POSTER: SOLVING THE FREE-RIDER PROBLEM IN BITTENSOR

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Motivation

Bittensor is the first and largest decentralized blockchain system to create value through Artificial Intelligence. Bittensor's corresponding token TAO is the 2nd ranked AI crypto token as of Oct 2024. The Bittensor ecosystem is growing rapidly, with over 8600 domain-expert participants (miners, validators, and protocol designers), 19600 staking participants (nominators, stakes), and more than 200 developers who regularly contribute to the Bittensor system. All these developers put their machine learning and other domain-specific expertise to do the validation and mining work, and in return are incentivized with Bittensor's native token TAO. However, during the rapid expansion of the Bittensor ecosystem, we observed a free-rider problem where validators do not do the work of evaluating miners but instead copy the work of other validators.

Compared to other peer-to-peer systems with solutions to the free-rider problem[4, 3, 1], in Bittensor the incentive of validators comes from reaching consensus, which is a piece of public and slow-moving information, with other validators [5]. As a result, validator j can optimize their return by copying the latest consensus reached by other validators.

Reward mechanism in Bittensor

The consensus mechanism is Bittensor's backbone. It calculates the statistical agreement from individual validators' evaluations of miners' performance. In a validator-miner relationship, when validator j gives weight $w_t^j(i)$ to miner i, validator j becomes affiliated with miner i and receives a bond $B_t^j(i)$. The more the miner i is rewarded with incentive I_t^i, based on consensus $\bar{w}_t$ agreed by validators, the more dividend D_t^j the validator j receives, based on the amount of bond that it holds towards miner i. Refer to Yuma Consensus mechanism [5] for the formal definition.

