# SportΞth

## Sports Betting Contracts

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**Abstract.** SnowBet is a blockchain contract for betting on weekly sporting events. Token holders administer an oracle contract that posts weekly events, odds, and results to a betting contract. Users can either bet or provide liquidity to accommodate residual imbalances. Cross-margining allows a small number of liquidity providers to support unlimited betting and diversify across events.

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# 1 Introduction

Sports betting is ideally suited for a completely on-chain smart contract. Consensus odds are well-known, statistically accurate, and stable for major sporting events. For American football and mixed martial arts, the weekly schedule gives the oracle enough time to validate off-chain data before sending it to the contract. Over $50B was wagered on US sportsbooks in 2021, and the demographic skews towards young men, just like crypto. A contract targeting a portion of this market is small enough to manage and big enough to matter.

There are three types of contract users: bettors, liquidity providers, and an oracle-admin. Bettors can take either side of any regular bet offered, subject to a size constraint that is a function of the amount of free liquidity provider (LP) capital. If the bettor wants to make a bet larger than what is available, he can post a bet of unlimited size, and other bettors can take any of these big bets.[1] The LPs do not get any of the vig for these large bets because they take no risk from these big bets (the oracle gets its regular fee). [2]

LPs earn a positive *expected* return for the risk they take, in that there may be periods where bettors make net profits implying LP losses. The ratio of LP capital relative to the amount of betting determines the return on equity, allowing the amount of capital to equilibrate this market (if the return is too low, capital will leave, raising the expected LP return). Bets are automatically cross-margined so that the capital required is minimized. For example, 10 AVAX collateralizes a single bet paying out 10 AVAX, and a contest where the winning payout is 510 AVAX if one team wins and 500 AVAX if its opponent wins.[3] The required capital on any single bet is a function of the net payout, not the notional bet amount. LP capital is applied to the entire slate of up to 32 events, and a parameter limits how much of this capital can be applied to any one event.

Oracle-admin tokens are designed for a real purpose, maintaining the integrity of the contract. The token holders only receive their full fee payment if they vote at least twice a week, which requires them to post their tokens on the oracle contract. If a token holder votes less than twice a week, their avax dividends are reduced proportionately (e.g., making one vote per week, which is half of the target, would entitle them to only 50% of their payout). The reduced amount is reallocated to the other token holders in the oracle contract.

The standard 4.5% vig has been stable for decades, reflecting an equilibrium balancing the demands of bettors and bookies more than path-dependent custom. The blockchain's relatively easy access makes an intelligent contract the preferred choice for many bettors even when offering identical odds to the major casinos. So, the focus should not be on significantly reducing this fee, which is essential for incenting our needed LPs and oracle, who split the fees evenly. The standard Vegas odds advertised online on major fights and football games are stable and efficient, so simply using these odds is also efficient.

The relative stability of odds, their historical accuracy, and the vig make the odds amalgamation simpler than for generating probabilities on binary options (e.g., will the price of ETH be above $2000 on

[1] Bet size must be greater than what is available for instant betting. adjustment: For large bets, the LP’s do not get any of the vig because they take no risk from these big bets. The oracle gets its regular fee.

[2] Definitions are somewhat arbitrary, but the traditional **vig** is calculated as ‘1 – p*q/(p+q)’, where p and q are the decimal odds of a team and its opponent. Eg, standard even moneyline odd, -110, have dec odds of 1.909, generating a vig of 4.55%. Alternatively, if 2 × 110 is paid into the book, and 210 paid out to one winner, the net book take is 10/220, which is 4.55%.

[3] A 5-1 contest with zero LP risk would have 5 eth bet on one team for every 1 eth on the other.

1/1/2024) or the price of ETH in USDC. Consider that your average daily stock price volatility of 2.5% is 16 times greater than the average bid-ask spread of 0.15%. A market maker who adjusted their bid-ask spread daily would be exposed as a 'money pump' by arbitrageurs, in that if the price moves up 2.5%, the market maker will almost certainly have sold on the way up, generating real-time losses.

In contrast, the implicit spread on money line bets is 2.5% in terms of a win probability. One needs a 2.5% edge in predicting which team wins to beat the house. The daily volatility of these odds is less than half of that, implying the book would make money even if it had day-old odds and the new odds were actually moving in the right direction. This would be like a stock with an annualized volatility of 1% given a bid-ask spread of 0.15%, which is more like a stablecoin than a stock price, making it easier to monitor.[i] In a worst-case scenario where posted odds deviate significantly from market odds, an event's new bets can be paused until the following odds update, preventing new bets on a contest until updated odds are posted. Pausing bets requires a minimum amount of oracle tokens and can be pushed immediately; it does not expose the LPs to risk.

Sports odd stability eliminates the adverse selection problem in high-latency centralized markets, which allows for a novel price-setting mechanism: post the widely available standard odds for a slate of upcoming contests. A singular oracle token holder submission grabbed *in toto* from a large sports book will be sufficiently close to the optimal odds to prevent bettors from arbitraging the LPs. A single human can easily find web pages that concisely present the odds or results of high-profile, straight-up bets on the two sports presented on SnowBet. There is no need for price discovery on high-profile sporting events.

