

Sentiment Protocol: A Decentralized Protocol Leveraging Crowd Sourced Wisdom

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The wisdom of the crowd is a valuable asset in today's society. It is not only important in predicting elections but also plays an essential rôle in marketing and the financial industry. Having a trustworthy source of opinion can make forecasts more accurate and markets predictable. Until now, a fundamental problem of surveys is the lack of incentives for participants to provide accurate information. Classical solutions like small monetary rewards or the chance of winning a prize are often not very attractive and also do not prevent multiple entries or randomly filling in answers. In this work, we present a framework that solves both problems via a customizable incentivization framework. Apart from predicting events, this framework can also be used to govern decentralized autonomous organizations.

KEYWORDS: sentiment, blockchain, ethereum, EVM, crowd-sourced wisdom, surveys, decentralized, smart-contract, polling

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1. Introduction

Sentiment in its broadest sense, is of great interest to both politics and industry. In the USA alone, the revenue of market research and public opinion polling reached \$18B in 2016 and continues to grow [5]. In spite of its size, political forecasts have failed to accurately predict two major recent political events, the US presidential elections and the decision of the UK to leave the EU [3, 4]. These failures may come as a surprise as, with the emergence of social networks and generally more interactive website, it has never been easier to source the opinion of the crowd.

In the financial industry, rating agencies are highly-paid providers of sentiment on a wide range of investment vehicles. However, if one takes for example a popular US stock such as TESLA, on Oct 13, 2017 out of 25 analysts, 35% recommended *buy*, another 35% recommended *hold* and the remaining 30% recommended *sell* [1]. Therefore, making the prediction no better than a simple guess [16]. Another well document fact is that most actively managed funds fail to beat the market, showing again that so-called expert opinions are not as valuable as they may seem [6, 9].

A common feature of the above cases is that repercussions (and rewards) for providing inaccurate (accurate) sentiment are extremely limited for both individuals, such as experts, and the crowd. For experts, this is not at last due to the difficulty of objectively evaluating their performance. Reasons include the phenomenon of survival bias, i.e. only the experts that made good predictions are cited, and also, if the expert is influential enough, the ability of turning ones prediction into a self-fulfilling prophecy. For crowd sentiment, some opinion polls offer small monetary rewards, usually in the form of a lottery, for filling out a survey. However, these rewards are paid irrespectively of the quality of the provided sentiment and in particular does not prevent anyone from intentionally providing false statements. Furthermore, specifically in web surveys, participants are able to repeatedly reply to the same surveys to increase their potential reward.

In the present article, we suggest a customizable decentralized framework that solves the aforementioned problems by providing a performance based reward for good forecasts and requiring a commitment of capital to provide sentiment. Depending on the choice of parameters (cf. Section 2), the Sentiment Protocol can be used for decentralized governance, similar to projects such as Aragon [2], or to obtain predictions for e.g. political events or stock prices.

The structure of this article is as follows: At first, we introduce the Sentiment Protocol in Section 2. The section starts with a high level overview and is followed by a detailed description of each component. Each stage includes basic examples that illustrate the respective concepts. In Section 3, we analyze the incentives for sentiment contributors and pollsters. We also discuss possible vulnerabilities and give suggestions on how they may be overcome. In Section 4, we dive deeper into two use cases for the Sentiment Protocol. In the final Section 5, we compare the

Sentiment Protocol to similar projects, most notably to the line of work by R. Hanson on prediction markets.

2. The Sentiment Protocol

It is now widely accepted that blockchain technology, the underlying concept of Bitcoin [18], has the ability to disrupt a wide range of industries including financial services, technology, media and telecommunications [20, 21]. Arguably, one of the most revolutionary emerging concepts are so-called smart contracts which are scripts executed on a world spanning super computer [10]. The Sentiment Protocol leverages these new possibilities to on the one hand immutably record provided sentiment and on the other hand conduct monetary transactions, such as rewards or penalties, without the need of trusting a third party.

