EdgeFund: A Decentralized Bankroll for Fixed Odds Games

EDGEFUND

"A decentralized 'smart contract'-based platform pricing provably fair fixed odds bets at the minimum possible edge, returning profits to token holders through deflation."

Colin McCrae
www.edgefund.net

Abstract

EdgeFund proposes the creation of an entirely decentralized bankroll of blockchain tokens, accessible soley via betting functions written in smart contract code which would allow fixed odds bets to be accepted and paid out without the need for any trusted central authority. The bankroll could be used by game operators who want to offer large payouts without risking their own funds. The smart contract code would protect its bankroll of tokens from bankruptcy by dynamically calculating the lowest possible platform edge it can charge for each bet based on the Kelly Criterion. The smart contract code would be publicly viewable and provably fair, with the outcome of bets determined by decentralized random number generation.

Game operators have freedom over the bet size, payout odds and total house edge, profiting on every bet from the difference between the total house edge and the platform edge. This profit (along with any user winnings) is returned to the game operator by the smart contract after every bet, regardless of the bet outcome. The platform will enable any number of fixed odds betting games to be built on top of it. Native platform tokens will become more scarce over time on average due to accumulation within the smart contract bankroll, in effect distributing profits to token holders through deflation.

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1. Summary

1.1. Introduction

In October 2008, Satoshi Nakamoto published a white paper describing a decentralized peer-to-peer version of electronic cash, Bitcoin [1]. The invention that made this network unique was the concept of a proof-of-work chain of blocks (a blockchain), providing for the first time a way for all parties to agree on a sequence of events without a central trusted party. This invention set the stage for a blockchain revolution that has quickly surpassed the original scope of the Bitcoin network.

Five years later in late 2013, Vitalik Buterin, a cryptocurrency researcher and programmer, published a white paper describing a blockchain-based distributed computing platform, Ethereum [2]. This platform built significantly on the capabilities of Bitcoin, adding comprehensive smart contract functionality executed by a decentralized network of public nodes on a Turing-complete virtual machine. Ethereum's decentralized blockchain and its native digital currency ether are currently proving the most widely used tools for dapp (Decentralized Application) building, with many others in development.

The nascent blockchain industry has many challenges ahead of it. Scaling these networks whilst keeping them secure has proven difficult. Transaction costs and validation speeds remain prohibitive for many applications. Differing opinions on proposed network changes between developers, miners, businesses, and users have led to network splits (hard forks). The value of the native tokens used by the networks (such as bitcoin and ether) remain extremely volatile. Legislation regarding the use of blockchain networks, distribution of tokens, and taxation is inconsistent across the globe.

Regardless, the opportunities created by blockchain technology are vast. Software developers across the globe are finding novel uses and building a new generation of online decentralized platforms. This newly invented network architecture promises to change the way the internet works, enabling decentralized applications that can autonomously transfer value.

1.2. Key Features

The EdgeFund platform will function as follows:

- We will create a shared decentralized bankroll of platform specific native tokens, locked inside a smart contract.
- This bankroll smart contract will only be accessible via betting functions. Game operators will send bets via these functions and are free to specify the bet size, payout odds, and total house edge (or win odds). This will be based on the games being offered to their users, and the users bet sizes.
- The lowest possible edge the platform can charge is dynamically and autonomously calculated for each bet inside the smart contract based on the Kelly Criterion [3]. This protects the smart contract from bankruptcy due to a sequence of losing bets.

- The platform processes all bets on the blockchain, returning any winnings (plus the difference between the total house edge and the platform edge) to the game operator after each bet is resolved. The game operator can then pass on any winnings to the user, keeping its profit on every bet regardless of the outcome.
- The smart contract bankroll takes the risk, ensuring game operators make a return on every bet.
- Game operators can build any number of games that link to our platform. These games can offer payouts using the shared decentralized bankroll without the game operator risking any of their own funds.
- Every transaction is executed by open source smart contract code on a public blockchain, making the platform provably fair for all parties interacting with it.
- The native tokens will be of fixed total supply to ensure value is retained over time.
- The small platform edge leads to a long-term accumulation of tokens in the shared bankroll, causing the remaining circulating tokens to become more scarce through deflation.