## Simplicity from Limited Focus

Football and MMA are almost exclusively weekend events. A focused set of weekly win/lose events makes incentivizing the oracle easier. In contrast, if we targeted a standard centralized sportsbook, it would cover many diverse events at all times on most days of the week. Only a subset of the oracle token holders could evaluate these data, creating edge cases where a minority equity stake is less than a potential cheat payout.

Augur is an example of a betting contract that was too general. The protocol allowed users to bet on an almost unlimited set of events; thus, it was a 'prediction market' instead of a betting market. Applying vending machine logic to one of the world's oldest professions seemed straightforward, enabling delusions that pushed Augur's token value to over $1B. However, even with protocol fees at zero to promote growth, the indirect costs from high spreads and month-long payout delays made it useless. Augur is inactive now, but when it was not an obvious failure, the small number of bets offered included many created by hackers promoting deliberately ambiguous wagers. A dapp designed for everything is useful for nothing.

Developers focus on generalizable protocols for two reasons. First, it enables delusions of grandeur as equity token buyers imagine the next Amazon on the blockchain. Secondly, they monetize their investment by incorporating, which creates a legal attack surface. The more generalizable the protocol is, the more difficult it is for regulators to prosecute these organizations. Neither of these is relevant to me, the creator of this contract. I will neither control nor profit from this contract, so I am not concerned with legal prosecution or pumping the oracle token. Bettors, oracle voters and LPs are responsible for minding their local regulators, and the global popularity of sports betting implies many people can use it.

# Oracle Incentive Compatibility

Incentive compatibility is vital to low-cost enforcement of contracts, and historically this mechanism centered on reputation, not contract law administered by the state.[4] The blockchain's transparency, immutability, and pseudonymity make reputation much easier to monitor. When agents have incentives aligned with their counterparties, we minimize indirect costs (delay and spread), making it more attractive for bettors. In SnowBet, bettors and liquidity providers cannot cheat without the oracle, so the only concern is ensuring honest reporting of odds and results is always the oracle collective's value-maximizing act.

Creating a game where honesty is an oracle/admin's best strategy is straightforward; the keys are simplicity and repeated game, which leads to easy monitoring and a strong incentive towards punishing cheaters. Adding superfluous parties, tokens, and scope increases cost, complexity, and delay. By putting players into a repeated game, a previously dominant strategy of defecting becomes dominated by cooperating because the one-time gain is offset by many future periods where payoffs are lower to the defector. Incentive compatibility is critical to low-cost enforcement of contracts, and historically this centered on reputation, not contract law administered by the state.[ii]

Consider the following cost-benefit analysis for SnowBet's oracle. A conservative equity price/earnings (P/E) ratio is 10. Assume a betting contract has 100 AVAX bets on its books, both long and short. As the oracle's fee is about half of the vig, this would average about 2.5 AVAX in weekly revenue. Given 50 settlement events over the year, this annualizes to 125 AVAX. Given a 10 P/E, this values the oracle collective at 1,250 AVAX. The maximum potential cheating revenue in this example is 100 AVAX, requiring the hacker to make all the book's net exposure on his pre-ordained picks, so the LPs have net exposure to the wrong side of every bet.

Such a scam would be conspicuous in the readable event logs, and no rational person would use this contract again, making the value of the oracle token zero. A voting majority's oracle token has a present value of 625 AVAX. Honest reporting is the clear dominant strategy in this improbable worst-case scenario, in that 625 >> 100.[5]

The oracle voters have, literally, all day to evaluate a data submission that can be evaluated in a couple of minutes. A majority 'no' vote among votes cast penalizes the proposer of the data, while a successful submission gets a small reward.[6] The focus and pace of oracle submissions remove any plausible deniability for the oracle cheat action in any single event each week. The website generates event log data in readable form, so one does not need specialized knowledge of hash functions, just access to the sporteth.co website (these are available for customization via GitHub).

While it is simple enough to incent the oracle properly, this only protects the contract against insiders. In contrast, decentralization defends this contract against outsiders. Powerful institutions have always used

[4] E.g., prior to commercial civil law there were courts along trade routes throughout Medieval Europe that enforced commercial laws (the *Lex mercatoria*), and its judgments were accepted not out of any legal authority granted by a state's monopoly on violence, but rather refusal would ruin one's business reputation and thus future revenue.

[5] 625 = 50.001% of 1250

[6] The reward is done so that, statistically, the submitter should make just enough to cover the costs of the occasional inadvertent (e.g., ‘fat-finger’) errors that may engender a data submission rejection. Otherwise, statistically, the data proposer would have only downside for his work. Nonetheless, we do not want to make proposing data too attractive because that would imply the proposer would eventually acquire a strong majority of the tokens.

centralized power to prevent competition, often using disingenuous rationales emphasizing safety. Such an attack needs a choke point, prevented if a collective of pseudonymous accounts worldwide administers the oracle. If the oracle is profitable, an effectively infinite number of people will replace oracle token holders captured by outside attackers. Oracle decentralization defends this contract against outsiders. Initially, the oracle will be relatively centralized. Still, token rewards for early LPs and, potentially, trading by initial oracle token holders will make the oracle decentralized when any outsider develops the will and means to attack an oracle token holder.

