Comparative Study of Data Availability Schemes in Various Blockchains

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***Abstract*—We make a Comparative benchmarking study of currently polkadot's ELVES data availability protocol with emerging data availability solutions which includes Avail, Celestia, Espresso's-Tiramisu and NEAR's sharded DA.**

We made a comparison in terms of bandwidth, time, latency, block time, block size, robustness degree and cost per megabyte of data availability.

I. Introduction

The Blockchain technology is a constantly evolving field that has garnered significant attention and value in recent years. However, despite its growing prominence, the decentralized systems are facing challenges in scaling Blockchains in terms of data availability. Data availability is a critically important aspect of blockchain technology. Data availability refers to the ability of a blockchain network to ensure that all necessary data is accessible and retrievable by all its participants. In a decentralized system, Where multiple nodes work together to validate and store data/transactions, ensuring that the data is avaliable, valid and accessible is quite a important factor for maintaining the integrity and decentralized nature of the network.

This study provides a Comparative study among the latest avaliable Data availability solutions/models in terms of bandwidth, time and other criteria to provide a bigger overview of pro's and con's of every model.

The Models included in study are as follows:

- Polkadot's ELVES
- Celestia
- Espresso Tiramisu
- NEAR
- Avail

The below is a breif short introduction of the models that will be discussed and analyzed in the study.

A. Polkadot ELVES

Polkadot is a sharded L0 multichain network the enables cross-chain interoperability and scalablity [1]. It utilizes ELVES (Economic Last Validation Enforcement System) to ensure data availability and validity of the parachains. Polkadot uses a hybrid consensus mechanism which uses BABE for block production and GRANDPA for its block finality. ELVES uses Reed Solomon encoding to split the data into chunks and then disperse it all across the network.

Polkadot uses Nominated Proof of Stake (NPoS) consensus mechanism which allows token holders to nominate entrusted validators to secure the network [2].

B. Celestia

Celestia is one of the first mover in the modular Data Availability solution space playing a major role in L2 and rollups developments. Celestia as of now utilizes 2D-Reed Solomon Erasure coding to split data into chunks and then encode into a matrix extension Namespaced Merkel Trees are then used to ensure the retirval and validity of the data. The root of the NMT is then stored in the block header [3].

As of now Celestia uses Tendermint consensus mechanism which uses BFT (Byzantine Fault Tolerance) style mechanism to ensure the finality of the blocks [3].

C. Espresso Tiramisu

Espresso-Tiramisu DA resolves the Data availability scaling issue with a three layred system below is the short overview of these three layers.

- Savoiardi (VID Layer) - Erause codes and stores data across all the nodes [4].
- Mascarpone (DA Committe Layer) - A Small elected Committee stores the full data and guarantees to efficiently recover data [4].
- Cocoa (CDN Layer) - Uploads the data on web2 based CDN solution for seamless and speedy data recovery [4].

Espresso utilizes Hotshot consensus which is a optimistically responsive, communication-efficient consensus protocol in a proof-of-stake setting that is resistant to bribing adversaries and scalable to large number of nodes.

D. NEAR

NEAR provides a high speed DA solution which porvides high transaction volumes with cost-effectivenes. NEAR utilizes the nightshade sharding mechanism, which parallelizes the network into multiple shards.Each shard processes its own transactions allowing the network to handle a higher volume of transactions approx 100,000 TPS [5].

As of now NEAR uses sharding-based proof of stake consensus mechanism.NEAR also implements unique validator elections to ensure security and decentralization of the network

E. Avail

Avail DA helps blockchains scale by providing an abundance of data availability capacity. Its modular design scales data availability capacity with demand, and transaction data can be cryptographically verified quickly by anyone running an Avail light client [6].Avail utilizes Erasure coding, KZG commitments along with light client to ensure its data availability.

As for consensus Avail uses BABE/GRANDPA hybrid consensus used by polkadot for block production and finality. Avail also provides Application Specific Data Retrieval (ASDR) this helps rollups to fetch and decode their own blobs even tho the block might contain many app's data. [7].

