The Graph Protocol Specification

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San Francisco, CA

July 11, 2022

Preface

This document is an evolving specification overview of mechanisms in The Graph protocol. Multiple existing media exist for learning about The Graph,† and these differ from our scope. Here our focus is on the mathematical and mechanism design aspects of various components within The Graph, which includes (but is not limited to) finalized descriptions of implemented Graph Improvement Proposals (GIPs). For any corrections to this document, please contact `howard@edgeandnode.com`.

– Howard Heaton

†For example, see The Graph Academy and the The Graph's Docs.

Contents

List of Figures

List of Tables

Chapter 1: Introduction

[A] mathematical problem should be difficult in order to entice us, yet not completely inaccessible, lest it mock at our efforts. It should be to us a guide post on the mazy paths to hidden truths, and ultimately a reminder of our pleasure in the successful solution.

– David Hilbert[1]

[1] Taken from the "Mathematical Problems" lecture delivered before the International Congress of Mathematicians in 1900 [2].

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Sample Table Goes here
Table Contents...

Table 1.1: Long caption goes here

[Insert Dependency Chart]

Figure 1.1: Graph for chapter dependencies.

Part I: Curation

Chapter 2: Sample Chapter

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Chapter 3: Bonding Curves

Knowledge work is not an assembly line, and extracting value from information is an activity that's often at odds with busyness, not supported by it. – Cal Newport [cite]

[This spec section will be updated using the Safe and Fair Continuous Organizations work, as that progresses.]

Curators perform an essential role within The Graph. They operate as knowledge workers that investigate subgraphs and identify which of these are of quality and ought to be indexed by The Graph's APIs. For an elementary introduction, we refer readers to existing guides [cite]. This chapter overviews bonding curves, principal protected variations, their incentives, the composition of two levels of bonding curves, and [return and complete].

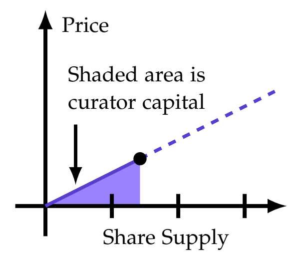

Figure 3.1: Example linear bonding curve with a single curator. The area of purple region is the amount of GRT paid by curator.

Bonding Curve Introduction

Curators provide signal on a particular subgraph by transacting GRT to mint shares of a continuous organization (CO) [cite white paper] associated with that subgraph. That is, each subgraph's bonding curve is unique. The price of shares is defined as a function $p(s)$ of the number of minted shares s (*i.e.* total currently existing supply), increasing as the number of shares increases. In The Graph, these curves are linear (*e.g.* see Figure 3.1), *i.e.* there is[1] $k > 0$ such that

$$p(s) = k \cdot s. \tag{3.1}$$

[1] The implemented value as of writing is $k = 0.03$.

Curators can burn there shares in return for GRT. We emphasize curators can profit by burning shares if, after they mint shares, several more shares are minted by other curators.[2] We refer readers to prior works (*e.g.* with fixed reserve ratios)

[2] Many discussions have ensued about phenomena relating to this feature.

for more bonding curve context [cite].

Composition of Bonding Curves

Two levels of bonding curves are used. The inner level, called the deployment curve, is accessible only to subgraph developers. The outer curve is referred to as the Graph Name Service (GNS) level curve, which is where exo-curators mint and burn shares. We define the composition of two bonding curves as follows.

$$p_g \triangleq (\text{GNS level curve}) \quad \text{and} \quad p_d \triangleq (\text{Deployment level curve}). \tag{3.2}$$

The composed curve is...

Principal-Protected Bonding Curves

Here we consider a new principal-protected bonding curve (PPBC) construction, unique to The Graph,[3] in which shares are minted proportional to reserves deposited. When shares are burned, users are guaranteed to be able to withdraw the amount they had deposited for those shares. In other words, usage of such a PPBC incurs no principal risk. We restrict our attention to two archetypal curators.[4] Some agents curate solely for the reward of capital gains from bonding curves and curation royalties. Other agents (*e.g.* some dApp developers) curate solely to get a particular subgraph being indexed (as use of the subgraph is relevant to the agents). We categorize these two types, based on motivation by exogenous and endogenous factors.

[3] PPBCs were initially proposed in GIP-0025. There they were proposed to be used at the subgraph deployment level.

[4] Although some curators do not cleanly fit into one category, portions of their behaviors can be analyzed by considering these two archetypes.

- *Exo-Curators* are motivated by external effects of a subgraph being indexed.
- *Endo-Curators* seek royalties and capital gains directly obtained by signaling.

The non-fungibility of PPBC shares requires special considerations when designing any kind of secondary market, automated market maker (AMM) or pooled funds that accept such shares.

For further details, we refer readers to the yellow paper[5] [cite].

[5] This technical paper proposes and analyzes the signal renting automated market maker used by The Graph. This is tied with GIP–0029.

Part II: Rewards

Chapter 4: Indexing Rewards

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Relevant Links

- `https://observablehq.com/@zerim/stake-rebate-paramter-sweep`
- `https://thegraph.com/blog/the-graph-network-in-depth-part-2`

Chapter 5: Arbitrum Rewards

You only find out who is swimming naked when the tide goes out.