# 2 Contract Basics

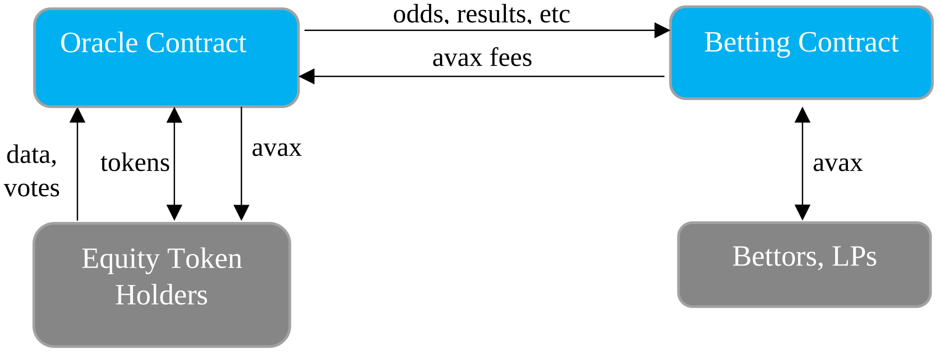
## 2.1 Outline

Event data, including odds, are sent to the contract early in the week, allowing people to bet on the events offered. After the weekend, the oracle sends the results to the betting contract, settling that week's bets, and the contract then repeats the process.

Bettors and LPs interact only with the betting contract, while the token holders only interact with the oracle contract. All transactions with the betting contract are denominated in AVAX, including providing liquidity and betting.

The LP capital backstops residual imbalances in the book. The LP's total capital is available for all contests that week, and there is a limiting mechanism on how much AVAX can be allocated to any single contest. This diversifies the LPs, reducing the chance that a single contest outcome could extinguish LP capital. The betting contract contains all the methods for bettors and LPs: betting and redemption for bettors, investing, and withdrawal for LPs.

A singular oracle token holder, with at least 5% of the oracle tokens outstanding, proposes the relevant data: the upcoming schedule (who plays whom, when), odds, results, and some technical parameters (e.g., minimum bet size). Each submission is then subject to an evaluation period subject to a majority vote: send or reject. A successful data submission is sent to the betting contract after a vetting period of 6 hours, giving the oracle collective sufficient time to veto a fraudulent or incompetent submission. To discourage misbehavior, token holders submitting failed datasets lose tokens.



**Weekly Schedule**

| | |
|---|---|
| Tuesday | schedule & odds posted |
| Wednesday | bettors bet<br>LPs deposit and withdraw<br>odds may be updated |
| Thursday | |
| Friday | |
| FridayNight | games played<br>LPs can not w/d or deposit<br>no bets on games once it starts |
| Saturday | |
| Sunday | |
| Monday | results posted and bets settled |

Each week the mma and football games that weekend are sent to the contract. The data are sent to the betting contract if most oracle token holders vote yes. At this point, bettors can bet, and LPs can withdraw or add liquidity to the contract. Odds on particular matches can be updated, but only once a day. LPs cannot withdraw or deposit during the period between the start of the first game and settlement, as otherwise, they could game the contract by anticipating unusual losses or winnings.

An initial schedule, updating odds, and results can only be posted from 12:00 to 13:00 GMT. Oracle token holders then have 11 hours to vote. After 11 hours, anyone can execute the function that counts the vote, which sends the data to the betting contract if approved. When the result data is sent to the betting contract, it settles all the week's bets, enabling the winners to redeem their bets immediately. The limited time for sending data makes it easy for oracle token holders to assess data submissions.

## 2.2 Schedule and Start Times

Each betting period will contain up to 32 events and generally target a weekend (e.g., Friday night through Sunday night). Each contest is slotted into an array that can be unambiguously linked to its outcome via event logs that expose what events odds were on the contract. The schedule array contains a string with the sport (NFL, MMA, etc.), the two opponents, and the starting time. Generally, the favorite will be listed first and the underdog second, though the odds can change over the week while the ordering of the contestants cannot.[7] Contest start times prevent bettors from taking positions on games after they have started.

## 2.3 Odds

The contract generates odds with an all-in vig of approximately 4.5%, the standard vig at major betting books.[8] The SnowBet.co frontend presents all odds in terms of payout to the bettor, the 'all-in' odds that include the fee to the oracle. Thus, when a bettor sees 2.000 decimal odds in the SnowBet gui they can be sure they will receive 2.0 AVAX if they bet 1.0 AVAX, etc. The website also allows users to see

[7] The favorite/underdog refers to the opening line, and so over the week the initial favorite may become the underdog. Nonetheless, the ordering is fixed in the initial event posting.