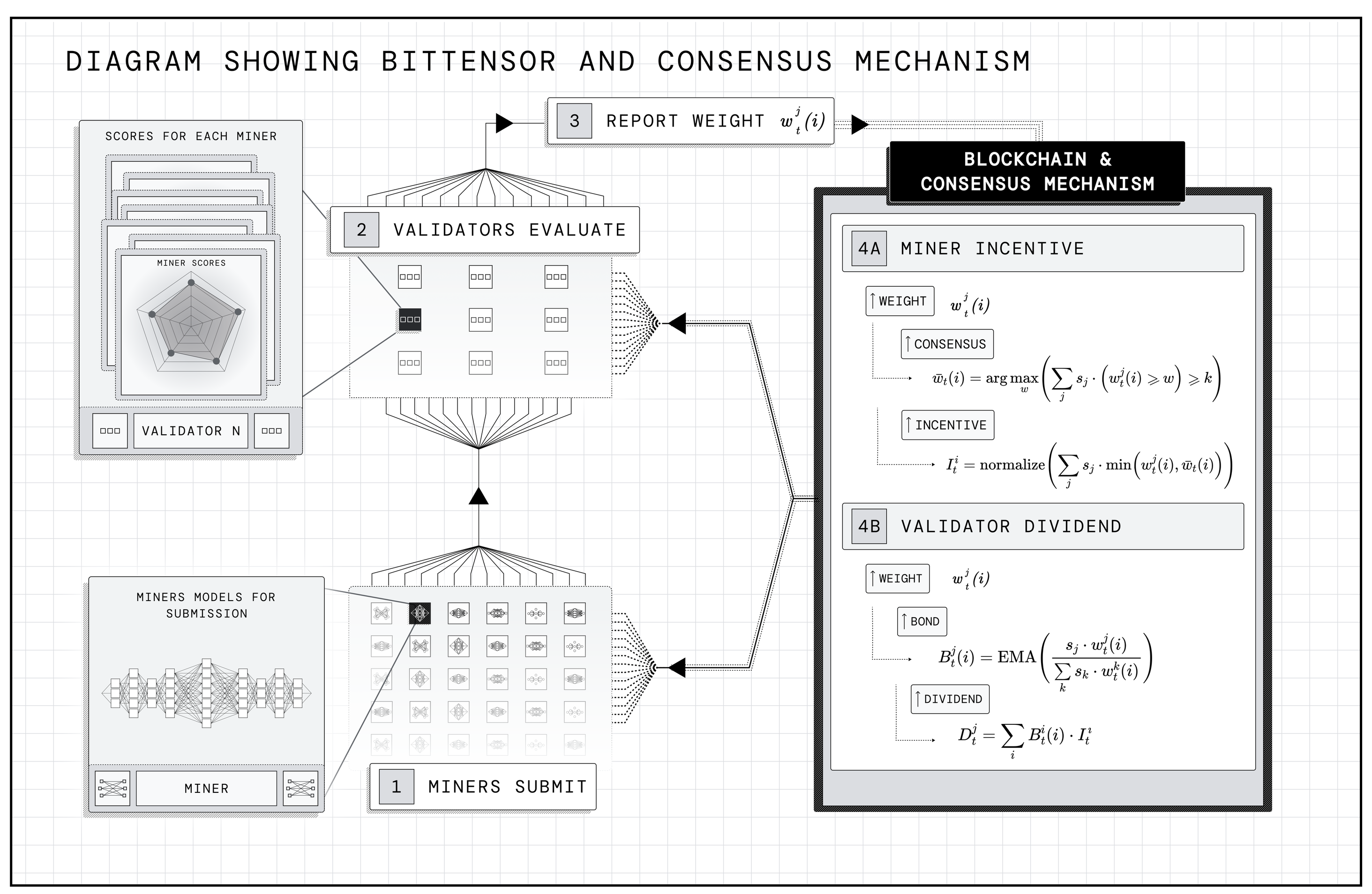

Fig. 1: Bittensor explained

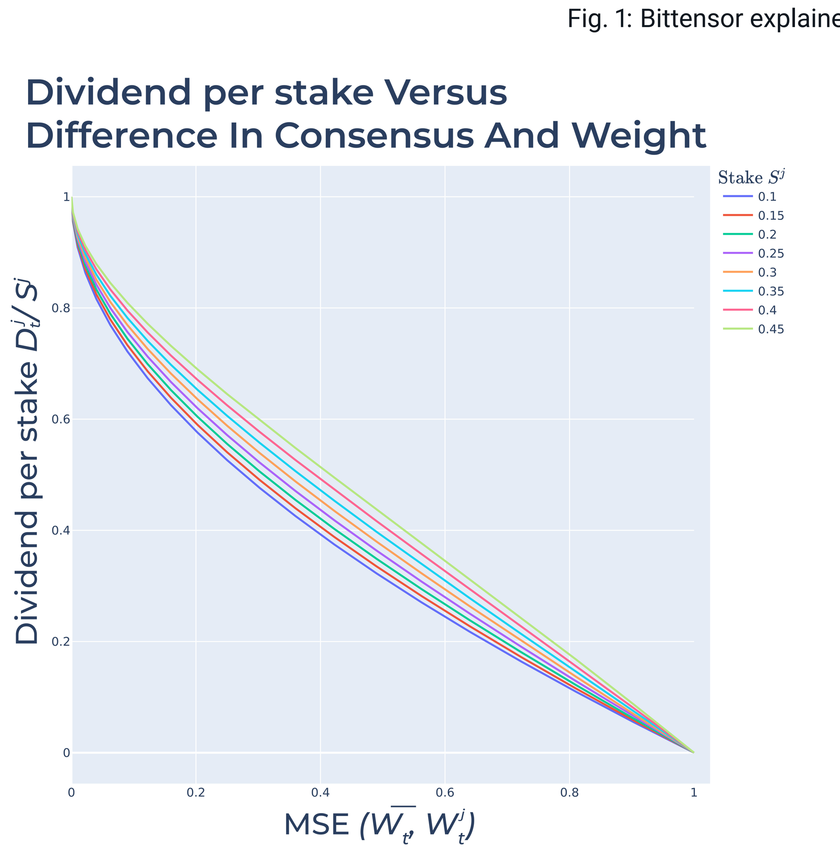

Fig. 2: Dividend per stake VS difference in consensus and weight

Proposition 1: For a set of reported weight w_t^{-j}, the dividend per stake D_t^j/S^j to j is monotone non-decreasing with the difference between consensus $\bar{w}_t$ and w_t^j.

Without providing any utility, dishonest validators can copy from the consensus $\bar{w}_t$, which is public information, to optimize their reward D_t^j. We address such free-riders as weight-copying validators in the rest of the poster.