Protocol overview — The Sentiment Protocol (cf. Figure 1) has three main components:

1. Sentiment Contribution Period,
2. Tallying and
3. Performance Evaluation.

During the Sentiment Contribution Period, users (sentiment providers) can submit their sentiment to the protocol. At the end of the Sentiment Contribution Period, and after a cool-down period ΔT_0 has lapsed (which may be 0), votes are tallied. The polling results can either be used for purely informational purposes or, in the use case of decentralized governance (cf. Section 4.1), directly trigger the policy that was voted on. After another cool-down period ΔT_1 (which may again be 0), users receive a (possibly negative) performance based reward.

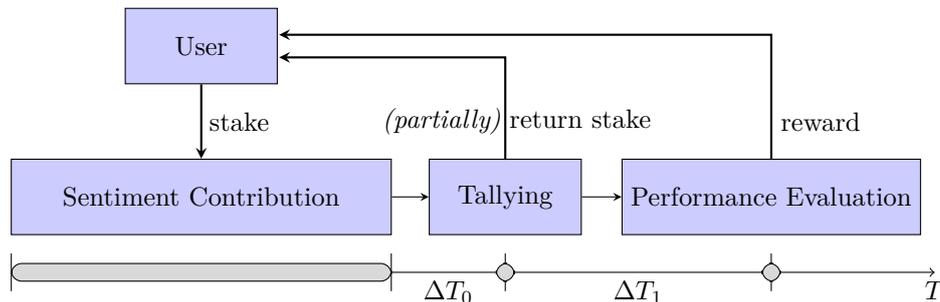


Figure 1: Overview of the Sentiment Protocol (*with penalties*).

Setting up a poll — To set up a poll, the creator needs to provide the following:

1. **Topic and set of possible outcomes** → Section 2.1

2. **Staking parameters** → Section 2.2
3. **Information on usage of results** → Section 2.3
4. **Performance evaluation parameters** → Section 2.4

2.1. Topic and outcome set

The creator of the poll has complete freedom over the choice of topic and also the set of possible outcomes \mathcal{O} . Outcomes can be discrete, such as multiple choice, or continuous, such as real numbers. The creator also has the option of using a public key encryption scheme for the submission of sentiment. By doing so, third parties are prevented from obtaining knowledge of the already submitted sentiment.

Example 1 (Discrete Outcome set \mathcal{O}). The poll wants to predict the outcome of the 2020 US presidential election. The outcome set is $\mathcal{O} = \{R, D\}$, where R is the republican and D the democratic candidate.

Example 2 (Continuous Outcome Set \mathcal{O}). The poll aims to predict the performance of the TESLA stock from 2017-11-01 to 2018-05-01. The outcome set is $\mathcal{O} = [0, \infty)$ and $\mathcal{O} \ni o = \frac{p(2018-05-01)}{p(2017-11-01)}$, where p is the price of TESLA at a given date.

2.2. Providing sentiment by staking

To provide sentiment, each participant needs to stake a corresponding amount of assets. For simplicity, we focus on the typical use case where the user needs to stake an ERC-20 token into the polling smart contract. The set of possible sentiments $\mathcal{S} \subset \mathcal{P}(\mathcal{O})$ is a subset of the powerset of the outcome set \mathcal{O} .¹²

During the sentiment contribution period any participant that holds the token required for staking can submit his sentiment $s \in \mathcal{S}$. The weight of the vote is directly proportional to the number of tokens submitted, i.e. 1 TOKEN = 1 SENTIMENT. The setup of the staking phase requires:

- **Token type**
- **Sentiment Contribution Period**
- **Limits on total submissions**

Having to commit tokens with each choice limits the amount of sentiment each participant can submit. Furthermore, in cases where the performance evaluation (cf. Section 2.4) can lead to penalties, the commitment of tokens exposes the provider to a financial risk. It is important to note that each staked token has equal weight in the sentiment contribution process. In particular, the rewards and/or penalties are directly proportional to the amount of tokens staked. This choice is due to

¹ Recall, that the powerset $\mathcal{P}(\mathcal{O})$ of a set \mathcal{O} is the set of all subsets of \mathcal{O} . ² For the technical reader: if \mathcal{O} is continuous we are using the Borel sigma algebra $\sigma(\mathcal{O})$ instead of $\mathcal{P}(\mathcal{O})$.

the pseudonymous nature of blockchain, where it is futile to limit sentiment per address. However, each pollster is free to use a custom staking token. Such a custom token could for instance be issued by the polling company and may have restrictions on transferability. Even in cases where no penalty is possible, obtaining a large amount of staking tokens puts the buyer at the volatility risk of the token price. Moreover, even if contributors are willing to accept the volatility risk, as a major stakeholder, they would have little interest in a behaviour that would undermine the polling process.