We believe that this platform will be attractive to fixed odds game operators and their users, as well as token holders looking for increasing value. It will allow licensed start-ups across the world immediate access to liquidity they would struggle to achieve on their own. As the platform grows, larger game operators will find they can make more profit at less risk by using our bankroll to underwrite large bets from their users. The more games built on the platform, the more valuable the bankroll becomes, and the smaller the platform edge becomes. This represents a significant step forward for game developers: for the first time, anyone will be able to develop and deploy a fixed odds betting game as easily as any other application.

"EdgeFund fundamentally changes the online betting landscape for game developers, opening up unparalleled liquidity at literally no risk."

1.3. Why EdgeFund?

EdgeFund believes that it can solve the problems that existing blockchain-based betting platforms suffer from:

- **A fixed platform edge.**Fixing your platform edge at an arbitrary percentage means that another platform can copy your smart contract code and redeploy the same code with a lower percentage edge (assuming this does not violate the Kelly Criterion, in which case you risk bankruptcy).
- **Limited odds available.** Virtually all smart contract platforms only offer a fixed selection of odds at which bets can be placed at. A fully flexible platform should accept any odds assuming the bet meets the Kelly Criterion.
- **Fixed maximum and minimum bet limits.** Bet limits should be calculated dynamically based on several factors including the current bankroll, blockchain fees, and the bet specifics.

- **Centralized random number generation.** Use of a centralized random number generation system (such as Oraclize at random.org) accessed via an API can be problematic. As with any centralized system, the users need to trust the provider to be honest. It would be difficult to prove if the provider influenced the result in their favor. Additionally, if the provider's URL is hard coded into the smart contract, the platform would cease to work if the URL changed, was shut-down, or otherwise intercepted.
- **Centralized control of bankroll.** If the developers or platform owners can update or change the smart contract code then the platform is fundamentally centralized, and requires trust in those individuals.
- **Iniquitous payout of profits.** The payment of profits to investors and owners creates a drag on the smart contract and means that the platform can be copied without such payouts. The ultimate solution is to ensure that all benefits go to token holders, such that copying the platform is not profitable. The cryptoeconomic incentives should always work to create network effects that benefit the decentralized platform's growth and survival.
- **A split bankroll across several smart contracts.** Splitting the bankroll over several smart contacts means you cannot offer the lowest possible platform edge, as bets are not backed by all available funds.

2. Evolution of Gambling

This section provides an overview of the evolution of gambling, and ultimately explains why blockchain technology will play a central role in the future development of the industry.

2.1. A Brief History of Betting

Betting has taken place, in some form or other, for hundreds if not thousands of years, and is inextricably linked to the history of humanity. From ancient China where indications of rudimentary games of chance were discovered on tiles, to Egypt where the oldest known dice were excavated, to scenes on Greek and Roman pottery which indicate that betting on animal fights was common. Humans love to bet and do so at every opportunity.

As betting spread and evolved throughout society it became more organized and regulated. The first casinos appeared in Italy in the 17th century; The Ridotto was established in Venice in 1638 to provide a controlled gaming environment. Casinos started to appear throughout continental Europe in the 19th century. Games like Roulette and Vingt-et-un arrived in the United States with early settlers from France, and steamboats on the Mississippi became the venue of betting for wealthy farmers and traders; a version of poker, having originated in 17th century Persia, was being played in New Orleans in 1829.

The mechanization of betting meant that winnings could then be regulated more accurately. The first betting machine was developed by Sittman and Pitt in New York, and around the same time the Liberty Bell machine was invented by Charles Fey in San Francisco. The first video slot was invented in 1976 which paved the way for the online video slots that followed.

The first fully functional betting software was developed by Microgaming (an Isle of Man-based software company), now one of the largest casino and slot game developers in the world. This was secured with software developed by CryptoLogic, an online security software company. Safe transactions became viable and led to the first online casinos in 1994. The first live dealer casinos appeared in 2003 courtesy of Playtech, which created a hybrid of ‘brick and mortar casinos’ and the virtual world.

