnet with the power to issue and design their own tokenomics or customise their own validation requirements, consensus mechanisms and entry barriers. Avalanche's unique proposition is its novel "Avalanche Consensus" protocol that uses repeated random sub-sampled voting. This consensus mechanism works by querying a few validators for approval and only further queries more validators when approval is conflicted. This way, Avalanche achieves consensus with minimal overhead per node. Avalanche is capable of scaling up to 10,000 validators per subnet.

Avalanche can also connect to other systems through bridges, through custom virtual machines made to interact with another ecosystem such as Ethereum and Bitcoin. An example is the centralised custodial Avalanche-Ethereum Bridge. The bridge works similarly to wrapped assets, which locks up original assets on Ethereum before minting a synthetic version of the said asset on the Avalanche.

4. Conclusion

The currently fragmented world of crypto is gradually reducing the roadblocks between blockchains and becoming a unified, interoperable ecosystem. An increasing number of cross-chain solutions are pushing the infrastructure frontier and driving this change. This report has provided a high-level overview of existing cross-chain solutions based on the purpose and protocol design, with examples of such projects.

As we move toward a multichain future, there should be a few noticeable signs. Firstly, if Ethereum's DeFi market share is diminishing, that would indicate that DeFi as a whole is becoming more interoperable. This is due to an increased number of newer smart-contract blockchains with high TVL entering the fray and attracting DeFi capital with more attractive yields.

Secondly, all eyes are on big 'Internet of Blockchains' projects such as Cosmos, Polkadot and Avalanche. By observing the TVL and the number of projects launched on these platforms, we can have a good understanding of the progress of cross-chain activities.

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