– Warren Buffett [cite]

Introduction

With rising gas costs, there is great community interest in a Layer 2 (L2) scaling solution for The Graph's protocol. As mentioned in GIP-0031, several forums discussions highlight this need, and conversations among core development teams point toward optimistic rollups, and particularly Arbitrum, as a reasonable first step in this direction. This is a significant change, however, and not risk-free. For example, this may yield uncontrolled GRT production on L2, which could be a disastrous risk.[1] Hence, we use an Arbitrum protocol implementation that works initially as a devnet, with no indexing rewards and therefore useful for experimental subgraphs. This is a first step towards running the protocol with rewards on Arbitrum, assuming the devnet is a successful experiment. It would be beneficial for the mechanism for rewards distribution to be implemented from the beginning, so that governance can gradually increase rewards in Arbitrum as the community gains confidence in the L2 network.

[1] This motivates the chapter's opening quote about risk management.

This chapter overviews deployment of The Graph Protocol to the Arbitrum One L2 blockchain.[2] We outline how the protocol coordinates between Ethereum mainnet (L1) and the protocol on L2. The community will gradually move to L2, starting with a "devnet" phase in which indexing rewards are disabled, and then slowly increasing the proportion of rewards in L2. The scheme here builds upon a prior distribution proposal on Ethereum [1].

[2] A more expanded version of this chapter is provided in GIP-0034, which was principally architected by Pablo Carranza Vélez.

Definitions

Several variables are used to describe the relations for rewards herein.

$$\rho \equiv \text{rewards per signal} \tag{5.1a}$$

$$R \equiv \text{rewards} \tag{5.1b}$$

$$p(t) \equiv \text{total GRT supply produced by accumulating rewards up to time } t \tag{5.1c}$$

$$\sigma \equiv \text{signal, } \textit{i.e.} \text{ tokens on curation contract} \tag{5.1d}$$

$$\omega \equiv \text{allocated tokens, } \textit{i.e.} \text{ tokens from indexer's stake that are allocated to a subgraph} \tag{5.1e}$$

$$\gamma \equiv \text{rewards per allocated token} \tag{5.1f}$$

$$r \equiv \text{issuance rate (including the +1)} \tag{5.1g}$$

$$S \equiv \text{set of all subgraphs} \tag{5.1h}$$

$$A \equiv \text{set of all allocations} \tag{5.1i}$$

Reward Calculations

Reward distribution follows the approach of Batog *et al*. [1], but here distribution is done twice: first, treating each subgraph as a staker for the total rewards (computing rewards per signal), and secondly, treating each allocation as a staker for the subgraph's rewards (computing rewards per allocated token). The global reward function R is defined to encompass the rewards functions R_1 and R_2 for L1 and L2, respectively. That is,

$$R(t) = R_1(t) + R_2(t), \quad \text{for all times } t. \tag{5.2}$$

The evolution of rewards is captured via "snapshotting" of differences,[3] *i.e.*

$$R(t) = R(t_0) + \Delta R(t; t_0), \quad \text{for all times } t \geq t_0, \tag{5.3}$$

[3] Snapshotting is a key tool for executing efficient updates in Solidity. Rather than update continuously, we aim to update precisely when there are external changes to the system. This enables us to only keep track of a snapshot of the system at a previous time in order to update it to the present.

where $\Delta R(t; t_0)$ is the change in rewards distributed between time t_0 and t. Rewards accrue continuously according to the issuance rate r, and so

$$\Delta R(t; t_0) = p(t_0) r^{t-t_0} - p(t_0). \tag{5.4}$$

The proportion of updates to each chain are defined analogously via

$$R_1(t) = R_1(t_0) + (1 - \lambda(t_0))\Delta R(t; t_0), \tag{5.5a}$$

$$R_2(t) = R_2(t_0) + \lambda(t_0)\Delta R(t; t_0) \tag{5.5b}$$

Then

$$p(t_0') = p(t_0) + \Delta R(t_0', t_0). \tag{5.6}$$

Drip Function

Test

Rewards Distribution

$$R_i(t) = R_i(t_0) + \Delta R_i(t;\ t_0). \tag{5.7}$$

$$\Delta R(t;\ t_0) = p(t_0) r^{t-t_0} - p(t_0) \tag{5.8a}$$

$$\Delta R_1(t;\ t_0) = (1 - \lambda(t_0))\, \Delta R(t;\ t_0) \tag{5.8b}$$

$$\Delta R_2(t;\ t_0) = \lambda(t_0) \Delta R(t;\ t_0). \tag{5.8c}$$

Here R_i is stored in the reservoir for each layer.

Burning Denied/Unclaimed Rewards

Minting on L1 versus L1 + L2

[single source of failure versus many]

Appendices

Something Appendix Worthy

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References

[1] Bogdan Batog, Lucian Boca, and Nick Johnson. “Scalable Reward Distribution on the Ethereum Blockchain”. In: *DappCon* (2018). batog.info/papers/scalable-reward-distribution.pdf.

[2] David Hilbert. “Mathematical problems”. In: *Bulletin of the American Mathematical Society* 8.10 (1902), pp. 437–479.