Across protocol data research

Study: Evaluating the cross-chain intent economy and decentralization depth of solver networks in intent-based systems: A case study on Across protocol

This document outlines the data methodology used to analyze Across Protocol. It defines the twenty core metrics tracked in this study, detailed by their operational definition, calculation method, and economic significance.

A. Cross-Chain Intent Economy Metrics

These metrics evaluate the demand side of the protocol (user activity) and the efficiency of the fulfillment mechanism.

1. Intent Volume

- **Definition:** The total number of unique deposit transactions created by users on all `SpokePools` requesting a cross-chain transfer.
- **Calculation:** A simple count of valid `FundsDeposited` events over the selected time period.
- **Significance:** This serves as the primary proxy for user adoption and network demand. High intent volume indicates strong organic usage, independent of the dollar value of those transactions.

2. Intent Dollar Volume (USD)

- **Definition:** The aggregate United States Dollar value of all user intents.
- Calculation:

$$V_{total} = \sum_{i=1}^{n} (Amount_i \times Price_i)$$

Where $Amount_i$ is the token quantity of deposit i and $price_i$ is the USD price of the asset at the time of the deposit block.

- **Significance:** This measures the economic weight of the network. It determines the depth of liquidity required by relayers to function effectively.

3. Fill Volume

- **Definition:** The total number and USD value of intents that were successfully fulfilled by relayers on the destination chain.
- **Calculation:** A count and sum of `FilledRelay` (or `FilledV3Relay`) events.
- **Significance:** This metric isolates the activity of the solver network. A discrepancy between Intent Volume and Fill Volume indicates market inefficiency or solver unwillingness to service specific routes.

4. Fill Success Rate

- **Definition:** The percentage of user intents that are successfully filled by relayers rather than falling back to slow settlement.
- Calculation:

$$R_{success} = \left(\frac{\text{Total Filled Intents}}{\text{Total Created Intents}}\right) \times 100$$

- **Significance:** This is a Key Performance Indicator (KPI) for the protocol's "trust-minimized" promise. A high rate proves that the solver market is functioning correctly; a low rate implies users are being forced into slower, costlier fallback mechanisms.

5. Average Fill Time

- **Definition:** The average duration between a user's deposit and the relayer's fulfillment.
- Calculation:

$$T_{avg} = \frac{\sum(Timestamp_{fill} - Timestamp_{deposit})}{N}$$

- **Significance:** This measures the latency of the intent network. In a competitive solver market, this time should approach the block time of the destination chain. Increases in fill time suggest a lack of competition or liquidity constraints among relayers.

6. Slow Fill Frequency

- **Definition:** The count of transactions that bypassed the fast relayer network and were settled via the HubPool's slow verification process.
- **Calculation:** A count of `RequestSlowFill` or `ExecuteSlowRelayLeaf` calls.

- **Significance:** This represents market failure. It identifies specific routes, asset types, or time periods where relayers deemed the risk or cost of fulfillment too high to intervene.

7. Relay Fee Levels

- **Definition:** The effective percentage fee paid by users to relayers to incentivize fulfillment.
- Calculation:

$$Fee_{\%} = (\frac{\text{Relayer Fee}}{\text{Total Deposit Amount}}) \times 100$$

- **Significance:** This acts as the "price of speed." It reflects the supply and demand equilibrium for liquidity. Rising fee levels indicate capital scarcity among relayers; falling fees indicate high competition.

8. Rebalance Frequency

- **Definition:** The frequency with which the HubPool executes "Root Bundles" to move funds from the Hub back to SpokePools.
- **Calculation:** A count of `RootBundleExecuted` events over a given period.
- **Significance:** This measures operational overhead. High rebalance frequency implies that SpokePools are draining quickly (unidirectional flow), requiring constant intervention from the Hub to maintain solvency.

9. TVL Concentration in HubPool

- **Definition:** The total value of assets locked in the Ethereum L1 HubPool.
- **Calculation:** The sum of ERC20 token balances held by the HubPool contract.
- **Significance:** This represents the ultimate backstop of the system. It determines the maximum theoretical capacity the network can settle if all relayers fail simultaneously.

10. Capital Efficiency

- **Definition:** The ratio of volume processed relative to the total value locked (TVL) in the system.
- Calculation:

$$E_{cap} = \frac{\text{Daily Volume}}{\text{Total TVL}}$$

- **Significance:** A high ratio indicates that the protocol uses liquidity efficiently (high turnover), which is characteristic of intent-based systems. A low ratio suggests idle capital and lower yields for liquidity providers.