TABLE I: Comprehensive Comparison of Data Availability Solutions

Feature	**Polkadot ELVES**	**Celestia**	**Espresso Tiramisu**	**NEAR**	**Avail**
Consensus & Architecture					
Consensus Mechanism	BABE + GRANDPA(PoS)	Tendermint BFT	HotShot PoS	Nightshade Sharding	BABE + GRANDPA(PoS)
DA Model	Reed-Solomon Erasure Coding	2D Reed-Solomon + Namespaced Merkle Trees	Three-layer Tiramisu System	Sharding-based Parallelization	KZG + 2D Reed-Solomon Erasure Coding
Native Token	DOT	TIA	-	NEAR	AVAIL
Total Validators	600	100	100	300	105
Performance Metrics					
Block Time	20s	6s	$\sim$6s	1s	20s
Block Size	5 MB	8 MB	1 MB	4 MB	4 MB
TPS	10	0.48	N/A	53	420
Max Throughput	40 MB/s	$\sim$0.0159 MB/s	$\sim$5 MB/s	16MB/s	$\sim$0.2 MB/s
Finality	6–30s	5–15s	N/A	1–2s	20–40s
Economic & Security					
Cost per MB	$\sim$\$516	$\sim$\$0.08	N/A	100kb per NEAR token	$\sim$\$0.0173
Nakamoto Coefficient	174	9	N/A	10	34
Key Features					
Unique Advantages	Cross-chain interoperability via parachains	First modular DA solution for rollups	Web2 CDN integration (Cocoa layer) (High speed retrieval)	High-speed sharding 100k TPS	Application Specific Data Retrieval (ASDR)

II. Methodology

In this section, we detail the methods and approaches we will be using in our research. The methodology is structured as follows:

A. Parameters descriptions

We will be using the following parameters for this comparative analysis. Having a general understanding of these parameters will help in better understanding the study.

1. **Consensus Mechanism**: The underlying protocol on chain that ensures the agreement on the state of the blockchain among validator nodes.For example, Proof of Stake (PoS), Byzantine Fault Tolerance (BFT), Proof of Work (PoW) etc.

2. **Data Availability Model**: The specific approach used to ensure that all necessary data is accessible and retrievable by all participants in the blockchain network. For example, Reed-Solomon Erasure Coding, 2D Reed-Solomon with Namespaced Merkle Trees etc.

3. **Throughput**: The maximum rate at which a DA solution can process data, typically measured in Megabytes per second (MB/s).

4. **Latency**: The time taken for a DA solution to finalize a block, typically measured in seconds (s).

5. **Transactions Per Second (TPS)**: The number of transactions a DA solution can handle per second.

6. **Block Size**: The maximum size of a block that can be processed by the DA solution, typically measured in Megabytes (MB).

7. **Cost per MB**: The cost incurred to process one Megabyte (MB) of data using the DA solution, typically measured in USD.

8. **Nakamoto Coefficient**: A measure of the decentralization of a blockchain network, indicating the minimum number of entities that would need to collude to compromise the network's security.

B. Code Module Setup

The code module will be set up for all the DA solution to run in a simulated environment. This will help us to benchmark the performance of each DA solution under controlled conditions. The code module will have the below specified structure:

Also the code module will be open sourced for the community to use and verify the results.

C. Comparative Graphs

We will be using various comparative factor to graph out the differences in the data availability solutions. We will also provide a code based module setup that will generate the graphs based on the performance of the actual data availability solutions.

1) Throughput Analysis: This section will analyze the maximum throughput capabilities of different DA solutions under various network conditions/data sizes. We measure transactions per second (TPS) and data processing capacity.

- **Test Parameters:** Time taken, data sizes
- **Metrics:** seconds
- **Environment:** Simulated network with controlled conditions

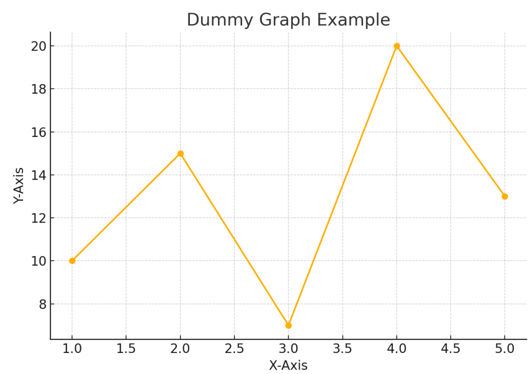

Fig. 1: Comparative Throughput Analysis of DA Solutions

2) Latency: This section will analyze the maximum time taken by the DA solution to finalize a block.

