GHO

A flexible, decentralized stablecoin

Emilio Frangella, Steven Valeri*

October 2022

*The Aave Companies are a group of software development companies that develop open source, blockchain-based software for Web 3.0, the next generation of the internet. The Aave Companies developed the code design for GHO and have prepared this technical paper.

Summary

The below summary is solely an introduction to the GHO technical paper and is intended only to describe the software-based mechanisms for GHO. Nothing in this paper is intended to be an offer or solicitation to mint or otherwise participate in any activity with GHO.

This technical paper describes GHO (pronounced "GO"), a decentralized, overcollateralized crypto-asset intended to maintain a stable value. GHO is minted upon the supply of crypto-assets in excess of the value of GHO to be minted. This is intended as a stabilization mechanism to reduce the impact of any price fluctuations on the value of the underlying collateral during periods of volatility. GHO is created ("minted") or liquidated ("burned") by Facilitators. GHO is designed to accrue interest when supplied to a liquidity protocol, and this interest rate is determined by Aave Governance.

1 Introduction

This paper describes the fundamental characteristics of GHO, a flexible, decentralized, configurable token designed to maintain a stable value. The code design includes basic software-based mechanisms for the emission and destruction of GHO, for controlling the stability of GHO, and for the role of Aave Governance and Facilitators in managing and maintaining GHO.

Stablecoins are digital currencies pegged to reserve assets as a stabilization mechanism to prevent fluctuations in value. Designed to reduce volatility compared to unpegged assets like Ethereum, overcollateralized stablecoins, like GHO, are backed by excess collateral, which means that the value of the collateral is higher than the value of the outstanding tokens. If collateralized positions drop, a liquidation (or other stabilization mechanisms) is triggered to protect GHO from fluctuating away from its peg.

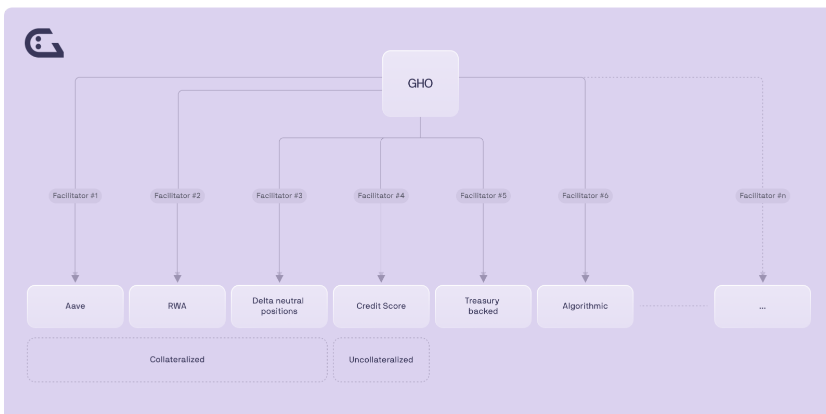
2 GHO Dynamics

Available in the form of an ERC20 token on the Ethereum Mainnet, GHO will be minted (at a user's direction) through various strategies. These strategies can be enacted by different entities that may employ varying strategies for integrating with GHO (each entity, a "Facilitator"). A Facilitator ("F") can trustlessly generate (and burn) GHO tokens. Each Facilitator is assigned a Bucket ("B") with a specified capacity. The Capacity ("C") represents the upward limit of GHO that a specific Facilitator can generate. The amount of GHO tokens generated per each Facilitator is called Level ("L"). Fundamentally, all Facilitators must adhere to the following equation:
Given a set of Facilitators $F_0, F_1, ...F_N - 1$ each of which is associated with a certain Bucket with capacity ("CB_t") and a current Bucket level at a given time

("LB_t"). The Available Supply (AS_{GHO_t}), is the maximum amount of GHO available to be minted through all the Facilitators at a given time t, defined as follows:

$$AS_{GHO_t} = \sum_{n=0}^{N-1} max(0, CB(n)_t - LB(n)_t)$$

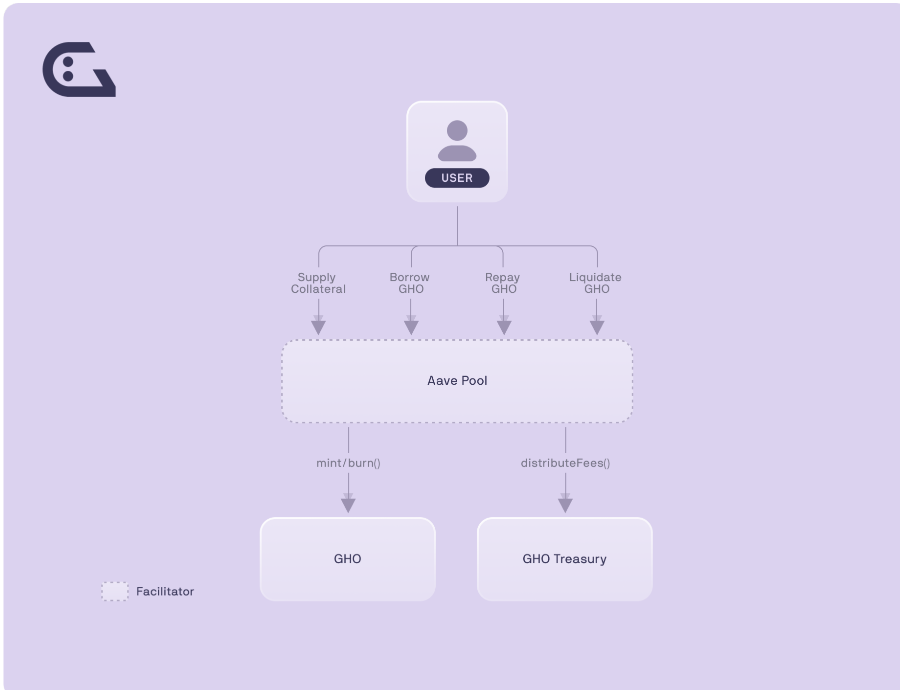
Facilitators can be substantially different in technical nature. As mentioned above, stablecoins can differ depending on the stabilization mechanisms they employ. With GHO, the idea is to employ potentially all stabilization mechanisms, in a controlled fashion via the Aave DAO by properly balancing each Bucket capacity to not compromise overall system collateralization and stability.



3 The First Facilitator: The Aave Protocol

The Aave Protocol ("Aave") is a liquidity protocol available on Ethereum and various other L1 and L2 networks. Aave allows users to supply a range of crypto-assets and borrow against them while simultaneously earning yield. The scope of this technical paper does not include describing how Aave works, as this is discussed in the Aave white papers [1][2][3].

This chapter aims to explain how the Aave DAO works as the initial Facilitator, which supports the GHO supply in a decentralized, permissionless fashion. The Aave-GHO integration employs similar mechanisms as any other asset listed on Aave (i.e., a specific GHO AToken and GHO Debt Token will be deployed). These tokens can be used, upon approval by the Aave DAO, for the GHO token on the Aave Ethereum Pool. The diagrams below describe how the GHO AToken and GHO Debt Tokens function in relation to user interactions:

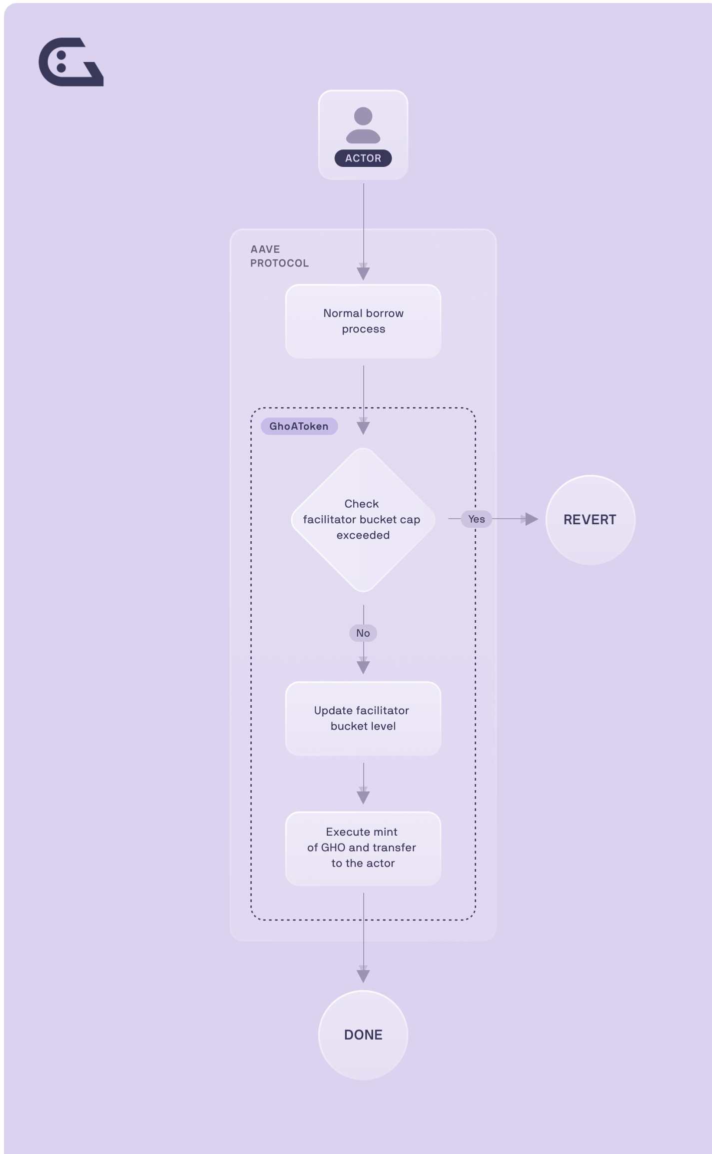


3.1 GHO Supply

Given the nature of GHO and the way it interacts with Aave, GHO cannot be supplied on the Aave Ethereum Pool. Therefore, the supply action fails if the specified asset is GHO.

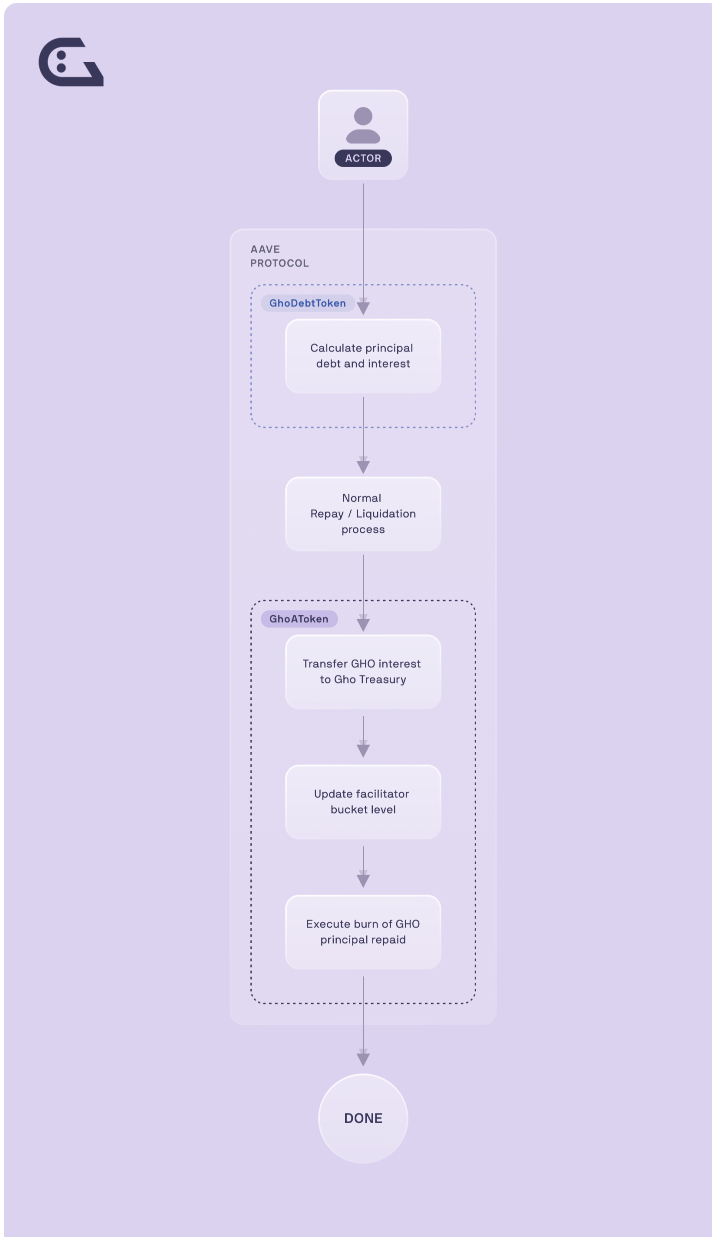
3.2 GHO Borrow

When borrowing GHO from the Aave Ethereum Pool, based upon standard collateralization requirements built into the smart contracts, new GHO and GHO Debt Tokens are automatically generated and transferred to the user. During a borrow transaction, the current Bucket level for the Facilitator is updated to reflect the new amount minted. The borrow action fails if the amount requested exceeds the Bucket capacity assigned to the Facilitator.