Commitment scheme

Our main contribution is to provide a solution to attenuate the free-rider problem in the Bittensor system through a two-step commitment scheme, outlined below:

1. At time T_1, validators should commit a hashed weight $hash(w_{T_1})$ to the chain.
2. At time $T_2 = T_1 + \epsilon$, where $\epsilon > 0$ is the commitment period, validators would reveal the set of weights w_{T_1} to the chain that matches with $hash(w_{T_1})$.

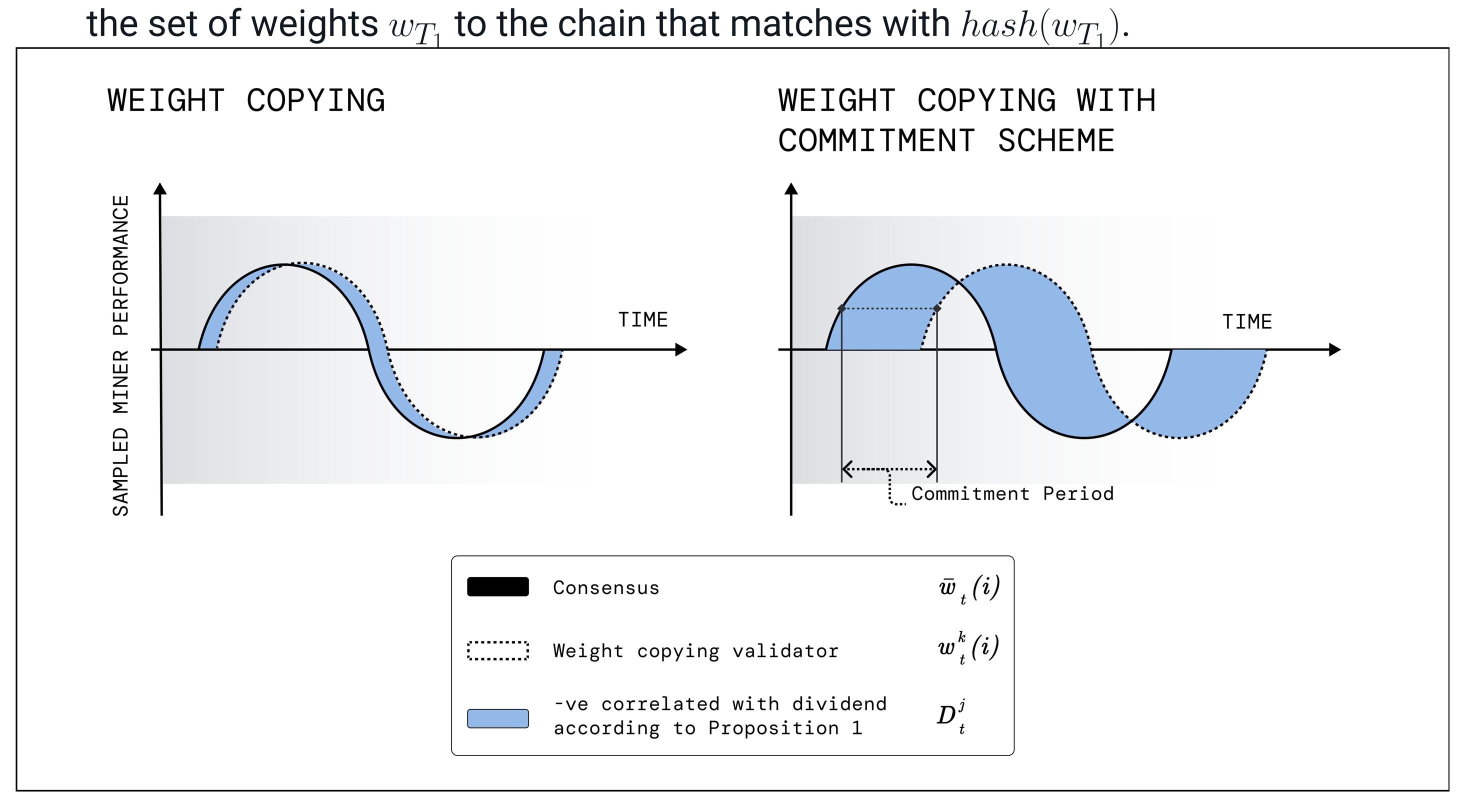

Fig. 3: Working of commitment scheme

The commitment scheme guarantees two properties [2]:

1. Hiding: Between the first step and the second step of the validators (i.e., the interval of length ϵ), no participant can gain any knowledge of the weight vector w_{T_1}, even with knowledge of $hash(w_{T_1})$.
2. Binding: Only one value can be accepted as the revealed weight vector w_{T1} at the second step.