Once the Sentiment Contribution Period has ended and a time ΔT_0 (which may be 0) has lapsed, the votes are tallied. If the votes were encrypted, the pollster will have to use his private key to encrypt the submissions. If the performance evaluation does not involve penalties, the stake is returned to the sentiment provider. If penalties are possible, the stake minus the maximal possible penalty is returned.

Example 3 (Staking without penalties). Let us return to the previous example of the 2020 presidential election and assume that no penalties are possible. We set $\Delta T_0 = 24h$, $\mathcal{S} = \mathcal{O} = \{R, D\}$ and choose the following staking parameters:³

- Type: ETH,
- Sentiment Contribution Period: 2017-12-01 to 2017-12-10,
- Limits on total submissions: Minimum 1000 ETH (1000 SENTIMENT) and maximum 10,000 ETH (10,000 SENTIMENT).

Thus, a sentiment provider who wants to provide 100 SENTIMENT for the democratic candidate D needs to submit 100 ETH together with his (possibly encrypted) choice D to the polling smart contract.⁴ Since no penalties are possible, 100 ETH are returned to the sentiment provider on 2017-12-11.

2.3. Usage of results

Apart from simply aggregating information on behalf of the pollster, the Sentiment Protocol provides the basis for running decentralized autonomous organizations. In particular, polling results can be used to directly execute other smart contracts to e.g. implement policy changes within the organization (cf. Section 4.1).

2.4. Performance Evaluation

The payment of performance based rewards is a key feature of the Sentiment Protocol. The distribution of rewards/penalties is determined by the performance evaluation function provided by the poll creator.

³ For the technical reader: we identify $\{\{R\}, \{D\}\} \cong \{R, D\}$. ⁴ For the technical reader: the user needs to encrypt the value with a nonce and also submit the encrypted nonce.

Definition 1 (Performance evaluation function f_{PE}). The performance evaluation function $f_{\text{PE}} : \mathcal{O} \times \mathcal{S} \rightarrow [-1, \infty)$, depends on the outcome $o \in \mathcal{O}$ and the submitted sentiment $s \in \mathcal{S}$ and specifies the reward/penalty per submitted token.

The supremum⁵ of the performance evaluation function determines the size of the reward pool that needs to be provided to set up the poll. It is given by

$$(\text{reward pool}) = \sup f_{\text{PE}} \cdot (\text{limit on total submissions}),$$

where all values are in units of tokens. If $f_{\text{PE}} \geq 0$ (as a function), the poll does not involve penalties and thus the stake is returned immediately after tallying. If f_{PE} takes negative values, $(1 + \inf f_{\text{PE}}) \cdot T$ tokens are returned after tallying, where T is the number of submitted tokens.

Once the performance evaluation time is reached (ΔT_1 after tallying), the rewards are determined and payed out to the sentiment providers. Any remaining balance in the reward pool is returned to the pollster. See also Appendix A for an extension of the protocol that allows multiple performance evaluations.

Example 4 (Constant f_{PE}). In this trivial case $f_{\text{PE}} \equiv c \in \mathbb{R}$ and thus the reward is independent of both the provided sentiment and the outcome. Assuming the same staking parameters as in Example 3, the reward pool is $10,000 \cdot c$ and, since the reward is independent of the outcome or sentiment, there is no need to wait ($\Delta T_1 = 0$) and all sentiment providers receive $(1 + c)T$ tokens on 2017-12-11, where T is the number of submitted tokens. This trivial case corresponds to the current practice of most polling companies.

Example 5 (Positive f_{PE} for discrete \mathcal{O}). We return to Example 3. To incentivize sentiment providers to make good predictions we define

$$f_{\text{PE}}(D, D) = f_{\text{PE}}(R, R) = c \text{ and } f_{\text{PE}}(D, R) = f_{\text{PE}}(R, D) = 0.$$

Thus, only people that voted for the winning candidate get rewarded. Since the results of the elections will not be finalized until mid November 2020, $\Delta T = 1071$ days. As in Example 4, the reward pool is $10,000 \cdot c$.

