Rho Protocol

The on-chain institutional interest rates market

Executive Summary

Interest rate derivatives (IRDs) are the **single largest asset class in traditional finance**, with total outstanding interest amounting to over $400 trillion and trading volumes amounting to over $250 trillion in 2022, according to the Bank of International Settlements[1] and ISDA association[2].

In crypto, a number of interest rate-bearing products rose to prominence in the 2018-2022 cycle, with **billions of USD** in payouts accrued yearly.

However, the digital asset ecosystem still lacks an institutional-grade market that would allow investors to efficiently **hedge against or make bets on fluctuations in such rates.**

With the inevitable arrival of large-scale institutional capital and tokenization of securities, an on-chain market that would enable the management of blockchain-native and macro rate risks will become an even more essential part of the market infrastructure.

RHO PROTOCOL: OPPORTUNITY

This paper covers the core principles and purpose of the **Rho Protocol**, a novel **decentralized marketplace allowing professional traders to efficiently exchange rate risk via on-chain swaps and futures** in a secure, efficient, and compliant manner.

Rho Protocol's first family of products are fixed-to-floating interest rate swaps on a diverse set of index rates. In TradFi, this product comprises over 60% of the total outstanding interest in interest rate derivatives.

In digital assets, fixed-to-floating swaps can be used for **hedging against and speculation on future shifts in various on-chain floating rates,** including:

- Centralized and decentralized **lending/borrowing** market rates (conservatively estimated at >$200Bn in centralized loan originations in '22[3] and >$50Bn of DeFi TVL at the cycle peak[4])
- **Staking reward** rates ($70Bn+ staked in top-10 PoS chains[5])
- Other floating rates that already exist or will emerge in the digital assets ecosystem

The above use cases present a lucrative, virtually untapped opportunity worth hundreds of billion USD in outstanding notional and 100s of millions in revenues today.

FUTURE USE CASE: KEY RATE RISK & TOKENIZED SECURITIES

Bulge bracket TradFi firms, with their projects such as Goldman Sachs DAP, BNY Mellon Digital Assets, State Street Digital, and HSBC Orion, are pushing forward with the **tokenization of traditional securities**, including the $100 Tn+ bonds market[6]. As allocations to digital assets and tokenized securities become an everyday practice for institutional investors, the influence of key rates on digital asset prices will become as prominent as in traditional markets.

By successfully addressing the established and emerging use cases, Rho Protocol aims to provide critical risk management tools to the ecosystem and

help establish the on-chain equivalents of market-defining reference rates forming yield and swap curves.

Bringing interest rate trading on-chain offers significant benefits for all market participants, including enhanced transparency and efficiency of risk management, efficient near real-time settlements, and reduced agency risks.

TO RECAP

- Rho Protocol is **bringing interest rate derivatives, the largest global asset class worth over $400 trillion in open interest** and used to hedge against or speculate on fluctuations in interest rates, into the DeFi ecosystem.
- Rho Protocol will initially address the rate risks of **crypto lending, staking, and other floating rates today**, addressing the existing **market worth over $300 Bn in outstanding interest.**
- Rho Protocol is **built for institutions** and offers features uniquely catering to this client base, **including innovative market pricing (vAMM), risk management, and compliance (permissioned market sections)** solutions.
- By becoming a pre-eminent digital asset rates market, Rho Protocol will be best positioned to offer on-chain rates trading and management for the arrival of major institutions and securities tokenization.

Subsequent sections further expand on the core components of the protocol and define Rho Protocol's approach and methodology to solving the stated problems.

1. Rho Protocol

INTEREST RATE SWAPS IN TRADITIONAL FINANCE

A swap is an agreement between two parties to exchange cash flows over a period of time. In the interest rate swap (IRS), such cash flows are calculated based on the fluctuations of underlying rates. One of the parties, a "payer", will be paying the other party, a "receiver", a pre-agreed fixed swap rate in exchange for floating rate payments determined by a chosen index rate.

Traditional interest rate products are typically used for:

- **Hedging**: Interest rate swaps tend to be used for hedging, typically in the context of a broader investment strategy. For example, banks or corporates may enter a lender/borrower arrangement and use interest rate swaps to sell their rate risk and manage a bond portfolio's duration.
- **Speculation**: Taking a view on the future movements in rates and using the interest rate swaps to benefit from implied mispricing of such movements by the market.
- **Arbitrage**: Taking advantage of arbitrage opportunities that may exist in the existing swap spread (spread between current swap and yield curves) or between swaps and other instruments, either in proprietary trading or when acting as a swap dealer.

USE CASES IN THE DIGITAL ASSET ECOSYSTEM

As mentioned in the executive summary[7], a set of rate-based products rose to prominence in the digital asset ecosystem over the past cycle.

- **Centralized and decentralized lending/ borrowing rates**

Credit is a cornerstone part of any financial arrangement, and in the crypto ecosystem, both centralized and DeFi lending volumes reached new heights during the past cycle.

At the peak, the top-3 DeFi lending protocols (Aave, MakerDao, and Compound) have reached c. $50 Bn of TVL (Total Value Locked). Similarly, before the 2022 market crash, the largest centralized lender, Genesis, reported over $83 Bn in new loan originations in H1 '22.

As markets mature, the next iteration of digital asset lenders promises to professionalize further and grow the industry, creating demand for traditional risk management instruments for credit markets, such as interest rate and credit default swaps.

The current slowdown in crypto lending presents a unique opportunity to build the tools required to support the next wave of professional lenders.

- **Staking reward rates**

Proof-of-Stake is the current industry standard consensus mechanism for blockchain networks. As of January '23, c. $80 Bn of assets on top-20 PoS chains are receiving staking rewards, generating over $4 Bn annually at today's rates.

The largest PoS asset, Ethereum, currently stands at only 15% of total asset staked, versus 60-70% averages for most significant networks[8], leaving significant growth potential in USD terms even at today's depressed market prices.

A number of participants in the crypto ecosystem heavily depend on staking reward rates as a source of their revenue.

ADVANTAGES OF DEFI AND ON-CHAIN TRADING

- **Enhanced transparency.** Collateral balances and position health metrics can be made available to all members of the ecosystem. At the same time, modern blockchains enhanced with zero-knowledge solutions offer ways to obfuscate specific account and transaction data without compromising overall risk and security.
- **Immutability of records and risk algorithms, possibility of near real-time risk management.** Smart contracts deployed on public blockchain do not offer mechanisms for further human intervention, creating a universal set of rules to be followed by all participants and negating opportunities for a subset of actors to create systemic risks for the ecosystem.
- **Efficient, near real-time T+0 settlement.** In addition to simplifying settlement and cash management and releasing working capital, blockchains may enable complex, conditional, multi-leg DvP-like atomic settlements, minimizing settlement risks and reducing middle & back office operational overheads.
- **Mitigation of agency risks.** Regulators around the globe are primarily concerned with incentivizing better alignment between principal investors, financial intermediaries, and service providers, mitigating inherent agency problems. Offering a trustless and transparent mechanism to manage risk and exposure, on-chain finance optimizes for the best alignment between all actors in the ecosystem. It significantly reduces the burden on the regulators and compliance investment requirements for the institutions.

2. Protocol Architecture

Rho's architecture graph can be found in *Appendix A* of this document

CORE FEATURES & COMPONENTS

Rho Protocol is the first on-chain rates market built with a primary focus on institutions and professional market participants. It includes:

- **Rho Perpetuals: Swap and future contracts** that maximize liquidity, improving pricing and capital efficiency for all participants
- **Rho Pricing Engine:** Introducing a **unique price discovery mechanism** (vAMM), further expanding on the most recent developments on the classic XYK $(x \times y = k)$ model to **best serve yield discovery in a derivatives market**

- **Rho Risk Management:** Cutting-edge **risk management engine**, allowing for maximum utilization and efficiency of the maker and taker capital while maintaining the appropriate level of risk in the ecosystem
- **Permissioned market sections**: By building permissioned sections of the Rho market, with access governed by consortia of trusted market participants, Rho Protocol enables regulated firms and institutions to take full advantage of transparent and efficient on-chain markets in a secure and compliant way
- **Abstractable swap issuance and management:** Enabling issuance, as well as risk and collateral management for a broad range of contracts, starting from interest rate swaps

3. Rho Interest Rate Swaps

Rho Interest Rate Swaps are innovative financial instruments designed for professional investors looking to optimize their portfolios, manage risk, and seize market opportunities securely and transparently. Rho merges the well-established efficiency and advantages of traditional interest rate swaps with the evolving dynamics of crypto assets and decentralized finance. By leveraging compounded rates, a virtual Automated Market Maker ("vAMM"), and a unique token-based approach, Rho enables seamless trading between payers and receivers of various underlying rates and maturities.

KEY BENEFITS

- **Compounded Rates:** Rho aligns fixed and floating leg calculations, ensuring an accurate representation of financial returns over time, consistent with major DeFi lenders like Aave and Compound.
- **Liquidity:** Rho's perpetual contract design and standardized term reset dates enhance liquidity, allowing trading between holders of the same risk with different initial maturities and promoting longer-term participation.
- **Benchmarking and Forward Rates:** Rho's rates simplify comparisons between swaps of different maturities, enabling the development of a reliable swap rate curve based on zero-coupon flows and the calculation of forward rates.
- **Versatility:** Rho's methodology supports the future expansion into various interest rate derivatives, including forward rate agreements, cross-currency swaps, and more, broadening the scope for portfolio optimization and risk management.

MAIN TERMS

Rho Interest Rate Swaps are defined by:

- **Swap term reset date** - Analogous to maturity, it is the point at which payments are settled and the fixed swap rate is re-calculated.
- **Swap currency** - Either fiat or crypto, it denominates each party's payment obligations,
- **Underlying floating rate** - Varies based on an external reference index such as Libor or DeFi lending/borrowing rates.

Rho interest rate swaps are single-period contracts with fixed and floating cash flows netted at each term reset and no intermediate cash flow exchanges.

Term reset dates are standardized and set at the end of specific periods, such as the end of a calendar month (e.g., March 31st or June 30th). This aids the concentration of liquidity for the same risk (same remaining time to reset), enabling trading between positions with different original terms.

The perpetual nature of the Rho Protocol allows participants to remain in a swap and continuously hedge fixed-floating exposure across multiple terms. Net swap payouts are calculated by netting the fixed and floating leg values at the end of each term.

As most of Rho's underlying floating rates are compounded and reset in high frequency (seconds), Rho fixed rates are also expressed in annual percentage yields (APY).

$$APY = (1 + ratePerSecond)^{secondsPerYear} - 1 \quad (1)$$

Compounding rates are essential for accurately representing investment growth over time. This convention enables seamless trading between holders across all maturities, providing flexibility and liquidity in the market while facilitating the creation of a reliable swap rate curve that incorporates longer maturities.

SWAP LEGS AND VIRTUAL TOKENS

Floating leg: Rho's floating leg tracks an external index rate, such as lending/borrowing rates on DeFi platforms like Aave or Compound, or other index rates previously mentioned. Rho's Oracle component is responsible for obtaining reliable rate measurements.