3.3 GHO Repay/Liquidate

When repaying/liquidating GHO from the Aave Ethereum Pool, after automatic and smart contract-based collateralization checks, GHO is returned from the user/liquidator to the pool and burned. The interest repaid is automatically transferred to the Aave DAO treasury while the original supply is burned, and the Bucket level for the Facilitator is decreased.



3.4 GHO Interest Rates

Compared to other assets within Aave, GHO smart contracts do not follow the usual supply and demand dynamics, as the supply side does not exist. Therefore, it is impossible to algorithmically determine interest rates relying on utilization rates in the same fashion as other stablecoins (e.g., USDC). For GHO, the Aave integration requires interest rates to be determined by a coordination entity, specifically, Aave Governance, which will statically adjust interest rates depending on the need for the GHO supply to contract/expand. This will be achieved in Aave through a specific "InterestRateStrategy" deployed independently by each Facilitator, featuring a method to update the GHO borrow rate and callable only by an entity approved by Aave Governance.

3.5 A Discount Model on Borrow Rates

The Aave-GHO integration features a novel implementation providing utility to the Aave community through a borrowing rate discount model. The discount model applies to Safety Module participants. The Safety Module is a crucial component of the Aave ecosystem designed to be a risk mitigation mechanism for Aave; more details on the Safety Module are available in the Aave-nomics paper [4]. The discount model is interchangeable and can be redesigned and replaced if needed. Aave Governance has the right to determine the discount model parameters and eventually propose changes to the current implementation. The initial design of the discount model aims to provide additional utility to stkAAVE token holders (stkAAVE represents a tokenized share of the Safety Module).

The initial implementation defines:

- A threshold T: Maximum amount of GHO that can be generated at discount through the Borrow interaction within the Aave Protocol, per stkAAVE held.
- A total discount rate R_d: The discount on the borrow rate that the user will receive per discounted GHO.

Given the discount model, the final borrow rate a user will receive is defined as follows:

$$R_{GHO_u} = \begin{cases} R_{GHO} & \text{if } B_{stkAAVE}(u) = 0 \\ R_{GHO} - R_{GHO} * R_d & \text{if } B_{stkAAVE} > 0 \wedge P(u) \leq B_{stkAAVE} * T \\ \frac{R_{GHO} * P_{nd}(u) + (R_{GHO} - R_{GHO} * R_d) * P_d(u)}{P(u)} & \text{if } B_{stkAAVE} > 0 \wedge P(u) > B_{stkAAVE} * T \end{cases} \tag{1}$$

Where:

- u is the user
- $B_{stkAAVE}(u)$ is the stkAAVE token balance of the user u
- R_{GHO} is the current, governance-controlled borrow rate for GHO (without any discount applied), $0 <= R_{GHO} <= 1$

- T is the maximum amount of GHO that can be generated at discount through the Borrow interaction within the Aave Protocol, per stkAAVE held (per user u)
- R_d is the global discount rate, the discount on the borrow rate that the user will receive per discounted GHO Tokens, $0 <= R_d <= 1$
- $P(u)$ is the current principal borrowed by u, in GHO tokens
- $P_d(u)$ is the part of the principal at a discount (when $B_{stkAAVE}(u) > 0$), $P_d(u) = B_{stkAAVE}(u) * T$
- $P_{nd}(u)$ is the part of the principal that exceeds the discount (when $B_{stkAAVE}(u) > 0$), $P_{nd}(u) = P(u) - P_d(u)$
- R_{GHO_u} is the borrow rate for GHO for the user u with discount applied, $0 <= R_{GHO_u} <= 1$

An example; Given:

- $R_{GHO} = 0.02$
- $T = 100$ (100 GHO at discount per stkAAVE held)
- $R_d = 1$ (100% discount on the discounted GHO)
- $P(u) = 200$ (user borrowed 200 GHO)
- $B_{stkAAVE}(u) = 1$
- $P_d(u) =B_{stkAAVE}(u) * T = 100$
- $P_{nd}(u)$ =P(u) - $P_d(u) = 100$