Example 6 (f_{PE} for continuous \mathcal{O}). We return to Example 2 and use the same staking parameters as in Example 3. The sentiment set is $\mathcal{S} = \{\text{buy}, \text{sell}\}$ and we wish to choose f_{PE} such that providers of buy ratings get rewarded for a positive development of the TESLA stock price ($o > 1$) and penalised for a negative development.⁶ Similarly, providers of sell ratings shall get rewarded for a negative development of the TESLA stock price ($o < 1$) and penalised for a positive development. In the interest of fairness, if the stock price e.g. doubles ($o = 2$), the buy rater should get the same reward as a sell rater if the stock price halves ($o = 1/2$).

⁵ If $|\mathcal{O}| < \infty$, $\sup f_{\text{PE}} = \max f_{\text{PE}}$. ⁶ We can identify the *sell* rating with $[0, 1) \in \mathcal{P}(\mathcal{O})$ and the *buy* rating with $(1, \infty) \in \mathcal{P}(\mathcal{O})$.

A natural choice for f_{PE} that satisfies these requirements and is also bounded is

$$f_{\text{PE}}(o, s) = \frac{2c}{\pi} \cdot \text{sgn}(x - 1) \cdot \arctan(\max\{o - 1, o^{-1} - 1\}) \cdot g(s),$$

where $g(\text{buy}) = 1$ and $g(\text{sell}) = -1$. Note that \arctan has the appealing properties of being approximately linear around 0, strictly monotone increasing but still bounded by $\pi/2$. Thus for small price changes

$$f_{\text{PE}}(o, \text{buy}) \approx \begin{cases} c(o - 1), & o \geq 1 \\ -c(o^{-1} - 1), & o < 1 \end{cases}$$

and similarly $f_{\text{PE}}(o, \text{sell}) \approx -c(o - 1)$ for $o \geq 1$ and $f_{\text{PE}}(o, \text{sell}) \approx c(o^{-1} - 1)$ for $o < 1$. Owing to monotonicity, higher (sentiment aligned) performance results in higher rewards. As in the previous examples, the reward pool is $10,000 \cdot c$. The maximal possible penalty is $-c$ and thus only $(1 - c)T$ tokens are returned after tallying.

3. Incentives and vulnerability analysis

In this section, we analyse the incentives for pollsters and sentiment providers to use the Sentiment Protocol. We distinguish between public polls and polls amongst experts. We also explain its advantages over current (centralized) polling mechanisms and discuss possible vulnerabilities.

3.1. Benefits of using blockchain technology

Firstly, it is important to note that opinion polling is not a truly decentralized mechanisms and in particular the Sentiment Protocol does not claim to be fully decentralized. Nonetheless, using blockchain technology offers important advantages over classical, completely centralized, solutions. For the Sentiment Protocol, the two most important properties of blockchain technology are:

1. the ability to easily transact and store value without the need of trusting a third party and
2. the ability to immutably store data.

The Sentiment Protocol uses (1) for both the staking and the rewards/penalties. In a centralized system, users are hesitant to commit a significant value for period of time ($\geq \Delta T_0$) for the chance of receiving a comparatively small reward. Furthermore, by additionally using (2), the submitted sentiment is immutably stored and the user can easily prove that he is entitled to receive a reward - which may be far ahead in the future (cf. Example 5 and Appendix A).

3.2. Public polls

The goal of a company conducting public polls is to receive reliable sentiment from a large number of users. The users on the other hand wish to be rewarded for providing accurate information. In the following we describe a possible setup of the Sentiment Protocol to align their interests.