A virtual floating token called '**rflToken**' represents the accrued value of floating rates on a specific swap trading platform for a given notional amount, similar to tokens like aETH and aUSDC on Aave.

For example, when creating a swap platform for ETH lending rates on Aave, the protocol generates a virtual token named 'rflaETH' as an index with an initial value of 1 ETH for all participants. Rho's oracle tracks Aave lending rates, adjusting the rflaETH value accordingly. If, after one year, the compounded interest rate for Aave ETH lending reaches 10%, 1 rflaETH would be worth 1.10 ETH. At this point, a trader paying rates on 110 ETH notional would receive 100 rflaETH. Assuming the Aave lending rates accrue 1% in the next month, 1 rflaETH will be worth 1.10*1.01=1.111 ETH, and the trader's floating position will be valued at 111.1 ETH.

Fixed leg: Rho's swap fixed leg effectively represents zero-coupon security. Rho Pricing Engine expands on the concept developed by the team behind Yield Protocol, which emphasized the importance of time to maturity for derivatives markets (as opposed to spot asset prices) and has introduced the concept of 'fyTokens' to model fixed-rate loans.

Similarly, Rho designed a virtual fixed token called '**rfxToken**.' Each rfxToken represents the total payout of 1 (one) Token at term reset.

$$FV = PV \times (1 + YTM)^t \qquad (2)$$

Equation (2) defines the relationship between present value (*PV*), future value (*FV*) at term reset (*t*), and yield-to-maturity (*YTM*). At the swap negotiation, the yield represents the fixed rate of the fixed leg. For example, a theoretical value of 1,000 rfxETH is worth 980.392 ETH today (present value) and would accrue to a 1,000 ETH total payout (future value) at the term reset date, yielding 2% over the period.

From a risk perspective, Trader A is a **receiver** by holding long virtual rfxTokens and short virtual rflTokens positions. This asset and liability position is equivalent to someone who borrows money at a floating rate and invests the same amount on a fixed-rate asset, except there is no actual cash transaction – it is simply a collateralized derivative. At the swap reset date, Trader A will receive a fixed-rate cash flow and pay the accrued interest rates replicating the underlying external index rate. Similarly, Trader B is a **payer** by holding long rflTokens and short rfxTokens positions. Trader B will receive a floating-rate cash flow at the reset date and pay fixed rates. In practice, Rho Protocol calculates the net amount of each participant and redistributes the profits and losses.

At term reset, long and short positions of rfxToken and rflToken determine the swap's fair value. Before the term reset, one can calculate the future value of 'rflTokens' using the market-traded fixed rate. Rho uses similar calculations to maintain appropriate margin levels.

4. Rho Pricing Engine (Virtual AMM)

Rho Pricing Engine utilizes a **virtual Automated Market Maker (vAMM)** model for efficient trading, offering multiple advantages over traditional solutions such as order book-based exchanges:

- **Continuous liquidity** through liquidity pools for instant trade execution, even in less liquid markets
- **Transparency and trust** due to a predeter-mined formula for asset pricing, reducing susceptibility to market manipulation

- **Concentrated liquidity** solutions for efficient capital allocation, optimized returns for liquidity providers, and minimal slippage for price takers
- **Scalable and adaptable** technology, allowing for future growth and expansion into new markets and asset classes

vAMM & INVARIANT LIQUIDITY CURVE

Rho's swap rate discovery mechanism relies on the vAMM model to find the price equilibrium between payers and receivers. This equilibrium is reached according to the supply and demand of fixed and floating tokens, using the constant product formula pioneered by Uniswap:

$$x \times y = k \qquad (3)$$

where x represents virtual reserves of rfxToken in the vAMM, y represents virtual reserves of rflToken, and k is a constant factor representing the total liquidity provided.

According to the constant product formula, the implied price of rfxTokens in terms of rflTokens p_x is given by the ratio between reserves:

$$p_x = \frac{y}{x} \quad (4)$$

Additionally, the exchange of a small amount dx of rfxToken reserves for dy of rflTokens is expressed as the same ratio y/x:

$$-\frac{dy}{dx} = \frac{y}{x} \qquad (5)$$

In other words, the implied swap rate will be fixed at the equilibrium price (or rate) for slight variations in the reserves.

Rho creates a swap market and vAMM for each Rho IRS Swap, defined by the term reset, currency, and underlying floating rate.

MARKET PARTICIPANTS

Rho protocol offers two modes of participation:

- **Price takers** are receivers or payers and must accept the prevailing market price to transact. They rely on the liquidity available in the vAMM for their trades.
- **Liquidity providers ("LPs")** or **market makers** are passive traders who maintain liquidity reserves in a swap's vAMM, taking either the payer or receiver side. They must specify the maximum notional amount for transactions and can remove liquidity at any time. LPs earn premiums from the liquidity fees paid by price takers.

Users can participate in both modes according to their needs. However, price takers cannot transact directly with each other. To open or close swap positions, a price taker will access the liquidity provided by market makers. Likewise, market makers cannot trade swaps directly among themselves in the liquidity provider mode. When market makers want to increase or reduce a position, they can access the vAMM's liquidity and execute a trade as a price taker.

Liquidity fees at Rho Protocol compensate liquidity providers (LPs) for the risks they incur. Factors such as the time remaining until the term reset and the volatility of the underlying floating rates influence these fees. Additionally, the fees take into account the trade size relative to available liquidity in the vAMM, addressing the slippage risk faced by LPs.

The collected fees are then distributed among LPs based on their liquidity contributions to the vAMM. This structure ensures that LPs' returns increase with trading volume, rewarding them for their essential role in maintaining a liquid and efficient market.

$$LiquidityFee = Notional * SlippageFactor * FeeCoeff$$

$$SlippageFactor = \left| (1 + r_{postTrade})^t - (1 + r_{Trade})^t \right|$$

RHO'S VALUATION MODEL

Rho Protocol has developed a model that enables participants to evaluate both the individual and relative prices of fixed and floating legs using fixed and floating tokens (rfxToken and rflToken). This approach enhances risk transparency and facilitates the application of the tested Automated Market Maker model $x \times y = k$, which is best suited for generalized asset price discovery.

Price (P) and yield can both be used to express the value of fixed-income securities. In the case of a zero-coupon bond, the equation is as follows:

$$P = \frac{PV}{FV} = \frac{1}{(1+yield)^t} \qquad (6)$$

Yield (or rate) typically provides a more intuitive value measure for comparing different instruments and maturities. Many DEX protocols (examples include Yield Protocol or Voltz) use the concept of yields/rates to represent the market for negotiating fixed-income assets and derivates.

However, Rho has opted to use price in its vAMM model, as it provides a clearer representation of risks and fair values for financial instruments like interest rate swaps. This method emphasizes the impact of time-to-maturity on the present value and market risk of these instruments. Due to duration risk, long-term swaps' mark-to-market (MtM) values exhibit greater variation (volatility) than short-term ones.

Using the principle of non-arbitrage, the present value of the floating leg equals the present value of the fixed leg at the swap inception, so the MtM is zero:

$$MtM = PV_{floatleg} - PV_{fixedleg} = 0 \qquad (7)$$

As the present value of the floating leg equals its notional, we derive the following relationship (8) between the fixed leg price (P_{fx}), fixed leg future value (FV_{fx}), and the floating leg notional (N_{fl}). Alternatively, the price P_{fx} can be expressed by a relationship between the future value of fixed tokens and the present value of floating tokens (9).

$$MtM = FV_{fx} \times P_{fx} - N_{fl} = 0$$

$$P_{fx} = \frac{N_{fl}}{FV_{fx}} \qquad (8)$$

$$P_{fx} = \frac{rflTokenNumber \times rflTokenPV}{rfxTokensNumber \times rfxTokenFV} \qquad (9)$$

With a few arithmetic manipulations, we derive the formula (10) for p_x, the price of rfxTokens in terms of rflToken, consistent with the formula used in the vAMM (4).

$$P_{fx} = \frac{y * rflTokenValue}{x * 1}$$

$$p_x = \frac{P_{fx}}{rflTokenValue} = \frac{y}{x} \qquad (10)$$

Due to the interchangeability between price and yield, equation (11) will define the swap's fixed rate.

$$y_{swap} = \left(\frac{1}{P_{fx}}\right)^{\frac{1}{t}} - 1 \qquad (11)$$

CONCENTRATED LIQUIDITY

Traditional $x \times y = k$AMM models can be inefficient for both yield-based and asset price-based markets, as they distribute reserves across the entire price curve (0,+∞), while fixed-income assets are typically traded within a narrower price range. Additionally, zero-coupon bond prices tend to converge around their notional as they approach maturity in the absence of default risk.

Rho Protocol addresses these efficiency issues by implementing the Concentrated Liquidity concept introduced by Uniswap in their V3 protocol in 2021. This concept enables market makers to supply their liquidity within a specific price interval, expressed as a yield range, offering significant benefits:

- **Capital efficiency and minimal slippage:** By concentrating liquidity in narrower ranges, market makers can achieve higher returns on their capital investment, while price takers benefit from reduced slippage.
- **Precision allocation:** Market makers can reduce potential losses by directing liquidity on relevant price ranges and avoiding areas they deem unlikely for market trading.
- **Enhanced market efficiency:** Market converges quickly towards fair swap prices, promoting an efficient price discovery process.

For instance, a market maker may choose two 50bps ranges and deploy 100ETH of notional between 10% to 10.5% yield and 50ETH from 10.5% to 11%. The protocol converts the chosen rates into a price grid using equations (6) and (10), taking into account the remaining time to term reset.

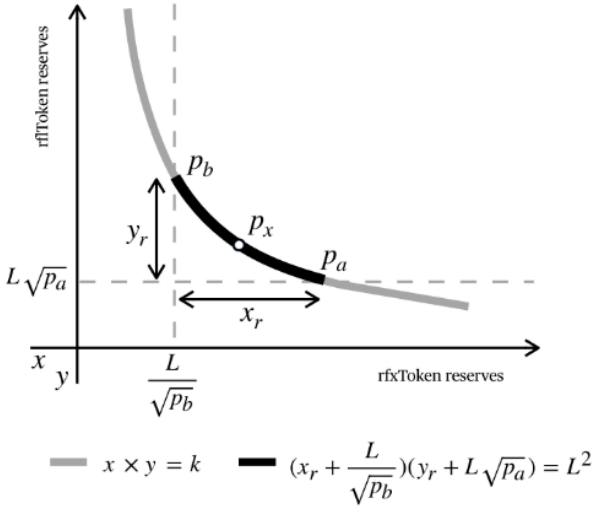
For each interval $[p_a, p_b]$, the constant product formula (3) is transformed into equation (14), where the reserves x_r and y_r of rfxToken and rflToken represent the specific market maker's liquidity L within these defined ranges.

$$x \times y = k;\ k = L^2$$

$$x = x_r + \frac{L}{\sqrt{p_b}} \quad (12)$$

$$y = y_r + L\sqrt{p_a} \quad (13)$$

$$(x_r + \frac{L}{\sqrt{p_b}})(y_r + L\sqrt{p_a}) = L^2 \quad (14)$$



Liquidity providers must specify the maximum notional amount available for transactions in each interval. In the interval i, $[p_{a_i}, p_{b_i}]$, the maximum notional amount for the floating leg occurs when $x_{rMin_i} = 0,\ y_{r_i} = y_{rMax_i}$ and $p_x = p_{b_i}$. Using $y_{rMax_i} = \frac{MaxNotional}{P_{rflTokenValue}}$ as an input, Rho calculates L_i as follows:

$$L_i = \frac{y_{rMax_i}}{\sqrt{p_{b_i}} - \sqrt{p_{a_i}}} \quad (16)$$

The values of x_{r_i} and y_{r_i} depend on the current swap equilibrium rate and its equivalent price p_x. This rate is determined based on the previous swap trade.