[8] It is implicit in the common -110 moneyline, in that paying 110 to win 100 means the bettors post 220 and the winner receives 210. The 10 goes to the house, which is 4.5%.

American money line odds by toggling a button, but know that odds submitted to the contract via the frontend are in decimal form. Odds are initially uploaded with the weekly schedule for the following weekend's games. The oracle may update odds up to game time, but the odds posted on the contract at the time of the bet are applied to any bet.

## 2.4 Margin Requirements

Margin rules make sure all bets are fully collateralized. Unlike in futures markets, the margin is not derived from a probabilistic risk, such as an instant 20% price movement. In betting, we can identify a worst-case scenario for the LPs and make sure the contract will always have enough money to avoid insolvency.

As bettors take the opposite side of a contest, it is a waste of capital to require the LPs to collateralize both sides independently. The solution involves netting exposure incrementally.

Example: Assume two teams are given even odds so that for either team, a 1 AVAX bet pays the winner 2 AVAX. If there is 10 AVAX on team A, and 10 on its opponent, team B, it would be a 'flat' book in that the LPs have no exposure to this game; payoffs are funded by betting counterparties, not the LPs. A new bet that pushes the book to have a net exposure would necessitate LP funds as collateral, so a bet of 2 AVAX on team A would move 2 AVAX from the LP's free margin to the LP's required margin. With a new total of 12 on team A, and 10 on team B, a bet of 2 AVAX on team A would move 2 AVAX *out* of the required margin to the free margin because the resulting book would be flat again.

Adjusting the net required LP margin involves 'linear programming' where the LP's net game exposure is the maximum liability of either team winning. The margin adjustment is applied at the time of a bet, so there will always be sufficient collateral to accommodate any accepted bet.

A contract parameter prevents an overconcentration of LP capital on one event. For example, 123 AVAX in total LP capital and a concentration parameter of 10 implies a maximum of 12.3 AVAX LP exposure for any event. Thus, if the current LP liability for team 0 winning was 10.0 AVAX, it could only accommodate an additional payout of up to 2.3 AVAX on team 0. In contrast, a bet on team 1 could accommodate a bet payoff of 22.3 AVAX. This concentration parameter can be adjusted over time by the oracle collective, as experience will inform the best parameter value.

The concentration parameter and a limited LP pool limit the damage to stale odds. If a contest had odds significantly off the true odds, the LPs are limited on their exposure to that one contest. The concentration parameter and the amount of LP capital not currently used as required collateral determine the maximum bet size on any contest and can be seen on the front end.

## 2.5 Betting and Redeeming

All ties, canceled, and 'no contest' games give bettors their initial bet back. Winners receive their bet amount plus the payoff implied by their bet odds. When the week's results are sent to the betting contract, all bets are settled, and the oracle payment is sent to the oracle contract. Settlement creates a mapping allowing bettors with a win or tie outcomes to redeem their bets (ties an ‘no contest’ outcomes are considered draws, each bettor gets their money back). A bettor must redeem each bet to transfer AVAX back to their account balance, making it available for withdrawal or betting on a subsequent event.

Bettors and LPs do not use specialized tokens, just native AVAX. All bets are fully collateralized, so if one has access to the account used for sending the bet or LP investment, a user's funds are safe in the contract. Unclaimed bets will reside in the contract forever, as mechanisms to sweep neglected funds to LPs or oracle token holders would introduce attack surfaces.

### 2.6 Big Bets

Bet size is constrained by the amount of LP capital available for new bets, and odds for standard bets are not negotiable. A *Big Bet* would be larger than feasible given the maximum size allowed in the regular contract, and such bets allow users to post their own odds. For example, if the most one can bet on a team is 99 AVAX, a whale can post an offer to bet more than 99 AVAX with their own odds. The taker of this offer would then have a bet size consistent with the payout implied by the odds offered. These individualized bets generate zero risk to the LPs, as the offered payout for one side matches the bet size of the other side, so the LPs do not receive a fee from these big bets. If someone takes a big bet, both sides are processed like a regular bet at settlement. Untaken bets can be canceled and refunded at any time; an untaken bet for expired contests can no longer be taken and does not need to be canceled because bettor funds are only frozen if a big bet was taken.

### 2.7 Liquidity Providers (LPs)

To become an LP, one sends AVAX to the betting contract 'fundBook' method and then is credited with shares representing their pro-rata ownership of the LP pool. This LP claim exists only within the betting contract and is tied to the initial LP AVAX account address. It is not transferable to other AVAX addresses. The size of the LP capital should adjust to the volume and degree of cross-margined trading, which will determine the expected pnl. The relation of an LP's share value will be equilibrated by its net capital, which makes creating an LP share token problematic.

LPs cannot invest or withdraw when games are active, which is the period between the start time of the first contest and when the results are posted, and bets are settled. This is because recently decided events may imply a large win or loss to the LP collective and potentially present an arbitrage for LPs trying to capture or avoid these cashflows.