Technological advances have attracted a new generation of players. Evidence suggests that internet users are using their desktops less and are more inclined to use handheld devices. The same can be said of those who enjoy online betting and enjoy playing their favorite games whilst on the move. The top gaming sites have recognized this shift in usage, leading to many more opportunities for mobile online betting. Mobile devices are preferred by players for their convenience. Online betting and social networks are on the same mobile platforms, as operators recognize the growing interaction between the social network and betting.

2.2. Betting on the Blockchain

Blockchain technology and the emergence of cryptocurrencies is disrupting the gaming industry in ways we couldn’t have imagined even a few years ago. Using cryptocurrencies for betting is becoming widely popular for casinos and can be used either as the main payment system, or as an alternative to

fiat-based payment systems. The blockchain provides transaction transparency, provably fair random number generation, reduced house edge and lower transaction costs. The blockchain also allows the user to bet anonymously with almost instantaneous withdrawal and deposit times, and there is no need to hand over copies of documents or even create an account.

The advent of provably fair betting on the blockchain has the potential to be a paradigm shift for the whole gaming industry. What started with simple dice games has already grown to include Roulette, Blackjack, and many others. Developments in this space are likely to grow rapidly, with teams of developers introducing new opportunities for betting utilizing blockchain technology.

Betting has quickly found itself as one of the most popular uses for smart contracts on the blockchain. Simple contracts can be created which payout winnings based on provably fair rules. The open source code means that these rules are visible for all to see, so users can be assured that they are playing a fair game. Once deployed, the contracts are immutable, fully decentralized, and cannot be shut-down.

One of the earliest examples of blockchain betting was SatoshiDICE on the Bitcoin network. First launched in 2012, SatoshiDICE allowed anyone to send transactions to their address, and the user would either receive winnings or a tiny payout to signify a loss. Since then, many more competitors have established themselves, with many of these instead using the Ethereum network.

Ethereum is an especially appealing platform for blockchain betting. It has been designed from the ground up to be a global decentralized computer that anyone can use, and which can transfer value in the same way as the Bitcoin network. Any user can create new native tokens and deploy smart contracts directly onto the Ethereum blockchain with no permissions required.

Smart contracts on the blockchain are developing and advancing at a breathtaking speed. The reason for such rapid growth is that for these contracts to be provably fair, the developers must release their source code to the public. This also allows other developers to catch-up to the current state-of-the-art and indeed improve and easily re-deploy smart contracts. The immutable and provably fair properties of smart contracts make the blockchain a natural home for unstoppable code which can facilitate fixed odds betting games.

2.3. The Future of Online Gaming

The worldwide gaming market is prosperous and the outlook positive due to several factors, including an easing of government regulations in some countries, the potential to generate tax revenue and contribute to national economies, and the wider reach of online gaming. Global revenue from betting is expected to hit $635 billion by 2022, according to recent findings out of Dublin, Ireland from Research and Markets. This represents an annual growth of 5.7%.

While land-based casino gaming dominates the global gaming market, online gaming is becoming increasingly popular because of the convenience and privacy offered to players and vendors. With the increased penetration of smartphones and tablets, operators are attracting a larger audience and are better prepared to attract millennials, a customer segment that is tech savvy, mobile and interested in new varieties of games.

The rise of online gaming also creates opportunities to use emerging technologies to develop revolutionary solutions to the industry's biggest challenges. Although today the use of Bitcoin is a small portion of the online betting market, the use of the blockchain to manage transactions could solve issues with fairness, security, privacy and transparency. Already, online gaming with cryptocurrencies is a global market with a cap of around $30 billion and 10% annual growth. In 2016, the total amount of bets on cryptocurrency casinos exceeded 1.5 million BTC and now there are hundreds of online casinos.