For the interval $p_{a_i} \le p_x \le p_{b_i}$:

$$(17)\ x_{r_i} = L * \left(\frac{1}{\sqrt{p_x}} - \frac{1}{\sqrt{p_{b_i}}}\right),$$
$$y_{r_i} = L * \left(\sqrt{p_x} - \sqrt{p_{a_i}}\right)$$

When $p_x < p_{a_i}$:

$$x_{r_i} = 0, y_{r_i} = y_{rMax_i}$$

When $p_{b_i} < p_x$:

$$x_{r_i} = L_i * \left(\frac{1}{\sqrt{p_{a_i}}} - \frac{1}{\sqrt{p_{b_i}}}\right), y_{r_i} = 0$$

TERM & RATE RESETS FOR PERPETUAL CONTRACTS

Rho Swaps are perpetual in nature. At no point in the contract's lifetime (unless the contract is discontinued) will the traders' positions stop accruing interest, and all their funds be returned.

However, to limit the term of a payer's and receiver's liabilities, Rho uses rate resets at regular intervals. By default, all the assets in a Rho swap that possess sufficient collateral would be rolled into the next term after the rate reset. Rho Pricing Engine establishes the new rate based on the market conditions and liquidity available in the swap.

A trader can opt out of the rollover for a part or the entirety of the position by executing a risk-reducing transaction before the rate reset.

vAMM EXAMPLE : LIQUIDITY PROVISION & TRADING

Let's consider a market for Rho interest rate swaps using Aave lending rate on Ether as an external index rate, with a swap term on May 31st, 2023 (time till the next fixed rate reset).

On March 19th, 2023, 73 days from the term, the market is at equilibrium on a swap fixed rate of 10%. The equivalent price on a zero coupon bond expiring in 73 days is:

$$t = \frac{73}{365} = 0.2$$

$$P_{fx} = \frac{1}{\left(1 + 10\,\%\right)^{0.2}} = 0.98112$$

P_{fx} is the fair price of 1 rfxETH virtual fixed-rate token in ETH units. At the swap reset date, 1 rfxETH pays 1 ETH, but on March 19th, 2023, its present value is 0.98112 ETH.

The rflaETH, which mirrors the returns of an ETH-denominated loan on Aave, accrues every second, functioning as an Aave variable rate index. Let's assume that on March 19th, 2023, 1 rflaETH is worth 1.10 ETH. Then, using equation (10), the price of 1 rfxETH in terms of rflaETH is:

$$p_x = \frac{0.98112}{1.10} = 0.89192$$

As described by formula (4), one can find the equilibrium price p_x by observing the ratio between x and y reserves of rfxETH and rflaETH.

$$\frac{y}{x} = p_x = 0.89192$$

In other words, there must be 891.92 rfxETH virtual tokens in the vAMM for every 1000 rflaETH virtual tokens to preserve p_x.

Liquidity providers ("LPs") will deposit collateral and specify a maximum desired notional exposure (risk limit) for a given swap class. When adding liquidity to the pool, Rho Protocol will mint rfxETH and rflaETH on a new balance of x and y reserves that keep p_x and the equilibrium swap rate constant. 'Minting' in this context means that the virtual tokens will be available for price takers to transact as receivers or payers. It is the equivalent of putting live bid/offer trade orders in order book systems. No actual position or P&L is attributed to those virtual tokens before trades effectively occur.

Using the same example of the Aave lending rate swap market, a market maker LP A deposits 100 ETH as collateral, specifies maximum leverage of 50x (5,000 ETH notional), and chooses a fixed swap rate interval from 9.5% to 10.5% to deploy the notional.

By converting the swap rates into p_x, the $[9.5\,\%, 10.5\%]$ rate interval is equivalent to the price interval :

$$[p_a, p_b] = [0.89112, 0.89274]$$

Given the maximum notional amount of 5,000ETH, the maximum amount of rflaETH is y_{rMax}=4545.45 when x_{rMin}=0 and $p_x = p_b$. Rho Protocol uses the formulas (16) and (17) to derive the amount of x_r and y_r tokens to mint and the liquidity constant L. The increase in reserves must maintain the ratio $\frac{y}{x} = p_x$. In this case:

$$x_r = 2{,}553\ ;\ y_r = 2{,}267\ ;\ L = 5{,}294{,}222$$

At this point, LP A's swap balance is still zero, as there are no trades, only liquidity provisions.

Trader A wants to hedge an investment on variable Aave lending rates and wishes to receive fixed rates on Rho Protocol. Trader A will access vAMM to buy rfxETH (long fixed-rate cash flow) and sell rflaETH in exchange. Although Trader A doesn't initially own any rflaETH, Rho Protocol allows Trader A to become negative on virtual tokens. A short position of a virtual token represents a liability. As a numerical example, Trader A deposits 10 ETH as collateral and chooses leverage of 70x, corresponding to 700 ETH notional. This notional equals 636.36 rflaETH (since 1 rflaETH = 1.1 ETH). Trader A will sell 636.36 rflaETH and get an amount Δx of rfxTokens. The constant product formula (3) will determine the value of Δx.

Let's assume LP A is the only market maker providing liquidity in the rate interval $[9.5\,\%, 10.5\%]$. Using formulas (12) and (13) and the values of x_r and y_r, we can calculate the total number of virtual tokens in the vAMM before the trade.

$$x_0 = 5{,}605{,}802 \text{ rfxETH}$$

$$y_0 = 4{,}999{,}960 \text{ rflaETH}$$

To preserve the $x \times y = k$ invariance curve, only a reduction of $\Delta x = -713.38$ in the vAMM reserves can offset an increase of $\Delta y = 636.36$.

The price and rate of the swap are:

$$p_{xTrade} = -\frac{\Delta y}{\Delta x} = 0.89204 \text{ (in rflaETH)}$$

$$P_{fxTrade} = 0.98124 \text{ (in ETH)}$$

$$Swap\ Rate_{Trade} = 9.93\,\%$$

After the trade, Trader A becomes long 713.38 rfxETH and short 636.36 rflaETH. On the other side of the swap, LP A becomes long 636.36 rflaETH and short 713.38 rfxETH. Trader A will also pay LP A an additional liquidity fee for the trade.

If many market makers participate in the same rate interval, they will get a swap exposure proportional to the amount of liquidity provided.

The new reserves in the vAMM following the trade:

$$x_1 = 5{,}605{,}089 \text{ rfxETH}$$

$$y_1 = 5{,}000{,}597 \text{ rflaETH}$$

The new equilibrium price is:

$$p_{x_1} = \frac{y_1}{x_1} = 0.89215 \text{ and } P_{x_1} = 0.98137$$

Hence, the new equivalent equilibrium swap rate is 9.86%.

In this example, we note that the fixed leg price increases when price takers trade as receivers. The amount of x in the vAMM drops while y increases. Hence, the fixed rate falls.

In another scenario, if Trader B accesses the vAMM as a payer, the equilibrium will move in the opposite direction. The trader will be short rfxETH and long rflaETH. The amount of $x$in the vAMM increases and y decreases. Hence, the swap price p_x and P_{fx} decline, and the market fixed rate climbs.

Rho Protocol records the equilibrium swap rate achieved after the trade for the next transaction. In this example, the swap rate stored is 9.86%.

When a price taker requests a new trade, Rho will recalculate the availability of reserves x_r and y_r based on time to maturity, the accrual of the floating token, and the total notional amount specified by liquidity providers. This approach prevents differences in accruals between fixed and floating legs from moving the relative price of tokens p_x in the vAMM and its equivalent swap rate away from the previous equilibrium.

5. Risk Management

Transparency and immutability of collateral and risk-management mechanisms are undoubtedly the most attractive features of DeFi and broader on-chain trading.

Rho Risk Engine is responsible for defining and maintaining an appropriate level of risk on the protocol, including all aspects of margin management and liquidations. It is designed to support a range of swap instruments, starting with interest rate swaps.

Core components of the risk engine, responsible for the overall health and stability of the protocol, are:

- **Collateral Manager contract** that holds and releases the traders' margin verifies and orchestrates liquidation events
- **Independent liquidators**, appropriately incentivized to monitor the health of the traders' positions and promptly take over those insufficiently collateralized
- **Rho Stability Fund** provides an additional backstop in the unlikely case that liquidity in the protocol becomes insufficient to perform required liquidations and maintain an acceptable level of risk in the ecosystem

MANAGED RISKS

A collective exposure of all the protocol's traders to the following two risks are the main components of the systemic risk present in the ecosystem. Rho Risk Engine's core purpose is to maintain the appropriate level of this risk, ensuring security for all market participants.

- **Market Risk**: The risk arising from shifts in market rates to the index, or relevant token prices, between observations.
- **Liquidity Risk**: The cost of liquidating a position. Such costs may include any transaction costs, slippage or spread associated with unwinding a position. This risk becomes more significant in peak markets.

Maintaining collateral sufficient to account for both risks is critical for the market's health and its participants' security.

MARGIN THRESHOLDS

Traders with a position in a Rho Swap must deposit and maintain a required level of collateral to cover future swap payments.

The margin for each participant is defined as the sum of their collateral and P&L generated from swap positions:

$$Margin = CollateralValue + AccumulatedPnL$$

Two critical thresholds must be respected in Rho Protocol: the initial margin and the liquidation threshold.

- **Initial Margin:** Margin requirements are calculated based on the traders' projected liability under the terms of the Swap, which may be influenced by the position's parameters and the current market state. The initial margin is designed to cover both market and liquidity risks of the position.

  Traders whose margin falls below the Initial Margin requirement cannot add more risk on the same side or withdraw collateral until they restore the required amount of collateral to support their existing positions.

- **Liquidation Threshold** (Stop Limit): If the trader's margin falls below the liquidation threshold level, a liquidator may trigger the unwinding of exposure or take over the position according to the protocol rules. The liquidation threshold is set at a level that covers the liquidation risk plus a narrower margin than the initial margin to address market risk.

UNWINDS AND LIQUIDATIONS

At any point, except during liquidation, a trader can reduce their exposure by opening an opposite sign position in the same swap. When the balance of rflToken reaches zero, the trader no longer has exposure to further rate fluctuations. The residual balance of rfxToken represents the accumulated P&L that the trader will receive or pay at the term reset date. Rho Protocol allows traders to withdraw all margin accounts before this date if the risk is squared.