- **Test Parameters:** Network conditions, data sizes, node count
- **Metrics:** MB/s
- **Environment:** Simulated network with controlled conditions

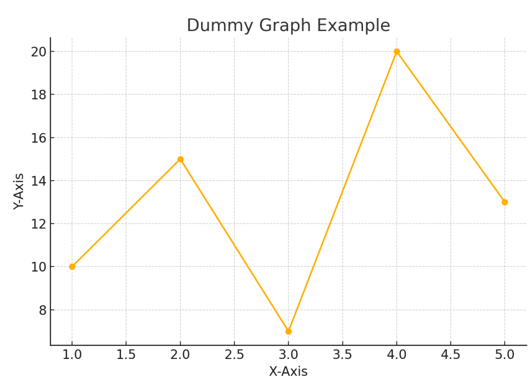

Fig. 2: Comparative Latency Analysis of DA Solutions

3) TPS: This section analyzes the transactions per second (TPS) capabilities of different DA solutions. We measure transactions per second (TPS) and data processing capacity.

- **Test Parameters:** Network conditions, data sizes, node count
- **Metrics:** TPS

- **Environment:** Simulated network with controlled conditions

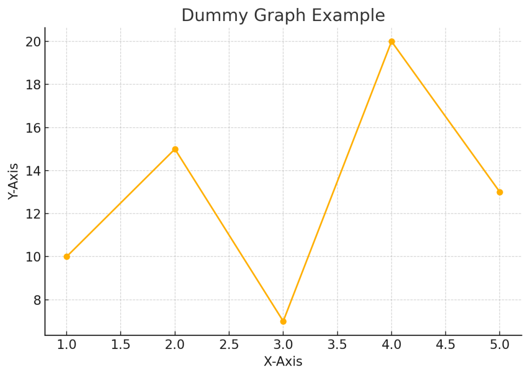

Fig. 3: Comparative Latency Analysis of DA Solutions

4) Max Block Size: This section analyzes the maximum block size capabilities of different DA solutions. We measure the maximum block size and data processing capacity.

- **Test Parameters:** Network conditions, data sizes, node count
- **Metrics:** Block size (MB)
- **Environment:** Simulated network with controlled conditions

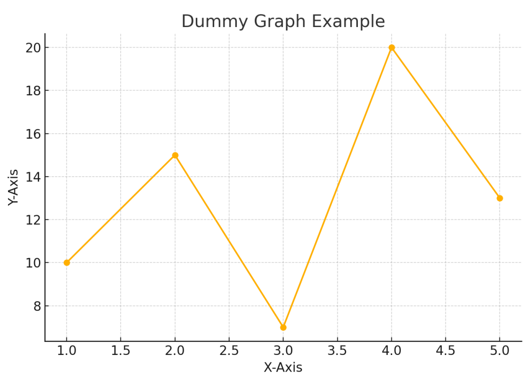

Fig. 4: Comparative Block Size Analysis of DA Solutions

5) Cost per MB: This section analyzes the cost per megabyte (MB) of data processed by different DA solutions. We measure the cost efficiency and resource utilization.

- **Test Parameters:** Data sizes, Cost in native token conversion to USD
- **Metrics:** $/MB
- **Environment:** Simulated network with controlled conditions

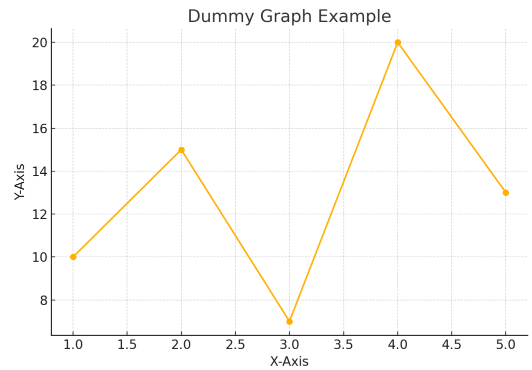

Fig. 5: Comparative Cost per MB Analysis of DA Solutions

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