LPs can only withdraw during the inactive period if margin is available, as the required margin is needed to collateralize active bets. Since there is at least a 24-hour window each week after settlement before new bets are offered, LPs are sure to be able to withdraw at least once each week. More practically, there will be free margin available for marginal LPs to withdraw over much of every week, as bettors will probably not max out the bookie's free margin in the first days of the week.

LPs must also have their AVAX in the contract for at least two settlements. If LPs could withdraw after only one settlement, people could add large amounts of AVAX at the end of a betting period when the pool has little net risk and then take it out right after settlement. For example, if all bets that other bettors fully collateralized week, the LPs would receive a certain profit given the vig built into the odds. Outsiders could provide superfluous liquidity just before the active period and withdraw immediately after settlement, generating a certain profit. This would dilute the profits of LPs providing 'real' liquidity. Therefore, an LP must expose herself to at least one betting period before withdrawing.

### 2.8 Emergency Functions

There is no outside adjudicator to rectify problems, as this would delay payments and complicate the contract (how to incent the adjudicator?). All problems must be solved on-chain within these contracts.

If a hacker could sneak in bad odds that enabled a cheat, the oracle collective could nullify this action by posting a result of a 'tie' regardless of the outcome. This allows the LPs and bettors to get their money back as if nothing happened, and the incorrect (but fair) tie result should be clearly explained by the event logs showing the earlier hack. This would be an extreme scenario, like a fork in a blockchain, but it is helpful to anticipate.

Suppose off-chain odds change quickly and significantly, exposing the LPs to arbitrage. In that case, oracle token holders can immediately pause up to two bets. This action does not require the usual 12-hour vetting period to allow oracle token voting. It does not expose LPs or bettors to losses but prevents new bets. This method is restricted to large token holders to avoid mischievous trolls who might want to annoy users at little cost.

# 3 Oracle Incentives

Initially, I distributed half of the immutable lifetime supply of oracle tokens to someone willing and able to administer this contract. I created this, but I have no control or financial interest.[9] The other half of the supply was sent to the betting contract, enabling LPs to acquire oracle tokens proportional to their relative liquidity.

While the initial token holder will have a monetary incentive to administer the betting contract honestly, decentralized oracle ownership is useful for several reasons. For example, one does not want too much responsibility in a single agent, as myriad scenarios could incapacitate someone. Thus initial Liquidity Providers are awarded tokens based on their relative size. After approximately one year, 60% of equity tokens will be distributed this way to the LPs.

## 3.1 Sending Oracle Data and Voting Administration

One needs at least 5% of the outstanding tokens to submit data to the betting contract. A power law distribution will always accrue in ownership, and the top owners should find it in their best interest to lead the oracle administration. While submitting data takes some effort, the cost is relatively low given the ease at which relevant data is available and the limited scope and frequency of data submissions. Larger token holders should be sufficiently motivated to send data to the contract promptly.

Tokens must be deposited within the Oracle contract to submit or vote on submissions. This prevents double-voting and forces the token holders to attend to the contract they should be monitoring. The tokens are meant for governance, not speculation, and generate dividends directly proportional to the bet volume. Token holders cannot vote more than once on any data submission, which requires that token holders cannot withdraw tokens while a vote is active.

[9] I created something that I would like to use, and if successful will serve as an example, refocusing development away from providing grist for new token scams.

Initial data proposals must be sent between 12:00 and 13:00 GMT (7-8 AM summer New York), and voting on proposals lasts at least 11 hours. This gives oracle token holders sufficient time each day to see each data submission.[10] Upon submission, the proposal can be submitted to a vote count at any time after 18:00 GMT. A yes vote sends the data to the betting contract, while a no vote burns a fraction of the proposer's bond and resets the state for the next data proposal.[11]

If a majority vote of token holders rejects the data sent, the contract is reset to allow a new submission. One-fifth of the bonding payment is burned, which should be large enough to discourage fraud but small enough to make gratuitous rejections unattractive.

### 3.3 How Oracle Token Holders Claim Oracle's Eth Revenue

Each week the oracle receives 5% of the bettor winnings as a fee for their service (about 2.5% of bet amounts). There is a state variable representing the cumulative per-token oracle AVAX revenue. By recording the value of this variable when the token holder deposited their tokens in the oracle contract and when they withdraw these tokens, oracle token holders receive their pro-rata share of the oracle AVAX revenue that occurred while their tokens were in the contract. As revenue is transferred at weekly settlement, the only periodicity relevant to oracle revenue is the number of settlements that have transpired while the tokens have been in the contract.

### 3.4 Tests

On GitHub, nine scripts document the integrity of all contract methods. One can use them to find edge cases that I may have neglected. There are only three contracts in this suite; it is straightforward to evaluate the contract suite.

## 4 Conclusion

Most sports betting sites touting their crypto functionality are conventional ones accepting crypto. A truly blockchain-based betting dapp upholds Satoshi's vision of *pseudonymity*, *confiscation-proofness*, and *permissionless access*, which requires it to have no off-chain presence. I hope that a focused dapp with good incentives can provide an example of what works on the blockchain. The purpose of the contract is to facilitate betting, not create a token. However, unlike most dapps, where tokens have a vague governance role and hypothetical fees, equity token holders have an essential job and get revenue instantly.