Rho Protocol's mechanism to actively manage market and liquidity risk is based on incentivizing independent third-party liquidators to monitor positions in Rho swaps and rapidly initiate liquidation when a position's health no longer meets the protocol requirements.

If a given position's margin falls below the liquidation threshold, a liquidator may take over the position. Liquidators will only reduce the necessary risk for the residual margin to remain above the recalculated initial margin limit. After the liquidation, they receive commissions using part of the original residual collateral. The reward size may depend on the current market structure and availability of liquidity: in peak markets, the liquidation may become expensive for the trader whose position is being liquidated, while in low markets, it may be far less costly. The remaining collateral, net of liquidation costs that include liquidator incentives, will be returned to the original holder of the position.

STABILITY FUND

Rho Protocol creates and maintains a Stability Fund to backstop the liquidator's incentives in the unlikely scenario when the liquidity in the protocol is insufficient to execute all the necessary liquidations. This vehicle is funded out of the fees paid by protocol participants when entering the swap.

SYSTEMIC RISK MITIGATION

Rho monitors two risk metrics at a macro level: global liquidity ratio and global collateralization ratio.

- **Systemic Liquidity Ratio:** This ratio represents the relationship between the total notional provided in the vAMM liquidity and the total notional of open swap contracts. It measures the protocol's resilience or vulnerability to sudden jumps in volatility due to market shifts. If the coefficient falls below a pre-defined level set by the protocol, price takers are not allowed to increase positions that add to systemic risk. Liquidity backstops or reserve pools may be activated in response.

- **Systemic Collateralization Ratio**: This ratio is determined by the relationship between the total collateral deposited in the system and the total market risk of open swap contracts. A low ratio signifies that many participants are near the liquidation threshold. If the coefficient falls below a pre-defined level set by the protocol, price takers are unable to withdraw the margin from the system until a safer level is achieved. This measure helps maintain the overall stability and health of the protocol.

CALCULATION OF THRESHOLDS

The liquidation threshold and initial margins are defined as:

$$InitialMargin = N_{fl} * [(1+y)^t - (1+y+\xi * \Delta y_{IM})^t]$$

$$LiquidationThreshold = N_{fl} * [(1+y)^t - (1+y+\xi * \Delta y_{LT})^t]$$

$$\Delta y_{IM} = K * \Delta y_{LT} \; ; \; K > 1$$

$$\Delta y_{LT} > \Delta y_{liq} + \Delta y_{mkt}$$

Here:

- y is the market rate of the swap at time t to reset date
- Δy_{IM} is a parameter defined by RhoProtocol as a rate change buffer to reduce the likelihood of liquidation events
- Δy_{LT} is a parameter defined by RhoProtocol to cover losses due to both market and liquidity risks in a liquidation event
- N_{fl} is the floating leg notional of a participant's consolidated swap position, which will be positive for payers and negative for receivers
- ξ is a side coefficient equal to 1 for receivers and -1 for payers
- K is a parameter greater than 1
- Δy_{liq} is a measure of liquidity risk representing the difference between the resulting liquidation rate and the market rate immediately before liquidation
- Δy_{mkt} is a measure of rate changes between two observations preceding a liquidation event and is calculated to account for expected rate changes within a 99% confidence interval

The liquidation threshold is established to mitigate potential losses incurred by a participant between two observations: one preceding the liquidation event and the one that triggers the event. This market movement during those observations is capped by the Δy_{mkt} measure. When liquidating a position, liquidators will access the vAMM as price takers to reduce the notional at risk. The trade will be executed at a specific rate based on the available liquidity. Δy_{liq} represents a maximum tolerated change in rates to execute the liquidation. The parameter Δy_{LT} used in the liquidation threshold is calibrated to cover the sum of Δy_{liq} and Δy_{mkt}.

Rho Protocol incentivizes independent liquidators to regularly monitor traders' health scores regularly to manage risks effectively. This practice narrows the time gaps between observations and enables liquidity providers to intervene and reduce risk exposures promptly, minimizing unforeseen losses.

Rho Protocol sets the initial margin using the coefficient $K > 1$, giving participants additional protection against market volatility and liquidation risks. Both parameters Δy_{IM} and Δy_{LT} are assessed by observing historical data of Rho's interest swaps and underlying external floating rates. All risk parameters are defined by Rho Protocol's governance.

6. Permissioned Market Section and Protocol Governance

As professional players started engaging broadly with the DeFi ecosystem following the "DeFi Summer" of 2020, it became apparent that regulatory and compliance concerns remain the most significant barrier to the mass adoption of DeFi among regulated institutions.

All major regulators require their firms to identify the counterparty of every trade to prevent breaches of regulations aimed at preventing money laundering (AML) and terrorist financing and to avoid any transactions with parties currently on the OFAC restricted lists (sanctioned entities).

These rules are non-negotiable, and the impact of any potential breach on regulated entities and individuals involved may be catastrophic.

Most regulated entities do not and will not engage with markets that do not impose some level of KYC/AML scrutiny at the access point. Offering a solution suitable for today's state of the regulations is critical to building an on-chain market for institutional participants.

PERMISSIONED MARKET SECTIONS

On Rho Protocol, members of the ecosystem who are required to follow strict compliance rules will be able to access Permissioned Sections of the protocol: ring-fenced parts of the market inaccessible for unverified traders.

Participants of the Permissioned Sections will only engage in trading with other entities who have passed relevant KYC/AML and other checks with one of the trusted Whitelister members of the protocol, the same way TradFi institutions rely on brokers and exchanges to only allow participation by the members who have passed necessary verifications.

At scale, Rho Protocol will allow multiple Permissioned Sections, each managed by its own set of governing Whitelisters. This would enable the creation of private sub-markets, including segregated markets based on geographical differentiation (for example, US/non-US).

THE ROLE OF WHITELISTERS

Whitelisters are governing members of the Rho Protocol, responsible for maintaining security and compliance of the Permissioned Sections of the market and participating in broader protocol governance.

All traders in Permissioned Sections rely on Whitelisters to perform adequate KYC/AML and other checks to remain compliant in their jurisdiction. The Whitelisters in each Section must agree on and maintain the similarity of their verification and admission standards. While certain universal practices would apply, at scale Rho Protocol envisages multiple Sections segregated jurisdictionally, by purpose, or by the strictness of the standards applied.

By the nature of their business, Whitelisters - crypto-native and traditional institutions are appropriately incentivized to perform the function and maintain the integrity of the protocol. Providing access to a compliant on-chain rates marketplace will attract more business to the Whitelisters and open up additional trading and risk management opportunities for themselves and their customers.

EXPLORING GRADUAL DECENTRALIZATION OF GOVERNANCE

While Rho Protocol stands firmly behind the strong-form decentralized finance thesis, today's institutional demand for solutions governed in a truly decentralized manner is minimal.

As Rho Protocol matures and the market grows more familiar and comfortable with DAOs and similar decentralized governance models, the team behind Rho Protocol aims to turn all ownership and control of the protocol to its governing members, starting from Permissioned Sections Whitelisters.

The existence of concepts similar to Rho Permissioned Sections is vital for the emergence of DeFi 2.0, a set of mature on-chain markets that allow for the full participation of regulated financial institutions, often governed by them. Governing members will determine overall market mechanics and define the participants' incentives via on-chain votes in their respective Sections.

At Rho Protocol, we believe that such a market will be most beneficial to all participants in the financial ecosystem, presenting an opportunity to unlock the most value, optimize for transparency and mitigate agency risks, which are characteristic of today's TradFi markets.

7. Note on Distribution

Bootstrapping and maintaining liquidity is one of the most significant challenges for any new market, including any protocol in the DeFi ecosystem.

Core features of swaps as an asset class and interest rate swaps in particular that pre-determine Rho Protocol's distribution strategy are:

- **Deeply institutional nature of the instrument**: over 97% of all swaps are traded by financial institutions and other professional market participants[9]. Individual clients may effectively fund interest rate swaps as payments for other instruments (such as fixed-rate mortgages) but do not interact with the product directly.
- Being used most often for hedging purposes, i.e., not as an independent investment but as a **part of a broader investment strategy or transaction**.

These features dictate an approach to distribution that differs from the typical approach of other successful DeFi protocols, such as Uniswap or Aave, which offer relatively simple instruments and often target a retail user base.

The team behind Rho Protocol appreciates the critical importance of distribution in the overall success of an institutional market. The go-to-market strategy will incorporate a mix of product-led and sales-led engagements for a range of B2B and B2B2C client scenarios appropriate for the target client base and the asset class.

8. Building on Rho Protocol

While retail users usually use the protocols' UI to execute trades, many institutional participants prefer to rely on their proprietary solutions and interfaces.

High-volume trading, characteristic of some protocol participants, such as liquidators and market makers, requires a significant degree of automation. Many B2B2C scenarios also require a combination of front-end and back-end integration work.

To minimize the costs of such integrations, Rho Protocol aims to provide its participants with sufficient development tools to lower integration costs by providing many essential methods to interact with the protocol as an SDK.

The current state-of-the-art technology stack for integrating EVM-based blockchains heavily relies on JavaScript as a dominant programming language. Following this trend, the team will provide:

- A GraphQL-enabled subgraphs indexing and organizing contract data and enabling advanced methods for querying data and performing operations such as aggregation, search, and non-trivial filters
- A JavaScript library that would allow developers to query data and execute transactions, performing various actions on the protocols
- Implementation of a Market Maker bot and a Liquidator bot, which could be used as examples for other developers or as is

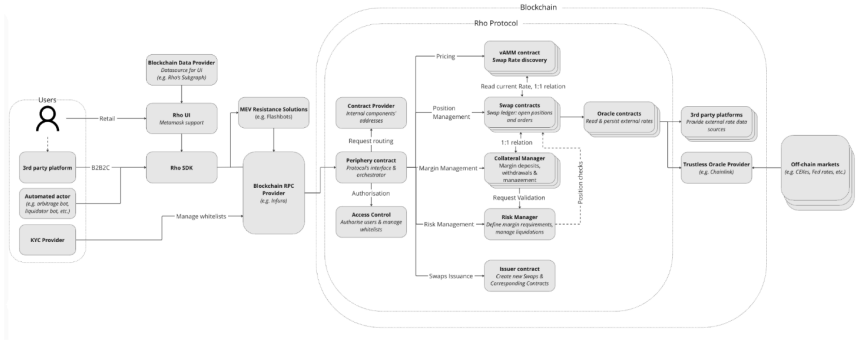
9. To Conclude

1. In traditional finance, Interest Rate Swaps represent the most significant asset class with a total outstanding interest of over $400 trillion, allowing traders to hedge against or speculate on interest rate fluctuations.
2. The growing importance of yields and risk management in the digital asset market (from lending, staking, and other floating rates) makes the availability of similar instruments critical. Rho Protocol estimates that the market allowing to trade current rates in crypto can reach at least $200Bn in outstanding interest.