Therefore,
$R_{GHO_u} = \frac{R_{GHO}*P_{nd}(u)+(R_{GHO}-R_{GHO}*R_d)*P_d(u)}{P(u)}$
$R_{GHO_u} = \frac{0.02*100+(0.02-(0.02*1))*100}{200} = 0.01$

3.6 Discount Accounting Implementation

GHO tracks accumulated interest on outstanding debt via a global borrow index parameter and user-based scaled balances, programmed into the code. This mimics the mechanism for earning interest on other assets in the Aave V2 and V3 pools. For more details on how interest set via Aave Governance is accumulated using an index value, reference the AaveV2 Whitepaper [2]. Additional logic is implemented on top of this accumulation to calculate and apply user discounts.

3.6.1 Initial Scaled Balance

Per the interest accumulation mechanism, a user's outstanding debt equals their scaled balance times the current global borrow index. Therefore, when users first borrow, their initial scaled balance is calculated by dividing their principal borrowed by the current borrow index.

$$B_{debt}(u) = ScB(u) * I$$

$$ScB(u)_{t1} = P(u)/I_{t1}$$

3.6.2 Non-Discounted Interest Accumulation

Over time, the borrow index will increase as interest accumulates. In a situation without discounts, at time $t2$, after the initial borrow, the user's total GHO balance is equal to their scaled balance times the updated global borrow index at $t2$. The user's balance increase from interest can also be calculated. Given there are no discounts, 100% of the balance increase from the global interest rate is applied to the user's balance.

$$B_{debt}(u)_{t2} = ScB(u)_{t1} * I_{t2}$$

$$\Delta B_{debt}(u) = ScB(u)_{t1} * I_{t2} - ScB(u)_{t1} * I_{t1}$$

3.6.3 Discounted Interest Accumulation

Each time a user's GHO debt balance is updated, Aave (the protocol) checks if the user should receive a discount per the active GHO discount strategy contract. If the user is entitled to a discount rate (R_d), that value is stored by the protocol. The next time the user's interest is accumulated, their discount rate is applied to their balance increase to calculate the discount ($D(u)$) they will receive.

$$D(u) = R_d * (ScB(u)_{t1} * I_{t2} - ScB(u)_{t1} * I_{t1})$$

The borrow index is a global variable applied to all user balances, so it cannot be used or adjusted to account for individual user discounts. Therefore, the discount is removed from the user's scaled balance. To do this, the discount amount must be scaled ($ScD(u)$). The user's scaled discount is removed from their scaled balance and that result can be multiplied by the current borrow index to calculate the user's debt balance.

$$ScD(u) = D(u)/I_{t2}$$

$$B_{debt}(u)_{t2} = (ScB(u)_{t1} - ScD(u)) * I_{t2}$$

3.7 Price Stability with the Aave Facilitator

As a Facilitator employs an over-collateralization strategy, it also employs technical mechanisms for price stability that are similar to other over-collateralized stablecoins, specifically:

- Users can always borrow, repay and liquidate GHO at \$1. This creates an arbitrage opportunity for borrowers; whenever the market price of GHO is below \$1, borrowers have incentive to purchase GHO at a discounted price and repay/liquidate, earning on the difference. When the GHO price is above \$1, there is incentive to generate new GHO and sell on the market, repaying once the price has lowered enough to be profitable.
- The Aave governance can control the borrow rate R_{GHO}, the discount threshold T and the discount rate R_d to stimulate the generation (expansion) or destruction (contraction) of GHO.

3.8 Price Oracle for GHO

The Aave Protocol will be programmed to always use to price of 1 GHO = \$1. This is different from using market pricing via oracles for other crypto assets. This creates stabilizing arbitrage opportunities when the price of GHO fluctuates as indicated in the section above.

References

[1] Aave. *V3 Technical Documentation*. URL: https://github.com/aave/aave-v3-core/blob/master/techpaper/Aave_V3_Technical_Paper.pdf.

[2] Aave. *Aave V2 Whitepaper*. URL: https://github.com/aave/protocol-v2/blob/master/aave-v2-whitepaper.pdf.

[3] Aave. *Aave V1 Whitepaper*. URL: https://github.com/aave/aave-protocol/blob/master/docs/Aave_Protocol_Whitepaper_v1_0.pdf.

[4] Aave. *Aavenomics Documentation*. URL: https://docs.aave.com/aavenomics/.