One should expect players to always act in their selfish best interest. A sustainable contract creates a repeated game where honesty is always the dominant strategy for every player. Simplicity is crucial in generating good game theory equilibria because the state space grows exponentially in the number of players and actions they can take. An incentive-compatible contract avoids the more costly solution of establishing adjudication procedures and slashing conditions for various infractions. The trust one puts

[10] Time is set as an offset to GMT, so these hours shift with daylight savings.

[11] The initial data provider’s tokens are credited as a yes vote, and votes are decided on a simple majority of votes cast.

into the SnowBet Oracle is fundamentally the same as why investors trust miners: the rational self-interested assessment that honesty dominates dishonesty for a hypothetical individual.

Blockchain betting contracts are the perfect application of straightforward rules to a common use case. SnowBet presents a quick and efficient way to get asset exposure without the many hassles in standard contracts. Sports betting is ubiquitous, but it should be easier. This contract provides a simple way to do that.

# Appendix

## Odds Translation

To convert moneyline odds into Decimal odds, we have the following.

For positive moneyline odds: (Moneyline odds/100) + 1 = Decimal odds
For negative moneyline odds: (100/Moneyline odds) + 1 = Decimal odds

To translate decimal odds into moneyline odds that are prominent on NFL betting sites, we have the following adjustment mechanism:

If decimal odds are greater than 2.0: 100 × (decimal odds – 1) = Moneyline odds
If decimal odds are less than 2.0: -100/(decimal odds -1) = Moneyline odds

To translate moneyline odds to fractional odds:

For positive moneyline odds: Moneyline odds/100 = Fractional odds
For negative moneyline odds: -100/Moneyline odds = Fractional odds

### Odds in the contract

The odds are available on many betting websites, and arbitrage limits how far these odds can differ. On average, a team's implied probability of winning will change by only 2% over the week, rarely over 5%. All odd postings and updates are recorded in event logs, observable in online queries at sportAVAX.co.

A contest will have a single odds number posted for a contest. These odds are supplied only for the initial favorite using a truncation of preliminary decimal odds. For example, 1.909 would be stored as 909, 2.50 as 1500, etc. This number, however, is just relevant to the team in slot 0, the favorite. Further, it needs to be adjusted to reflect the oracle fee that would be assessed. Thus, the betting odds for a favorite where the match odds were 955 would be 910, via

Bettor Odds (favorite) = (contractMatchOdds * 0.95)/1000 + 1

= 955*0.95/1000+1=1.907

The odds for its opponent are generated within the contract by the following formula:

$$underdogOdds = \frac{1e6}{\left(contractMatchOdds + 45\right)} - 45$$

This transformation generates odds on the team/player in slot 1, the underdog, such that the book has a 2.5% vig. The '45' parameter generates the spread.

Then to account for the oracle take, the all-in odds for team 1 would be

Bettor Odds (underdog) = (underdogOdds * 0.95)/1000 + 1

With this method, we can ensure that the set of odds for a contest generates a positive vig, removing a potential attack vector.[12] This formula generates a vig of 2.5% for the LPs via parameter 45 in the above equation, and the 5% take of winnings generates an approximate 2.5% vig for the oracle.

The website sportAVAX.co displays the decimal odds users receive if they win. For example, a user seeing odds of 1.900 will receive back 1.900 times their bet amount.

The most common odds offered for the NFL are presented in moneyline form as -110 for both teams. A flat book on such a wager would receive 220 and payout 210. In this way, the 'house' makes money used to pay for various costs and a profit from the house. The implicit profit ('vig') in this case would be 4.55%, 10/220. The general formula for estimating the vig is given by the following formula, where *p* and *q* are decimal payouts (e.g., 1.909 for a standard even money bet) for opposing teams.

$$vig = 1 - \frac{pq}{\left(p+q\right)}$$

The 45 in equation above and the 5% take of the oracle winnings combine to generate a vig of approximately 4.5%, just like standard betting books. The oracle collective and LPs have equal stakes in the contract's net revenues.

The spreadsheet 'SnowBet.xlsx' presents a page where people can see how these transformations are applied. Those interested in sending odds to the contract will find it a helpful template.

## Redeeming a Bet

A unique bytes32 hash identifies a bet, and each bet notes the Ethereum account address used to place the bet. Each bet is represented by the unique combination of epoch, match, and pick. At settlement, a bets hash refers to a struct containing this information, and a mapping generated at settlement allows redemption (1, a tie to a number 2). SportAVAX.co provides this data by reading the user's MetaMask address, allowing users to redeem bets by clicking a single button (it is one transaction). However, anyone can log onto the blockchain using the account used to make a bet and submit the bet hash.