   With the advancement of securities tokenization and the increase in institutional allocations to digital assets and tokenized instruments, this need will become even more profound, bringing about the advancement of on-chain SEFs (Swap execution facilities) and the arrival of the smart contract-based ISDA agreements.
3. Rho Protocol aims to become the pre-eminent rates market for ecosystems of crypto-native assets and tokenized securities.

   This will be achieved through a set of best-in-class features and approaches, starting from innovative

pricing, high-performance risk management, industry-first permissioned access into DeFi rates market, and an approach to distribution suitable for the nature of the asset class.


Blockchain
Rho Protocol
Users
Retail
B2B2C
Manage whitelists
Blockchain Data Provider
Datasource for UI
(e.g. Rho's Subgraph)
Rho UI
Metamask support
Rho SDK
3rd party platform
Automated actor
(e.g. arbitrage bot, liquidator bot, etc.)
KYC Provider
MEV Resistance Solutions
(e.g. FlashBots)
Blockchain RPC Provider
(e.g. Infura)
Contract Provider
Internal components' addresses
Request routing
Periphery contract
Protocol's interface & orchestrator
Authorisation
Access Control
Authorise users & manage whitelists
Pricing
vAMM contract
Swap Rate discovery
Read current Rate, 1:1 relation
Position Management
Swap contracts
Swap ledger: open positions and orders
1:1 relation
Margin Management
Collateral Manager
Margin deposits, withdrawals & management
Request Validation
Position checks
Risk Management
Risk Manager
Define margin requirements, manage liquidations
Swaps Issuance
Issuer contract
Create new Swaps & Corresponding Contracts
Oracle contracts
Read & persist external rates
3rd party platforms
Provide external rate data sources
Trustless Oracle Provider
(e.g. Chainlink)
Off-chain markets
(e.g. CEXs, Fed rates, etc.)

Appendix B - Sources

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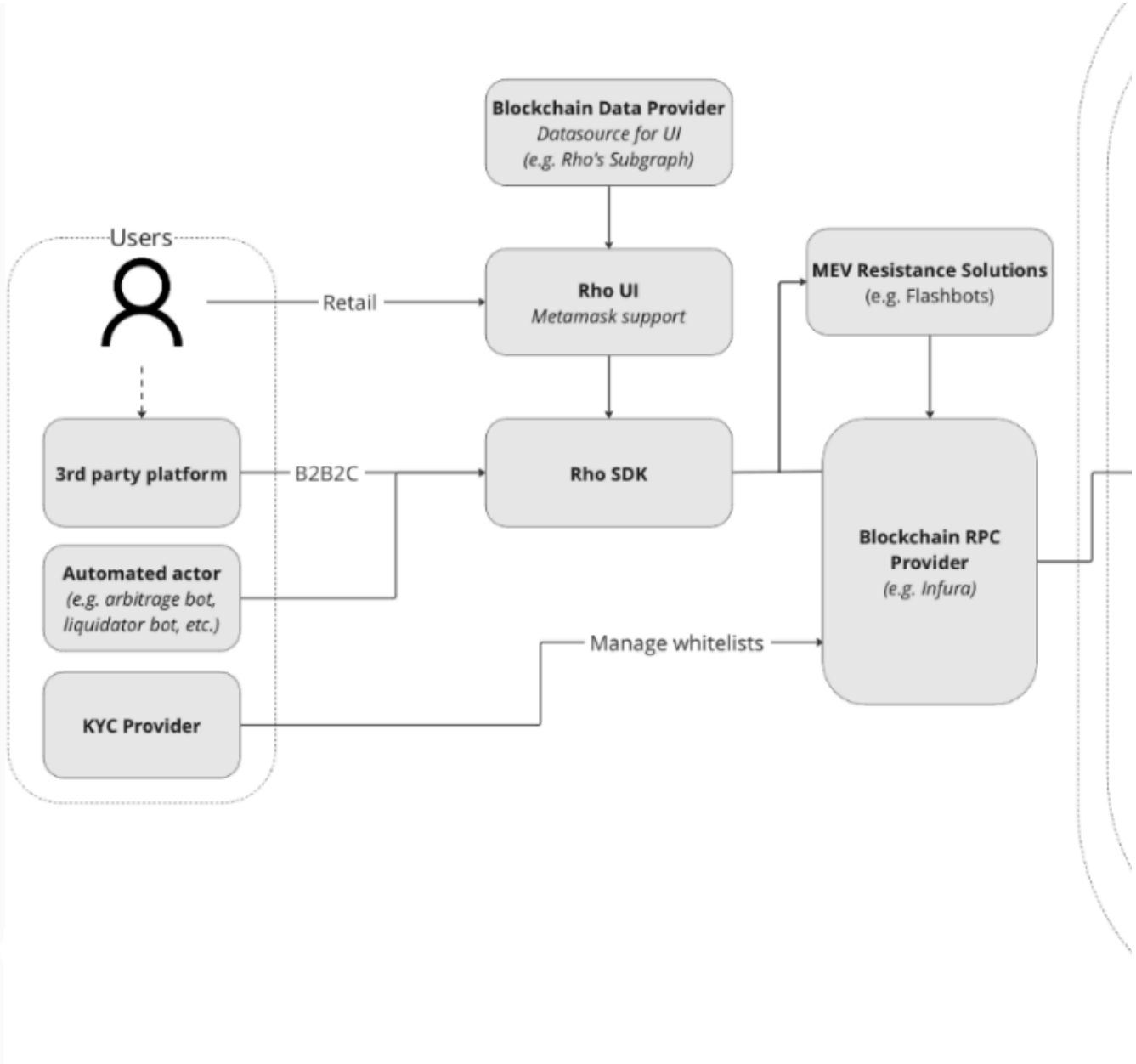
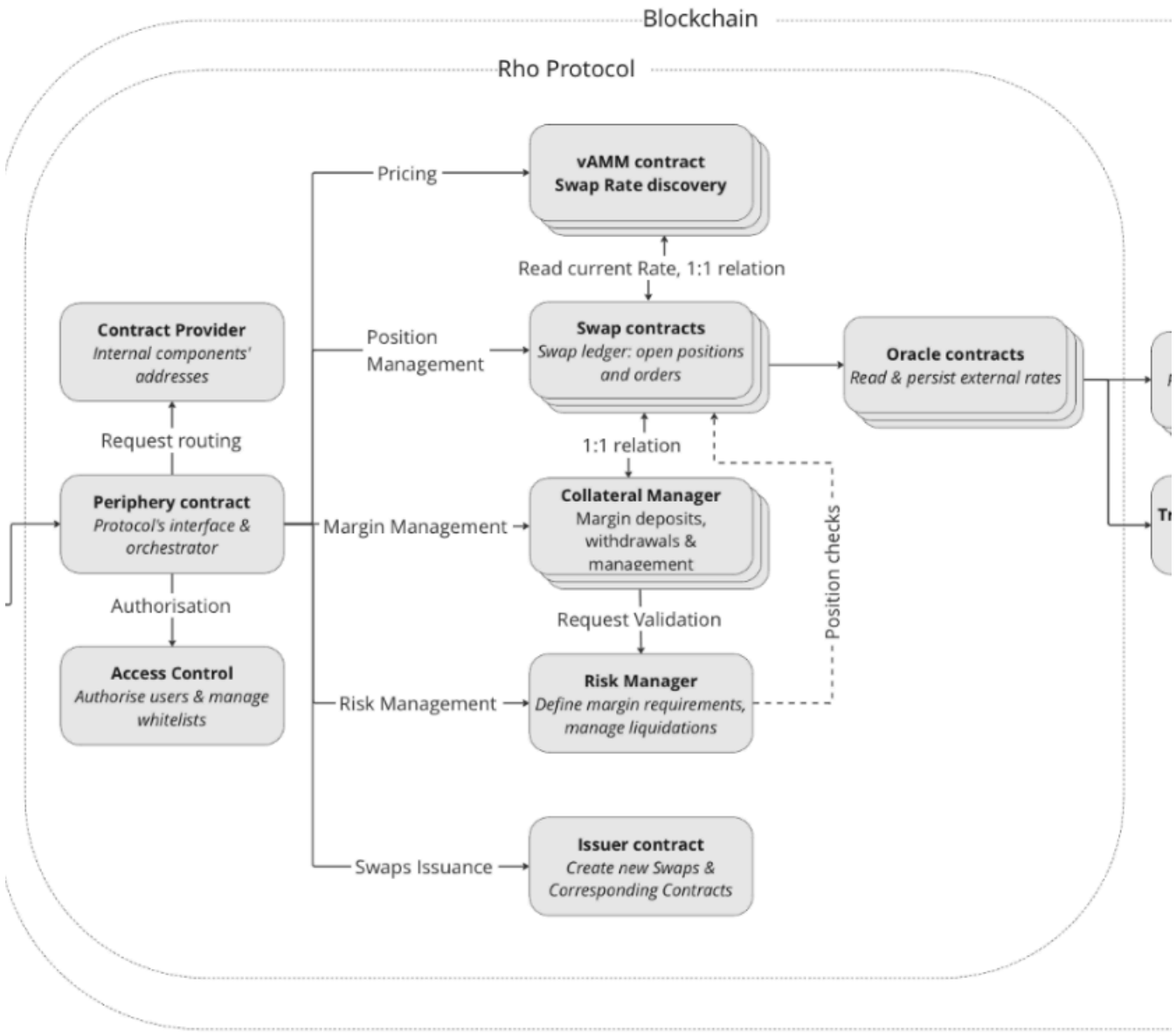
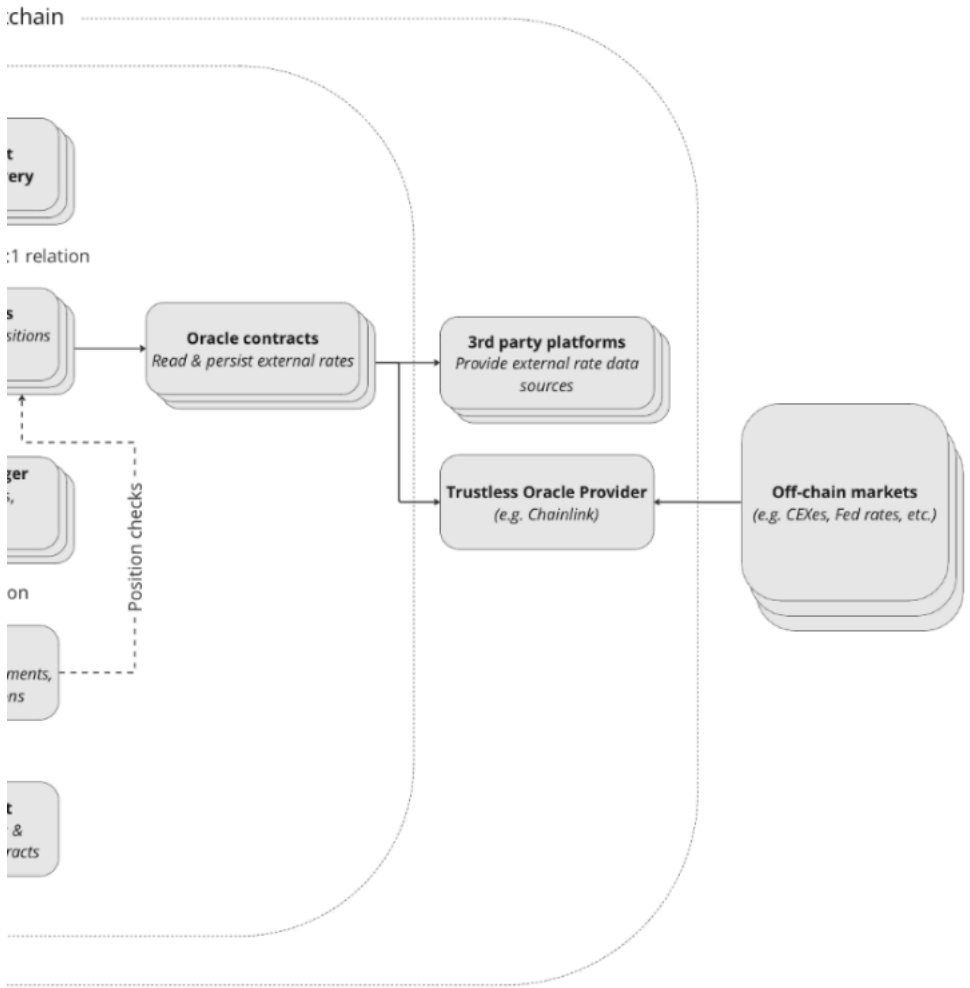