To ensure the diversity of sentiment providers, the polling company issues their own token called POLL which can be arbitrarily transferred to and from polling smart contracts but cannot be transferred between users. However, all earned rewards are freely transferable. Further, we assume that at most times there are several polls to chose from and that each user has a starting balance of 100 POLL. The performance evaluation function f_{PE} is chosen positive (i.e. no penalties) and the cool down period ΔT_0 is one week. Due to this long cool-down period, POLL holders are incentivized to participate in polls where they feel most confident in predicting the result. Unless they have absolute certainty that their prediction is correct, they are also incentivized to diversify their tokens on several polls. If however, they (think that they) are absolutely certain about the outcome, they may be inclined to stake all their POLL tokens on a single event. Of course, such behaviour is also in the interest of the polling company.

3.3. Experts opinions

The goal of the polling company is to receive high quality predictions. However, in contrast to public polls, the users (experts) may wish to demonstrate their commitment to a forecast by putting their own capital at risk and thus earn credibility.

Since the users have an interest in demonstrating credibility, the polling company chooses a performance evaluation function with penalties. Since each submission of sentiment may result in a loss of value, the company can simply choose ETH as a staking token. A sentiment provider that feels more certain about a prediction will choose to stake more tokens than a provider who is not as certain. As in the previous case, this behaviour is in the interest of the polling company.

3.4. Limitations and possible vulnerabilities

An important limitation of blockchains is their inability to source external information. Thus, in order to determine rewards, users needs to rely on oracles. This problem is not specific to the Sentiment Protocol but poses a general problem in developing truly decentralized applications. Another important limitation of smart contract platforms is their high cost for computations. Thus, the cost for determining performance based rewards may be significant.

If these general limitations of blockchains can be overcome (or are irrelevant as in Example 4) and if the incentive structure in the Sentiment Protocol is set up correctly, it is impossible for the pollster or the user to illegitimately receive funds.

Owing to currently having these limitations, the polling company may act in a much more centralized manner and may choose to conduct the rewards calculations off-chain with data provided by regular (centralized) data-feeds. Of course, this special rôle allows the pollster to illegitimately keep rewards. However, due to the public availability of the provided sentiment and the performance evaluation function, cheating by the pollster can easily be proven and the polling company will quickly lose credibility. Thus, cheating by the company becomes unprofitable in the long run.

To consider possible cheating from the users perspective it is convenient to distinguish between performance evaluation function with and without penalties. If no penalties are possible then a user has no risk of loss. However, even if the pollster does not use a custom token as detailed in Section 3.2, the commitment of huge amounts of tokens is on the one hand very costly and on the other hand only profitable if the predictions are right in the end. Furthermore, if the token is native to the polling company, amassing large amounts makes the user a major stakeholder of the company and thus any misbehaviour counterproductive.

If penalties are possible and if potential rewards/penalties are sufficiently large, it may be advisable to choose a 'zero-sum' performance evaluation function, i.e. there should not exist a combination of sentiments and staking choices such that the sentiment provider earns a profit independent of the outcome. Of course, as in the case without penalties, it is at the discretion of the pollster to allow this possibility.

4. Use cases

In this section we discuss two specific use cases. We will not discuss the two cases in full details but rather assume familiarity with Section 2.

4.1. Governance

Any token that is able to access smart contract functionality (e.g. ERC-20 tokens) can use the Sentiment Protocol for decentralized governance. Since policy changes are not objectively verifiable as right or wrong, it is natural to choose a constant performance evaluation function $f_{PE} \equiv c$ (cf. Example 4). Thus, each token holder that participates in the governance process gets a fixed reward for his engagement. The required reward pool can be provided by the token issuing company. To ensure an indefinite supply of reward pools R_i for the i th voting event, the company can e.g. use a distribution according to a geometric series. That is, if the company

plans on using 100,000 tokens for incentivizing governance participation (via the Sentiment Protocol), they can set $R_{i+1} = x \cdot R_i$, where $x < 1$ and⁷

$$R_1 = 100,000 \cdot (1 - x). \quad (1)$$

Since the performance evaluation function is independent of the outcome, neither oracles nor complex computations are necessary and thus the (governance) Sentiment Protocol can be entirely implemented on-chain. In particular, this allows running decentralized autonomous organization, where user are allowed to vote on policy changes and decisions are automatically executed according to the voting results.