## LP Eth to LP Shares to LP revenue

LPs own a pro-rata portion of the contract's revenue based on their percentage of LP capital before that week's events. Statistically, the LP capital will grow each settlement due to the vig; this is how LPs make money. As the relevant LP credit/debit occurs at settlement, the LP's AVAX/share value is fixed each week when users can withdraw or invest.

An initial investment generates the following shares:

LPshares =  AVAX invested × LpTotalShares / TotalCurrentLPAVAX

[12] A negative vig would allow someone to create positions that would generate arbitrage profits.

For example, assume the contract has 123 AVAX owned by its LPs, who have 100 shares. This AVAX may be sitting free or locked up as collateral for upcoming contests. This implies each LP share is worth 1.23 AVAX.

| LP AVAX | LP TotalShares | avax/Share |
|---|---|---|
| 123 | 100 | 1.23 |

Suppose Alice wishes to invest 10 AVAX into this pool. The above formula implies she would receive 8.13 shares (10/1.23). This would change the pool's balance sheet to

| LP AVAX | LP TotalShares | avax/Share |
|---|---|---|
| 133 | 108.13 | 1.23 |

Note the ratio of AVAX/share is the same after Alice's investment, so existing shareholders do not lose or gain money via Alice's new investment.

If we assume the LP collective gained 2 AVAX that week, the new balance sheet after a settlement will look like this:

| LP AVAX | LP TotalShares | avax/Share |
|---|---|---|
| 135 | 108.13 | 1.25 |

The increase from 133 to 135 reflects a 1.5% profit from that epoch's games. If Alice then sold her shares, she would receive AVAX using a transformation of the above formula:

$$\text{avax Withdrawal} = \text{TotalCurrentLPAVAX} \times \text{SharesSold} \ / \ \text{LpTotalShares}$$

Selling 8.13 shares would generate 10.15 AVAX, a 1.5% return on their investment, identical to how much the AVAX LP pool rose over that period.

In this way, any LP investment or withdrawal reflects the percent change in the size of the LP pool over the investment period.

## Oracle avax Revenue

Oracle token holders must deposit their tokens in the oracle contract to vote, and then are expected to vote at least twice a week. The two fundamental data submissions are the initial set of contests, odds, and start times, and then the results of those contests. When a weekly settlement transaction is executed, the oracle's 5% fee is applied to the winnings and sent to the oracle contract. The '*feePool'* state variable reflects the lifetime amount of AVAX per token paid to the oracle contract.

$$\text{feePool}=\text{feePool}+\text{oracleRevenue}/\text{OracleTokensInOracleContract}$$

When an oracle token holder deposits into the contract, their account notes the current value of *feePool*. When that oracle token holder withdraws or adds to their account, the token holder is sent their entire accrued AVAX using the formula

$$\text{avaxpayment}=(\text{feePool} - \text{user.OldFeePool})*\text{UserTotalTokenAmount}$$

This account's userFeePool is then updated to the currentFeePool, so another immediate add or withdrawal of a token by the same token holder would have CurrentFeePool – UserOldFeePool=0, and receive nothing.

With this method token holders can be sure the contract is in balance, where accounts payable are equal to AVAX in the contract at all times.

## Margin Adjustment for New Bet

There are three types of margin tracked by the contract, all held in the array variable' margin.'

**bookiePool**

This is AVAX owned by the LPs, both free and locked up as collateral.

**bookieLocked**

This is AVAX owned by the LPs that are unavailable for bookie withdrawal. It represents the gross worst-case scenario loss for the LPs.

**bettorFund**.

These are bettor funds applied to outstanding, taken, bets.

LPstruct. Mapping between an address and its share amount and time of investment. The total number of LPStruct.shares will equal sharesOutstanding, reflecting the percent ownership of an address of the bookie capital.

Free LP capital in margin [0] is available for new bets that increase the contract's net liability. New bets that increase the contract's net position will transfer AVAX out of margin [0] into margin[1]. Bets that decrease the bookie's net position will move AVAX from Margin [1] to margin [0]

For a team with standard decimal odds of 1.909. the total payoff for a win can be separated into two components: 1 + 0.909, the latter term representing the bettors net profit, and the former term representing the bettor's initial bet. The amount 1*betAmount is available from the bettor funds, while 0.909*betAmount must come from the LPs or bettors taking the other side. Odds are stored such that

$$DecOdds = 1 + ContractOdds / 1000$$

For example, the standard odds of 1.909 for an 'even' bet would have odds in the contract stored as 909.

LP Required Margin is the sum of the maximum liability for all the events in an epoch. Each event is independent, so the book is correctly margined by correctly margining all the individual bets. Thus we need merely describe how margining occurs for a single event, knowing these are then summed for determining the overall Required Margin.