Blockchain Data Provider
Datasource for UI
(e.g. Rho's Subgraph)
Users
Retail
Rho UI
Metamask support
MEV Resistance Solutions
(e.g. Flashbots)
3rd party platform
B2B2C
Rho SDK
Blockchain RPC Provider
(e.g. Infura)
Automated actor
(e.g. arbitrage bot, liquidator bot, etc.)
Manage whitelists
KYC Provider


Blockchain
Rho Protocol
Pricing
vAMM contract
Swap Rate discovery
Read current Rate, 1:1 relation
Contract Provider
Internal components' addresses
Position Management
Swap contracts
Swap ledger: open positions and orders
Oracle contracts
Read & persist external rates
Request routing
1:1 relation
Periphery contract
Protocol's interface & orchestrator
Margin Management
Collateral Manager
Margin deposits, withdrawals & management
Position checks
Authorisation
Request Validation
Access Control
Authorise users & manage whitelists
Risk Management
Risk Manager
Define margin requirements, manage liquidations
Swaps Issuance
Issuer contract
Create new Swaps & Corresponding Contracts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EXECUTIVE SUMMARY

Interest rate derivatives (IRDs) are the **single largest asset class in traditional finance**, with total outstanding interest amounting to over $400 trillion and trading volumes amounting to over $250 trillion in 2022, according to the Bank of International Settlements[1] and ISDA association[2].

In crypto, a number of interest rate-bearing products rose to prominence in the 2018-2022 cycle, with **billions of USD** in payouts accrued yearly.

However, the digital asset ecosystem still lacks an institutional-grade market that would allow investors to efficiently **hedge against or make bets on fluctuations in such rates**.

With the inevitable arrival of large-scale institutional capital and tokenization of securities, an on-chain market that would enable the management of blockchain-native and macro rate risks will become an even more essential part of the market infrastructure.

RHO PROTOCOL: OPPORTUNITY

This paper covers the core principles and purpose of the **Rho Protocol**, a novel **decentralized marketplace allowing professional traders to efficiently exchange rate risk via on-chain swaps and futures** in a secure, efficient, and compliant manner.

Rho Protocol's first family of products are fixed-to-floating interest rate swaps on a diverse set of index rates. In TradFi, this product comprises over 60% of the total outstanding interest in interest rate derivatives.

In digital assets, fixed-to-floating swaps can be used for **hedging against and speculation on future shifts in various on-chain floating rates**, including:

- Centralized and decentralized **lending/borrowing** market rates (conservatively estimated at >$200Bn in centralized loan originations in '22[3] and >$50Bn of DeFi TVL at the cycle peak[4])
- **Staking reward** rates ($70Bn+ staked in top-10 PoS chains[5])
- Other floating rates that already exist or will emerge in the digital assets ecosystem

The above use cases present a lucrative, virtually untapped opportunity worth hundreds of billion USD in outstanding notional and 100s of millions in revenues today.

FUTURE USE CASE: KEY RATE RISK & TOKENIZED SECURITIES

Bulge bracket TradFi firms, with their projects such as Goldman Sachs DAP, BNY Mellon Digital Assets, State Street Digital, and HSBC Orion, are pushing forward with the **tokenization of traditional securities**, including the $100 Tn+ bonds market[6]. As allocations to digital assets and tokenized securities become an everyday practice for institutional investors, the influence of key rates on digital asset prices will become as prominent as in traditional markets.

By successfully addressing the established and emerging use cases, Rho Protocol aims to provide critical risk management tools to the ecosystem and help establish the on-chain equivalents of market-defining reference rates forming yield and swap curves.

Bringing interest rate trading on-chain offers significant benefits for all market participants, including enhanced transparency and efficiency of risk management, efficient near real-time settlements, and reduced agency risks.

TO RECAP

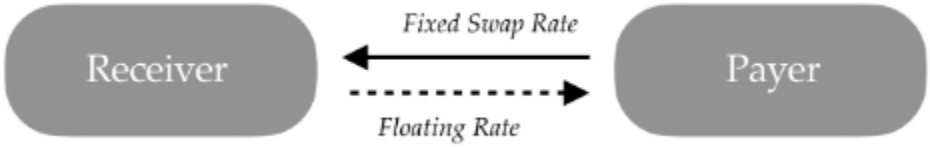
- Rho Protocol is **bringing interest rate derivatives, the largest global asset class worth over $400 trillion in open interest** and used to hedge against or speculate on fluctuations in interest rates, into the DeFi ecosystem.
- Rho Protocol will initially address the rate risks of **crypto lending, staking, and other floating rates today**, addressing the existing **market worth over $300 Bn in outstanding interest**.
- Rho Protocol is **built for institutions** and offers features uniquely catering to this client base, **including innovative market pricing (vAMM), risk management, and compliance (permissioned market sections)** solutions.
- By becoming a pre-eminent digital asset rates market, Rho Protocol will be best positioned to offer on-chain rates trading and management for the arrival of major institutions and securities tokenization.

Subsequent sections further expand on the core components of the protocol and define Rho Protocol's approach and methodology to solving the stated problems.

1. Rho Protocol

INTEREST RATE SWAPS IN TRADITIONAL FINANCE

A swap is an agreement between two parties to exchange cash flows over a period of time. In the interest rate swap (IRS), such cash flows are calculated based on the fluctuations of underlying rates. One of the parties, a “payer”, will be paying the other party, a “receiver”, a pre-agreed fixed swap rate in exchange for floating rate payments determined by a chosen index rate.



Traditional interest rate products are typically used for:

- **Hedging**: Interest rate swaps tend to be used for hedging, typically in the context of a broader investment strategy. For example, banks or corporates may enter a lender/borrower arrangement and use interest rate swaps to sell their rate risk and manage a bond portfolio's duration.
- **Speculation**: Taking a view on the future movements in rates and using the interest rate swaps to benefit from implied mispricing of such movements by the market.
- **Arbitrage**: Taking advantage of arbitrage opportunities that may exist in the existing swap spread (spread between current swap and yield curves) or between swaps and other instruments, either in proprietary trading or when acting as a swap dealer.

USE CASES IN THE DIGITAL ASSET ECOSYSTEM

As mentioned in the executive summary[7], a set of rate-based products rose to prominence in the digital asset ecosystem over the past cycle.

- **Centralized and decentralized lending/ borrowing rates**

Credit is a cornerstone part of any financial arrangement, and in the crypto ecosystem, both centralized and DeFi lending volumes reached new heights during the past cycle.

At the peak, the top-3 DeFi lending protocols (Aave, MakerDao, and Compound) have reached c. $50 Bn of TVL (Total Value Locked). Similarly, before the 2022 market crash, the largest centralized lender, Genesis, reported over $83 Bn in new loan originations in H1 ’22.

As markets mature, the next iteration of digital asset lenders promises to professionalize further and grow the industry, creating demand for traditional risk management instruments for credit markets, such as interest rate and credit default swaps.

The current slowdown in crypto lending presents a unique opportunity to build the tools required to support the next wave of professional lenders.

- **Staking reward rates**

  Proof-of-Stake is the current industry standard consensus mechanism for blockchain networks. As of January ’23, c. $80 Bn of assets on top-20 PoS chains are receiving staking rewards, generating over $4 Bn annually at today’s rates.

  The largest PoS asset, Ethereum, currently stands at only 15% of total asset staked, versus 60-70% averages for most significant networks[8], leaving significant growth potential in USD terms even at today’s depressed market prices.

  A number of participants in the crypto ecosystem heavily depend on staking reward rates as a source of their revenue.

ADVANTAGES OF DEFI AND ON-CHAIN TRADING

- **Enhanced transparency.** Collateral balances and position health metrics can be made available to all members of the ecosystem. At the same time, modern blockchains enhanced with zero-knowledge solutions offer ways to obfuscate specific account and transaction data without compromising overall risk and security.

- **Immutability of records and risk algorithms, possibility of near real-time risk management.** Smart contracts deployed on public blockchain do not offer mechanisms for further human intervention, creating a universal set of rules to be followed by all participants and negating opportunities for a subset of actors to create systemic risks for the ecosystem.
- **Efficient, near real-time T+0 settlement.** In addition to simplifying settlement and cash management and releasing working capital, blockchains may enable complex, conditional, multi-leg DvP-like atomic settlements, minimizing settlement risks and reducing middle & back office operational overheads.

- **Mitigation of agency risks.** Regulators around the globe are primarily concerned with incentivizing better alignment between principal investors, financial intermediaries, and service providers, mitigating inherent agency problems. Offering a trustless and transparent mechanism to manage risk and exposure, on-chain finance optimizes for the best alignment between all actors in the ecosystem. It significantly reduces the burden on the regulators and compliance investment requirements for the institutions.

PROTOCOL ARCHITECTURE

Rho's architecture graph can be found in *Appendix A* of this document

CORE FEATURES & COMPONENTS

Rho Protocol is the first on-chain rates market built with a primary focus on institutions and professional market participants. It includes:

- **Rho Perpetuals: Swap and future contracts** that maximize liquidity, improving pricing and capital efficiency for all participants
- **Rho Pricing Engine:** Introducing a **unique price discovery mechanism (vAMM),** further expanding on the most recent developments on the classic XYK $(x \times y = k)$ model to **best serve yield discovery in a derivatives market**

- **Rho Risk Management**: Cutting-edge **risk management engine**, allowing for maximum utilization and efficiency of the maker and taker capital while maintaining the appropriate level of risk in the ecosystem
- **Permissioned market sections**: By building permissioned sections of the Rho market, with access governed by consortia of trusted market participants, Rho Protocol enables regulated firms and institutions to take full advantage of transparent and efficient on-chain markets in a secure and compliant way
- **Abstractable swap issuance and management**: Enabling issuance, as well as risk and collateral management for a broad range of contracts, starting from interest rate swaps

- **Benchmarking and Forward Rates:** Rho's rates simplify comparisons between swaps of different maturities, enabling the development of a reliable swap rate curve based on zero-coupon flows and the calculation of forward rates.
- **Versatility:** Rho's methodology supports the future expansion into various interest rate derivatives, including forward rate agreements, cross-currency swaps, and more, broadening the scope for portfolio optimization and risk management.