4.2. Community driven rating agency

In this scenario, the polling company wishes to regularly receive sentiment on the performance expectations of a wide range of stocks. To ensure broad reach, the polling company issues 1,000,000 custom tokens of which 900,000 are distributed to the public and 100,000 are held by the company to fund reward pools. The transferability of originally distributed tokens between users is limited (e.g. only 10% per quarter). However, earned rewards can be transferred freely. To ensure the indefinite supply of rewards pools, the company chooses $x = 0.99 = 99\%$ (cf. (1)) and thus the reward pool for the first sentiment round is $R_1 = 1000$ tokens and each subsequent pool is 99% of the size of the previous pool. In each round the users are asked to provide their sentiment on the performance of 10 different stocks within the next three months ($\Delta T_1 = 3$ months) by choosing between \uparrow , \leftrightarrow and \downarrow for each stock.

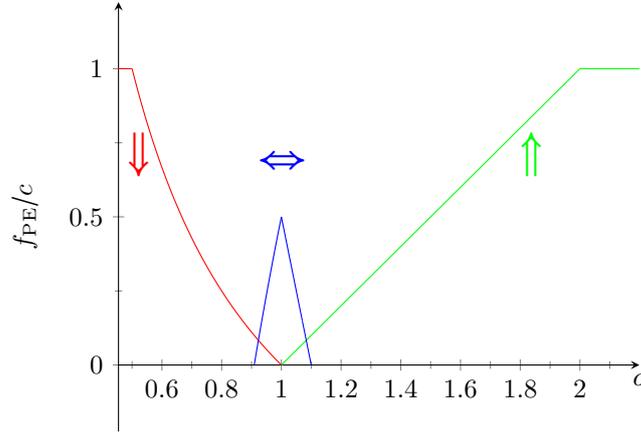


Figure 2: The performance evaluation function f_{PE} for the three sentiments \downarrow , \leftrightarrow and \uparrow .

⁷ Indeed, $\sum_{i=1}^{\infty} R_i = 100,000 (1 - x) \sum_{i=0}^{\infty} x^i = 100,000 (1 - x) \frac{1}{1 - x} = 100,000$.

The performance evaluation function (cf. Figure 2) is defined by $f_{\text{PE}}(o, \uparrow) = c \min\{1, \max\{0, o - 1\}\}$, $f_{\text{PE}}(o, \downarrow) = c \min\{1, \max\{0, 1/o - 1\}\}$ and

$$f_{\text{PE}}(o, \leftrightarrow) = \begin{cases} 5c(1.1 - 1/x) & x \in [0.9\bar{0}, 1], \\ 5c(1.1 - x) & x \in [1, 1.1], \\ 0 & \text{otherwise.} \end{cases}$$

Thus, a \uparrow -rater gets rewarded only for positive stock performance and his reward is linear in the performance with a cap at 100%. A \leftrightarrow -rater receives a maximal payout if the stock price does not change and does not get rewarded if the performance is outside the interval $(0.9\bar{0}, 1.1)$. Since the reward pool is 1000 tokens and 900,000 tokens are held by the sentiment providers we set $c = 1000/(10 \cdot 900,000) = 0.000\bar{1}$. By allowing the rating of 10 stocks simultaneously, users are incentivized to prioritize stocks (by staking more tokens) that they feel most confident in making a good prediction.

The obtained sentiment data is a valuable asset to the company and could for instance be sold to third parties or used to create a community driven portfolio. In the latter case, the community itself would have the chance to invest in such a portfolio and thus double their incentive to participate in the rating process.

5. Comparison to similar projects and ideas

The general idea of sourcing the wisdom of the crowds through economic incentivization is well-established and one of the most prominent advocates is R. Hanson [13] with his concept of Futarchy. However, a major difference to the Sentiment Protocol is how this information is sourced.