As a result, weight-copying validators using historic published weight would receive a lower reward. By the time w_{T_1} and $\bar{w}_{T_1}$ were made publicly accessible at T_2 for the weight-copying validator, the difference between $\bar{w}_{T_1}$ and $\bar{w}_{T_2}$ would be significant because of the natural dynamics that happen in the subnets. Following proposition 1, using the old information $\bar{w}_{T_1}$ at T_2, with $w_{T2}^j = \bar{w}_{T1}$, would create a loss for the weight-copying validator j due to the discrepancy with the consensus $\bar{w}_{T_2}$ produced by real-time working validators.

Preliminary result

We simulate the effectiveness of the commitment scheme using historical Bittensor data in the real-world setting corresponding to blocks (time instants) 2987500 to 3001180. In the simulation, we create an artificial validator k with 5% of the stake following the weight-copying strategy by always copying and reporting the most recently observed consensus $\bar{w}_t$.

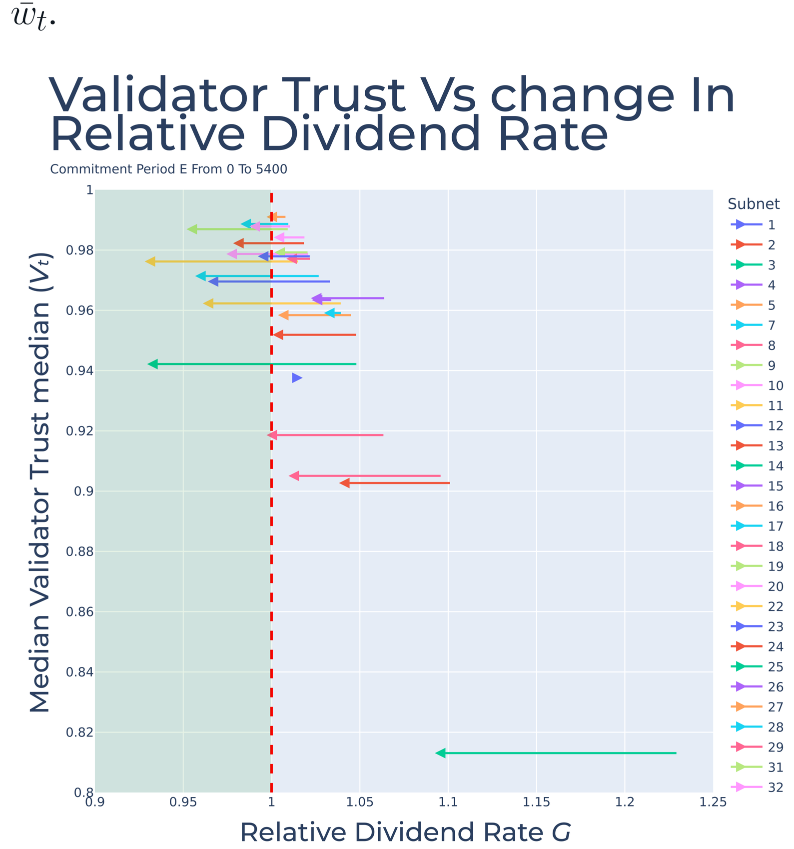

Fig. 4: Relationship between relative dividend rate G and median

$$G = \frac{D^k/S^k}{\underset{i \in \mathcal{Z}\setminus\{k\}}{\mathrm{median}}\{D^i/S^i\}}, \quad (1)$$

To measure the effectiveness of the commitment scheme, we calculate the relative dividend rate G in equation 1, which compares the dividend to a weight-copying validator to the median dividend across all validators. When the relative dividend rate $G < 1$, the weight-copying validator earns less than working validators, so the weight-copying validator would be incentivized to provide honest work.