3. Rho Interest Rate Swaps

Rho Interest Rate Swaps are innovative financial instruments designed for professional investors looking to optimize their portfolios, manage risk, and seize market opportunities securely and transparently. Rho merges the well-established efficiency and advantages of traditional interest rate swaps with the evolving dynamics of crypto assets and decentralized finance. By leveraging compounded rates, a virtual Automated Market Maker ("vAMM"), and a unique token-based approach, Rho enables seamless trading between payers and receivers of various underlying rates and maturities.

KEY BENEFITS

- **Compounded Rates:** Rho aligns fixed and floating leg calculations, ensuring an accurate representation of financial returns over time, consistent with major DeFi lenders like Aave and Compound.
- **Liquidity:** Rho's perpetual contract design and standardized term reset dates enhance liquidity, allowing trading between holders of the same risk with different initial maturities and promoting longer-term participation.

- **Benchmarking and Forward Rates:** Rho's rates simplify comparisons between swaps of different maturities, enabling the development of a reliable swap rate curve based on zero-coupon flows and the calculation of forward rates.
- **Versatility:** Rho's methodology supports the future expansion into various interest rate derivatives, including forward rate agreements, cross-currency swaps, and more, broadening the scope for portfolio optimization and risk management.

MAIN TERMS

Rho Interest Rate Swaps are defined by:

- **Swap term reset date** - Analogous to maturity, it is the point at which payments are settled and the fixed swap rate is re-calculated.
- **Swap currency** - Either fiat or crypto, it denominates each party's payment obligations,
- **Underlying floating rate** - Varies based on an external reference index such as Libor or DeFi lending/borrowing rates.

Rho interest rate swaps are single-period contracts with fixed and floating cash flows netted at each term reset and no intermediate cash flow exchanges.

Term reset dates are standardized and set at the end of specific periods, such as the end of a calendar month (e.g., March 31st or June 30th). This aids the concentration of liquidity for the same risk (same remaining time to reset), enabling trading between positions with different original terms.

The perpetual nature of the Rho Protocol allows participants to remain in a swap and continuously hedge fixed-floating exposure across multiple terms. Net swap payouts are calculated by netting the fixed and floating leg values at the end of each term.

As most of Rho's underlying floating rates are compounded and reset in high frequency (seconds), Rho fixed rates are also expressed in annual percentage yields (APY).

$$APY = (1 + ratePerSecond)^{secondsPerYear} - 1 \quad (1)$$

Compounding rates are essential for accurately representing investment growth over time. This convention enables seamless trading between holders across all maturities, providing flexibility and liquidity in the market while facilitating the creation of a reliable swap rate curve that incorporates longer maturities.

SWAP LEGS AND VIRTUAL TOKENS

Floating leg: Rho's floating leg tracks an external index rate, such as lending/borrowing rates on DeFi platforms like Aave or Compound, or other index rates previously mentioned. Rho's Oracle component is responsible for obtaining reliable rate measurements.

A virtual floating token called '**rflToken**' represents the accrued value of floating rates on a specific swap trading platform for a given notional amount, similar to tokens like aETH and aUSDC on Aave.

For example, when creating a swap platform for ETH lending rates on Aave, the protocol generates a virtual token named 'rflaETH' as an index with an initial value of 1 ETH for all participants. Rho's oracle tracks Aave lending rates, adjusting the rflaETH value accordingly. If, after one year, the compounded interest rate for Aave ETH lending reaches 10%, 1 rflaETH would be worth 1.10 ETH. At this point, a trader paying rates on 110 ETH notional would receive 100 rflaETH. Assuming the Aave lending rates accrue 1% in the next month, 1 rflaETH will be worth 1.10*1.01=1.111 ETH, and the trader's floating position will be valued at 111.1 ETH.

Fixed leg: Rho's swap fixed leg effectively represents zero-coupon security. Rho Pricing Engine expands on the concept developed by the team behind Yield Protocol, which emphasized the importance of time to maturity for derivatives markets (as opposed to spot asset prices) and has introduced the concept of 'fyTokens' to model fixed-rate loans.

Similarly, Rho designed a virtual fixed token called '**rfxToken**.' Each rfxToken represents the total payout of 1 (one) Token at term reset.

$$FV = PV \times (1 + YTM)^t \qquad (2)$$

Equation (2) defines the relationship between present value (*PV*), future value (*FV*) at term reset (*t*), and yield-to-maturity (*YTM*). At the swap negotiation, the yield represents the fixed rate of the fixed leg. For example, a theoretical value of 1,000 rfxETH is worth 980.392 ETH today (present value) and would accrue to a 1,000 ETH total payout (future value) at the term reset date, yielding 2% over the period.

From a risk perspective, Trader A is a **receiver** by holding long virtual rfxTokens and short virtual rflTokens positions. This asset and liability position is equivalent to someone who borrows money at a floating rate and invests the same amount on a fixed-rate asset, except there is no actual cash transaction – it is simply a collateralized derivative. At the swap reset date, Trader A will receive a fixed-rate cash flow and pay the accrued interest rates replicating the underlying external index rate. Similarly, Trader B is a **payer** by holding long rflTokens and short rfxTokens positions. Trader B will receive a floating-rate cash flow at the reset date and pay fixed rates. In practice, Rho Protocol calculates the net amount of each participant and redistributes the profits and losses.

At term reset, long and short positions of rfxToken and rflToken determine the swap's fair value. Before the term reset, one can calculate the future value of 'rflTokens' using the market-traded fixed rate. Rho uses similar calculations to maintain appropriate margin levels.

4. Rho Pricing Engine (Virtual AMM)

Rho Pricing Engine utilizes a **virtual Automated Market Maker (vAMM)** model for efficient trading, offering multiple advantages over traditional solutions such as order book-based exchanges:

- **Continuous liquidity** through liquidity pools for instant trade execution, even in less liquid markets
- **Transparency and trust** due to a predeter-mined formula for asset pricing, reducing susceptibility to market manipulation
- **Concentrated liquidity** solutions for efficient capital allocation, optimized returns for liquidity providers, and minimal slippage for price takers
- **Scalable and adaptable** technology, allowing for future growth and expansion into new markets and asset classes

5. Risk Management

Transparency and immutability of collateral and risk-management mechanisms are undoubtedly the most attractive features of DeFi and broader on-chain trading.

Rho Risk Engine is responsible for defining and maintaining an appropriate level of risk on the protocol, including all aspects of margin management and liquidations. It is designed to support a range of swap instruments, starting with interest rate swaps.

Core components of the risk engine, responsible for the overall health and stability of the protocol, are:

- **Collateral Manager contract** that holds and releases the traders' margin verifies and orchestrates liquidation events
- **Independent liquidators**, appropriately incentivized to monitor the health of the traders' positions and promptly take over those insufficiently collateralized
- **Rho Stability Fund** provides an additional backstop in the unlikely case that liquidity in the protocol becomes insufficient to perform required liquidations and maintain an acceptable level of risk in the ecosystem

MANAGED RISKS

A collective exposure of all the protocol's traders to the following two risks are the main components of the systemic risk present in the ecosystem. Rho Risk Engine's core purpose is to maintain the appropriate level of this risk, ensuring security for all market participants.

- **Market Risk**: The risk arising from shifts in market rates to the index, or relevant token prices, between observations.
- **Liquidity Risk**: The cost of liquidating a position. Such costs may include any transaction costs, slippage or spread associated with unwinding a position. This risk becomes more significant in peak markets.

Maintaining collateral sufficient to account for both risks is critical for the market's health and its participants' security.

DISTRIBUTION

Bootstrapping and maintaining liquidity is one of the most significant challenges for any new market, including any protocol in the DeFi ecosystem.

Core features of swaps as an asset class and interest rate swaps in particular that pre-determine Rho Protocol's distribution strategy are:

- **Deeply institutional nature of the instrument:** over 97% of all swaps are traded by financial institutions and other professional market participants[9]. Individual clients may effectively fund interest rate swaps as payments for other instruments (such as fixed-rate mortgages) but do not interact with the product directly.
- Being used most often for hedging purposes, i.e., not as an independent investment but as a **part of a broader investment strategy or transaction.**

These features dictate an approach to distribution that differs from the typical approach of other successful DeFi protocols, such as Uniswap or Aave, which offer relatively simple instruments and often target a retail user base.

The team behind Rho Protocol appreciates the critical importance of distribution in the overall success of an institutional market. The go-to-market strategy will incorporate a mix of product-led and sales-led engagements for a range of B2B and B2B2C client scenarios appropriate for the target client base and the asset class.

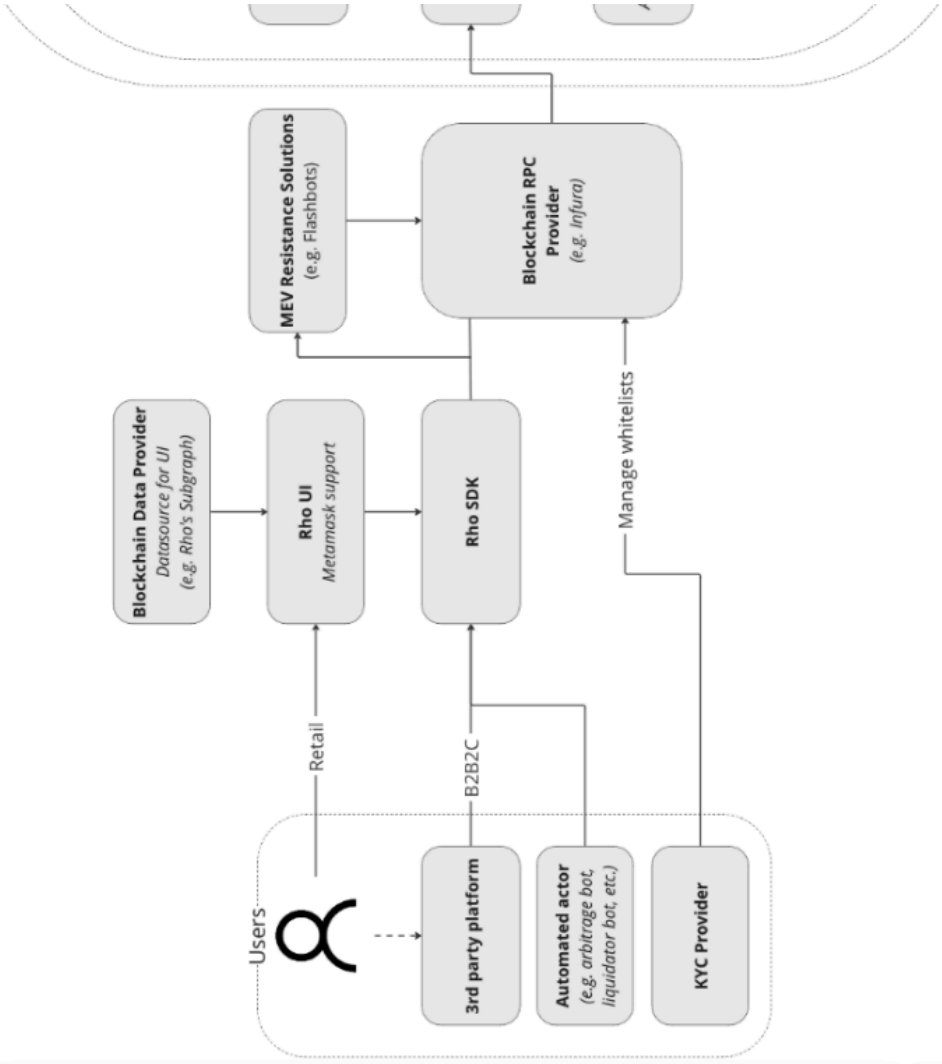
1. In traditional finance, Interest Rate Swaps represent the most significant asset class with a total outstanding interest of over $400 trillion, allowing traders to hedge against or speculate on interest rate fluctuations.
2. The growing importance of yields and risk management in the digital asset market (from lending, staking, and other floating rates) makes the availability of similar instruments critical. Rho Protocol estimates that the market allowing to trade current rates in crypto can reach at least $200Bn in outstanding interest.