The total amount owed if team 0 wins equal the sum of the bet amount and its payoff for all the bets taken on team 0. Let us define two types of capital used to pay bettors, the payout or profit, with must come from someone other than the bettor, and the bettor's initial bet amount, which is returned with his profit:

$$winSum_0 = \sum_j betAmount_0^j \cdot odds_0^j / 1000$$
$$betSum_0 = \sum_j betAmount_0^j$$

**betSum0** is the total amount bet on team 0, summing over all the bets on 0. Bettor funds are available for payout but not part of the LP's Required margin (which is in Margin [0] and Margin [1]). **paySum0** is the sum of the bettor's profit if team 0 wins, which requires AVAX from the LPs or bettors taking the other side. As the betSum of team 0's opponent, team 1, is available for paySum0, the trick is monitoring the ability to cover the LP's liability given the amount bet on its opponent. This generates the following maximum liability for the LP (*aka* required capital) for a contest in that it is the maximum liability to either team in a contest:

$$\max\left\{winSum_0 - betSum_1, winSum_1 - betSum_0, 0\right\}$$

We add the zero term because the house will have only non-negative liability on every contest. For a new bet long on team 0 playing, the new bet and payout are added to the above max() equation and compared to the extant maximum liability. The difference is the change in the LP's required margin (margin[1]), which is offset by a change in the LP's free Margin (Margin [0]).

$$\Delta RequiredMargin = \max\left\{winSum_0 - betSum_1 + \frac{odds}{1000} betAmount_0, winSum_1 - betSum_0 - betAmount_0, 0\right\}$$
$$-\max\left\{winSum_0 - betSum_1, winSum_1 - betSum_0, 0\right\}$$

This is calculated at the bet time, and the LP's capital is either locked or freed depending on whether the margin change is positive or negative. For example, an initial bet will increase the required margin, but a subsequent small bet on the opposing team would lower the required margin. A bet could move the book so that the net LP liability switches from team 1 to team 0 or consists of the decrease in the net liability on team 1. In any case, the above function captures the difference in the worst-case scenarios for contract liability.

In this way, the LP's total book exposure is cross-margined so that 1.0 AVAX capital can support many bets via incremental bets on both contestants. At settlement, only money not payable is returned to the bookie's free margin pool.

### Settlement Detail

Each bet creates a struct that contains the team and week of the bet. These two inputs create a hash mapped to a number representing its game outcome: 0 for a loss, 1 for a tie, and 2 for a win. When the array of 32 results is sent to the settlement method, the mapping is created (the mapping is zero for uninitialized hashes, so unless updated, the mapping is 0). This mapping is then used for redemptions, in that a bettor claiming his winnings will need the {epoch, match, team} hash to map to a 1 or 2 to generate a payout.

In addition to creating non-zero hash mappings for non-losing teams, the total payments to all bettors were generated using the results and the paySum and betSum arrays:

$$WeeklyPayBack = \sum\nolimits_{i=0}^{31} 1_{WinOrTie}\left(i\right) \cdot betSum_i$$
$$WeeklyWinnings = \sum\nolimits_{i=0}^{31} 1_{Win}\left(i\right) \cdot winSum_i$$

Here $1_x$ is an indicator function that is 1 if true, 0 else. The *WeeklyWinnings* represents the bettor profit, while the WeeklyPayBack represents the initial bettor funding. The oracle fee of 5% is applied to the bettor winnings, representing about 2.5% of the total bet amount. As individual payouts are less than or equal to the total payouts in any week, this rounding truncations on individual redemptions will not compromise contract solvency; rounding will not prevent redemptions.

At settlement, accounts are adjusted as follows:

Redemption capital = WeeklyPayBack

PayoffPot  = WeeklyWinnings * 95 /100

The bookie's capital then adds the money bet that week minus the payouts for wins and ties.

bookiePool = bookiePool + bettorLocked – redemptionPot – payoffPot

The oracle revenues are then just 5% of the WeeklyWinnings, and are transferred to the oracle contract.

The bettor's money exists in the residual and must be claimed via redemption. At redemption, their bet and its winnings are credited to the bettor's user balance, available for withdrawal or future bets.

After settlement, the bookieLocked is set to zero, so all bookiePool funds are available for withdrawal.

[i] Closing line odds are actually worse for bettors than the opening line, though not significantly. Regardless, the risk of arbitrage arises whenever the odds on both sides winning implies a probability of less than 1.0, which allows the bettor to make a certain profit regardless of who wins. If the odds were offered by the same book, and that book allowed margin accounting, this would create a money pump. In practice, the opportunity comes from the odds generated by two separate books, which prevents cross margining these bets. Given there is a limit to any one event, and the opening and closing line odds are statistically equivalent, the LPs would make money even if such an odds discrepancy arose.

[ii] In iterated prisoner's dilemma games, the optimal strategy is not to play the Nash strategy of the stage game, but to cooperate and play a socially optimum strategy. An essential part of a strategy in a repeated game is that uncooperative play will reduce the payoff to both players in future periods. A player may choose to act selfishly to increase their own reward rather than play the socially optimum strategy, but if it is known that the other player is following a trigger strategy, then the player expects to receive reduced payoffs in the future if they deviate at this stage. An effective trigger strategy ensures that cooperating has more utility to the player than acting selfishly now and facing the other player’s punishment in the future. This is reciprocal altruism: I play nice because I then expect you to play nice in the future.