B. Decentralization Depth Metrics

These metrics analyze the topology of the solver network to determine if the system is truly decentralized or dominated by a few oligopolistic actors.

1. Relayer Market Share

- **Definition:** The percentage of total fill volume attributed to specific relayer addresses.
- Calculation:

$$S_i = \frac{\text{Volume filled by Relayer } i}{\text{Total Volume}}$$

- **Significance:** This reveals dominance. If a single relayer controls a majority (>51%) of the flow, the network is vulnerable to censorship or service disruption if that actor goes offline.

2. Active Fillers Count

- **Definition:** The number of unique wallet addresses that have successfully filled at least one intent during the period.
- **Calculation:** A distinct count of `relayer` addresses in fill events.
- **Significance:** This measures the breadth of participation. A declining count suggests barriers to entry are rising, potentially pushing out smaller independent solvers.

3. Filler Concentration Index (HHI)

- **Definition:** The Herfindahl-Hirschman Index (HHI), a standard economic measure of market concentration.
- Calculation:

Where S_i is the market share of firm i. Scores range from close to 0 (perfect competition) to 10,000 (monopoly).

$$HHI = \sum_{i=1}^{n} (S_i \times 100)^2$$

- **Significance:** This provides a single, standardized score for decentralization. It allows for objective comparison of market health over time.

4. Geographic/Chain Distribution

- **Definition:** The operational scope of relayers, defined by the number of distinct chains they service.
- **Calculation:** Grouping relayer activity by chain ID.
- **Significance:** This distinguishes between generalist market makers (robust) and single-chain specialists (fragile). A network dependent on specialists is more vulnerable to chain-specific outages.

5. Fill Failure Rate

- **Definition:** The rate at which attempted fills by relayers revert or fail execution.
- Calculation:

$$Rate_{fail} = \frac{\text{Reverted Fill Transactions}}{\text{Total Fill Transactions}}$$

- **Significance:** High failure rates indicate operational instability or "gas wars" where solvers are aggressively competing for the same intents, leading to wasted block space and network congestion.

6. Relayer Refund Dependency

- **Definition:** The speed and volume at which relayers claim refunds from the HubPool relative to their filling activity.
- Calculation:

$$D_{refund} = \frac{\text{Refunds Claimed}}{\text{Capital Deployed}}$$

- **Significance:** This measures the balance sheet depth of relayers. If relayers claim refunds immediately after every fill, they are "capital constrained." If they delay refunds, they have deep balance sheets, making them more resilient to Hub bottlenecks.

7. Gas Efficiency per Filler

- **Definition:** The gas cost incurred per dollar of volume filled.
- Calculation:

$$E_{gas} = \frac{\text{Gas Used} \times \text{Gas Price}}{\text{USD Value of Fill}}$$

- **Significance:** This helps differentiate between types of solvers. High efficiency suggests sophisticated, custom-contract MEV bots. Low efficiency suggests standard EOAs (Externally Owned Accounts).

8. Adapter-Level Centralization

- **Definition:** An audit of the cross-chain messaging contracts to determine if a single adapter handles all verification for a specific route.
- **Calculation:** A logical check of the `HubPool` adapter registry.
- **Significance:** This identifies single points of failure in the verification layer. If an adapter is centralized or has a single owner, the security of that specific chain route is compromised regardless of how many relayers are active.

9. Settlement Path Diversity

- **Definition:** The ratio of transactions settled via Fast Fill (Relayer), Slow Fill (Hub), and Emergency Mode.
- **Calculation:** A breakdown of transaction counts by settlement method.
- **Significance:** This measures protocol robustness. A healthy network should be dominated by Fast Fills. A shift toward Slow Fills or Emergency Mode indicates systemic stress.

10. Upgradeability / Admin Control Analysis

- **Definition:** An assessment of the governance powers over the smart contracts, specifically TimeLocks and Proxy Admin rights.
- **Calculation:** Qualitative analysis of contract permissions (e.g., `timelock_delay`, `owner`).

- **Significance:** This is the "Admin Key" risk. Even if the solver market is decentralized, if a single admin key can upgrade the HubPool contract without a delay, the protocol remains centrally controlled at the root level.