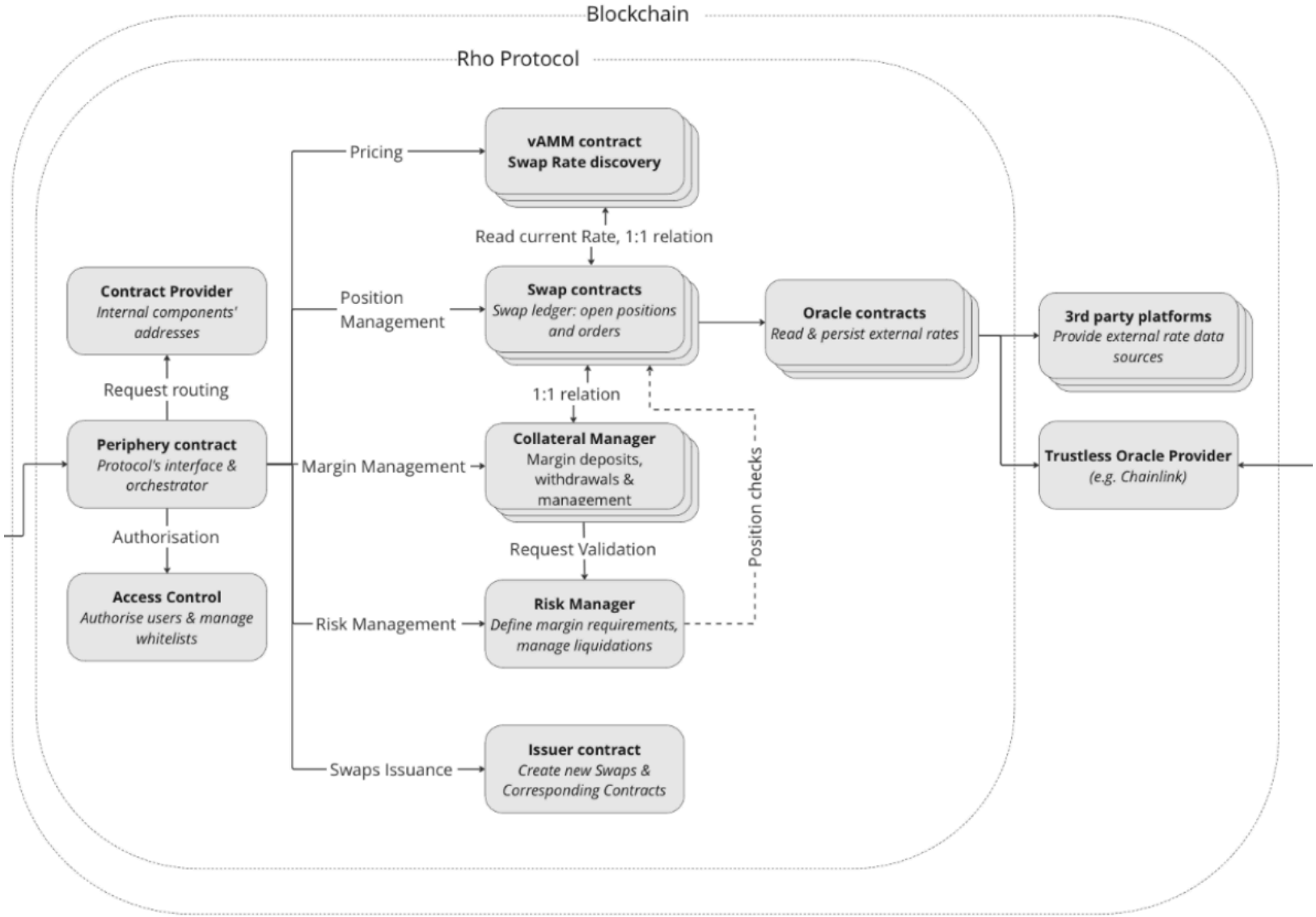
With the advancement of securities tokenization and the increase in institutional allocations to digital assets and tokenized instruments, this need will become even more profound, bringing about the advancement of on-chain SEFs (Swap execution facilities) and the arrival of the smart contract-based ISDA agreements.

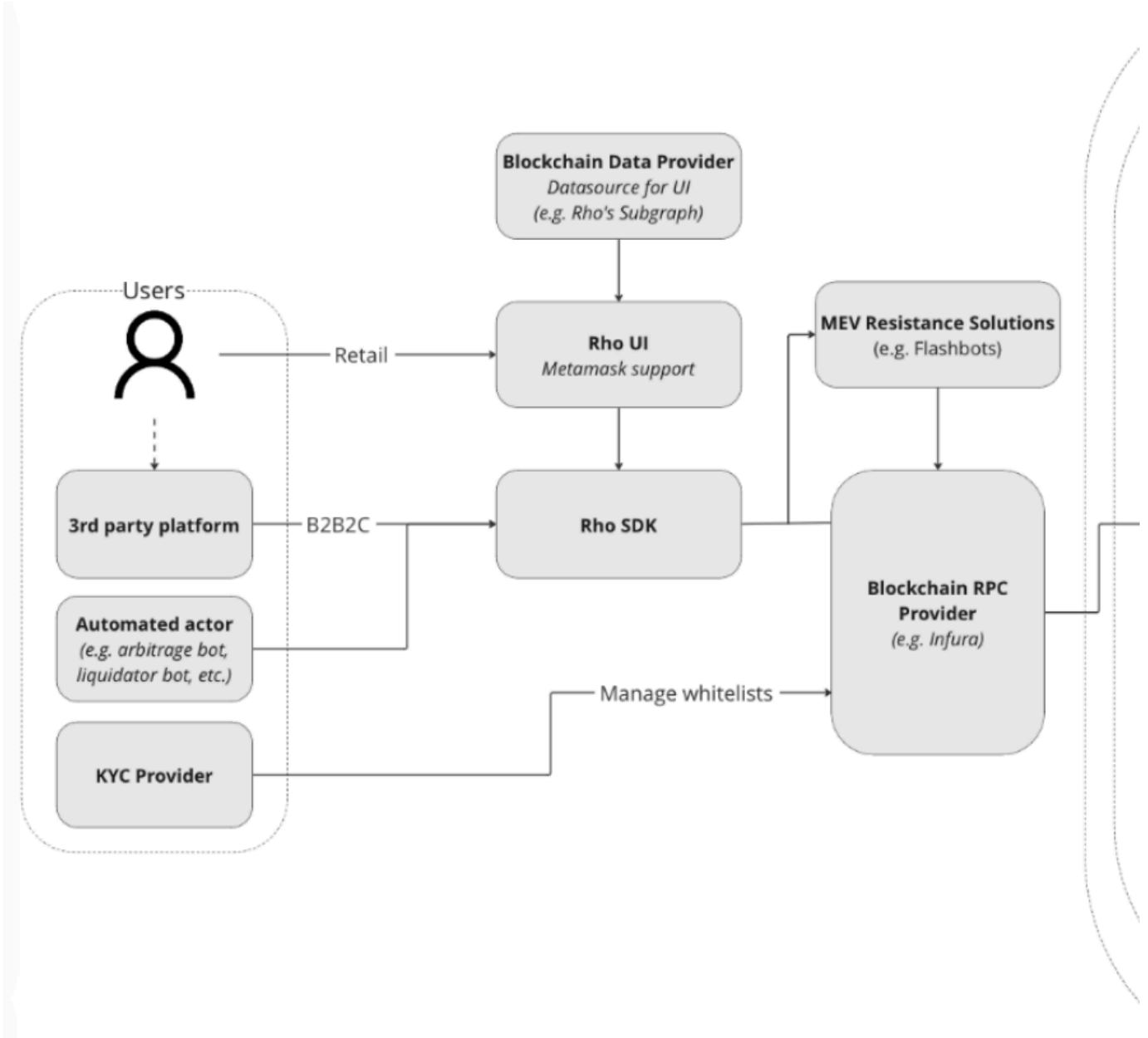
3. Rho Protocol aims to become the pre-eminent rates market for ecosystems of crypto-native assets and tokenized securities.

   This will be achieved through a set of best-in-class features and approaches, starting from innovative

pricing, high-performance risk management, industry-first permissioned access into DeFi rates market, and an approach to distribution suitable for the nature of the asset class.




Blockchain
Rho Protocol
Pricing
vAMM contract
Swap Rate discovery
Read current Rate, 1:1 relation
Contract Provider
Internal components' addresses
Position Management
Swap contracts
Swap ledger: open positions and orders
Oracle contracts
Read & persist external rates
3rd party platforms
Provide external rate data sources
Request routing
1:1 relation
Periphery contract
Protocol's interface & orchestrator
Margin Management
Collateral Manager
Margin deposits, withdrawals & management
Trustless Oracle Provider
(e.g. Chainlink)
Position checks
Authorisation
Request Validation
Access Control
Authorise users & manage whitelists
Risk Management
Risk Manager
Define margin requirements, manage liquidations
Swaps Issuance
Issuer contract
Create new Swaps & Corresponding Contracts


Blockchain Data Provider
Datasource for UI
(e.g. Rho's Subgraph)
Users
Retail
Rho UI
Metamask support
MEV Resistance Solutions
(e.g. Flashbots)
3rd party platform
B2B2C
Rho SDK
Blockchain RPC Provider
(e.g. Infura)
Automated actor
(e.g. arbitrage bot, liquidator bot, etc.)
Manage whitelists
KYC Provider