Figure 4 shows the success of the commitment scheme; when the commitment period ϵ increases from 0 to 5400, the relative dividend rate G for each subnet decreases in the range of 0% to 11%. Performance in the commitment scheme varies across subnets because the difference in consensus $\bar{w}_{T_1}$ and $\bar{w}_{T_2}$ depends on the individual subnet's design and dynamics.

With application to the blockchain industry, Bittensor's consensus mechanism, together with the commitment scheme can provide space for any proof of work system that does not have a universal truth, offering the flexibility and security to run a wide range of applications in the ecosystem.

Liquid Alpha scheme

On top of the commitment scheme, the liquid alpha scheme aims to amplify the first-mover advantage in Bittensor.

$$B_t^j(i) = \alpha_t \triangle B_t^j(i) + (1 - \alpha_t) B_{t-1}^j(i) \quad (2)$$

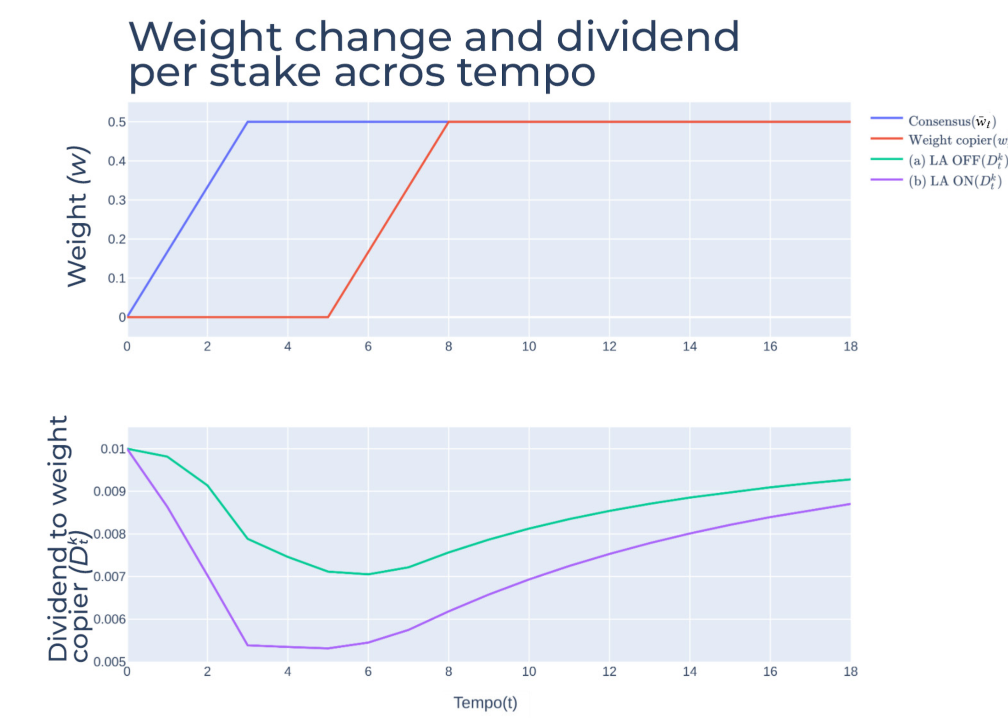

Fig. 5: Amplification in punishment to weight-copying validator k when liquid alpha is active (purple line VS green line) when the consensus $\bar{w}_t$ move from 0 to 0.5 (blue line) and weight-copying validator follows with delay from commitment period (red line).

Equation 2 shows the updated schedule of bond B_t^j with α as the smoothing factor. We modify the value of α_t to be a decreasing function of the miner i's consensus $\bar{w}_t(i)$. By doing so, the rate of bond growth would be faster when miner i's performance is considered generally inadequate, and slower when miner i's performance is deemed generally outstanding. Validators are thus incentivized to accumulate bonds when a miner is undervalued. For this reason, weight-copying validators would lose the first-mover advantage and receive a lower dividend, as shown in figure 5.

Note that if the sub-optimal miners do not improve, the bond will converge to the same value with and without liquid alpha.

Future work

We have observed that the commitment scheme and liquid alpha scheme require a lot of user action to run experiments and set parameters for the commitment period ϵ also to control the rate of bond growth, which is subject to change based on subnet design and dynamics. In the future, we will focus on adding robustness to the system to be less dependent on user input.

References

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