In Hanson's work, speculative markets are pivotal in the information aggregation. This usually means that the creator of a poll has no risk but instead the sentiment providers enter a free bidding market to buy and sell outcome shares. The relative price of each share then reflects the probability that the respective event occurs. To illustrate this concept we return to the setting of Example 1 of the 2020 presidential election. A market maker sells the pair of outcome shares R and D for \$1, where R pays \$1 if the Republican candidate wins and D pays \$1 if the democratic candidate wins. Since only one of the two events can occur, the market maker cannot lose money. On the other hand, both outcome shares can be traded freely amongst the market participants and by economic theory, the price of the shares should be a good representation of the probability that the respective candidate wins. While this form of information aggregation has been demonstrated to be very successful, see e.g. [7, 8, 12, 14], it is considering gambling and thus illegal under most legislations (in particular in the US). Irrespectively of the legal status, with the rise of blockchain technology, Hanson's concept has recently been imple-

mented into two major blockchain projects [15, 19]. Furthermore, in the context of governance, Hanson’s ideas have been extended theoretically by R. Merkle [17] who suggests an implementation based on DAOs. [11]

In the Sentiment Protocol, speculative markets are replaced by pre-defined reward functions (see Definition 1) and thus its approach is closer to classical (legal) polling with incentives for participation. By providing a reward pool and setting up the performance evaluation function, the pollster takes a distinguished rôle in the process and takes away speculative risks from the sentiment contributors.

If the reward function is constant ($f_{PE} = c$), the Sentiment Protocol resembles most closely the concept of classical polling mechanisms. However, by using a public blockchain and an on-chain implementation it offers a greater level of transparency and security. Depending on the type of staking token, the voting process can either resemble a shareholder or a direct democracy.

If the reward function is positive ($f_{PE} \geq 0$), the Sentiment Protocol offers the benefit of being rewarded for providing good predictions. Thus, it is similar to prediction markets but without the risk of speculative losses. In particular, it stays clear of the (illegal) gambling aspects of Futarchy.

If penalties are allowed, the Sentiment Protocol has some resemblance with prediction markets but again, since the reward pool must be provided by the pollster and since the rewards/penalties are fixed (and outcome dependent) it does not possess the same degree of speculativeness. Furthermore, even though not specifically excluded, the reward pool (and thus the rewards/penalties) are relative small compared to the staked capital and thus the sentiment contribution process is not attractive for participants seeking high risks and high rewards.

6. Conclusions

In this paper, we have shown how the Sentiment Protocol can leverage blockchain technology to align the incentives of pollsters and sentiment contributors. We discussed several use cases including decentralized governance and prediction markets. By introducing a fixed performance evaluation function we are able to reward predictions finely graduated. We have shown how such an approach offers a clear advantage over classical polling solutions, where rewards are either non-existing or small and independent of the quality of the contributed sentiment, and also over classical prediction markets, which are considered illegal in most jurisdictions.

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A. Sentiment protocol with multiple performance evaluations

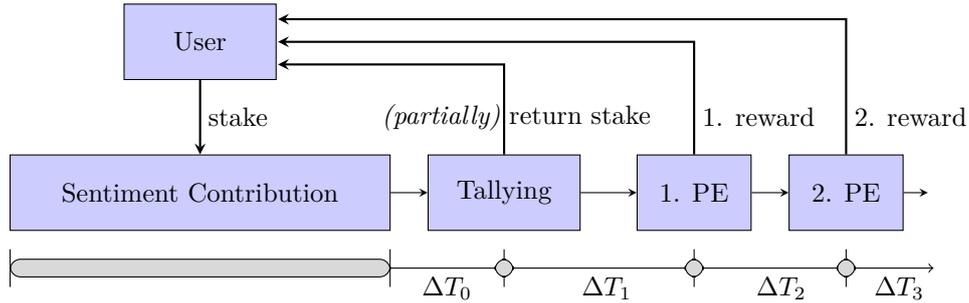


Figure 3: Overview of sentiment protocol (*with penalties*) with long term rewards.

To incentivize users to provide sentiment on long term performance (e.g. stock prices), we extend the protocol to allow several performance evaluations (cf. Figure 3). Let us illustrate this by assuming that the performance is evaluated every three months, i.e. $\Delta T_i = 3$ months. To this end, we can e.g. define the performance evaluation function f_{PE_i} at the i th performance evaluation as

$$f_{PE_i} = 2^{-i} f_{PE},$$

where f_{PE} is the original (single event) performance evaluation function. Since $\sum_{i=1}^{\infty} 2^{-i} = 1$, the reward pool does not need to be increased. Of course, the pollster is free to make different choices for f_{PE_i} . The only restriction is that the reward pool needs to be big enough to cover *all* performance evaluations.

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