Blockchain is a decentralized system; no one company or person can have an advantage over the players. This reinforces transaction fairness and allows for immediate deposits and, importantly, withdrawals. Overall, blockchain based casinos provide far more favorable odds and payouts than their real-money counterparts.

The use of blockchain technology also allows for secure and private transactions. Entering personal or banking information when registering at an online casino utilizing cryptocurrency is not required — typically a username and password is all that is necessary. The use of blockchain also drives transparency as it will ensure timely, meaningful and reliable disclosures about a company's performance.

The gaming industry is increasingly capitalizing on this trend. The number of Bitcoin-only and cryptocurrency-supported online gaming platforms are on the rise, with new platforms and game titles being added on a regular basis. A handful of gaming platforms have also gone further to develop blockchain-based games with smart contract integration to create a new generation of online betting games.

3. Technical Proposal

3.1. Trusting A Shared Bankroll

The benefits of a shared bankroll when taking on quantifiable risks such as fixed odds bets is significant. A larger bankroll allows for larger bets to be accepted and at longer odds. Historically it has been challenging for multiple game operators to share a single bankroll. Bankroll contributors must trust a single centralized party with their portion of the bankroll, and game operators must trust that the centralized service is indeed honest.

Shared bankrolls are subject to moral hazard (a form of 'tragedy of the commons'), whereby individual game operators are incentivized to take more risk than is rational because the cost of the risk is mostly borne by the other operators. Each individual game operator wants to maximize their gains and can do so by taking on risky bets, with payouts underwritten by the shared bankroll. This is contrary to the common good and depletes the shared bankroll through the collective action of all game operators acting in their own independent self-interest.

Consistently taking bets that break the Kelly Criterion will eventually lead the shared bankroll to ruin.

Even with meticulous accounting and auditing, it is impossible to verify with certainty that any individual game operator is correctly pricing bets relative to the bankroll, and indeed if their games are fair. It would be trivial for an individual game operator to fix payouts to 'insiders'. Assuming these winnings were within expected probability ranges, the fraud be hard to prove.

Provably fair betting and bankroll management has not been possible until the invention of the blockchain based decentralized ledgers and smart contracts. We propose a platform that offers a decentralized bankroll, protected by a smart contract that strictly enforces Kelly Criterion rules. Game operators can only interact with the smart contract through pre-defined functions hard-coded into the contract itself. Attempts to make bets outside of these constraints will be rejected and returned.

3.2. Why There Must Be an Edge

The new paradigm of blockchain based online betting undoubtedly offers great opportunities for enterprising game operators. However, there are a few fundamentals of autonomously accepting bets that cannot be ignored. One of the most important is why the platform must charge an edge.

It would be extremely desirable to build a platform to offer unlimited fixed odds bets with no edge. Such a platform would be unbeatable. Unfortunately, this is technically impossible without incorporating fatal restrictions. It can be shown mathematically that anyone with a finite bankroll accepting unlimited fixed odds bets with no edge is subjecting their bankroll to a risk of ruin (bankruptcy). This is true even when the house has a much larger bankroll than all of the bettors.

Imagine two people choose to bet $10 against each other at fixed odds (paying evens) on the flip of a fair coin. After each flip, the losing player must pay the winning player $10 from his personal bankroll. If both

players start with $100, it is only a matter of time before a long enough run of ‘bad luck’ strikes one player and he is bankrupted by the other player. Since they both start with the same bankroll, the initial conditions are symmetrical, so they both have a 50% risk of ruin assuming they continue to bet until one of them has $200 and the other has $0.

In the case above, both players have a long run risk of ruin of 50%, even though they both are betting at fair odds (neither player has an edge). This result still holds true even if their bankrolls were much larger (or their bets were smaller), although the average number of bets until bankruptcy would increase.

Consider the same scenario again, except this time one player starts with only $10 whilst the other again starts with $100. The game is otherwise the same, with both players still betting at fair odds. The wealthier player here could be considered the house, and the poorer player the bettor. Even in this case, there are still many scenarios where the bettor wins all the money in the long run, bankrupting the house. The probability of this occurring is slightly under 10% in this example.

Hence having a substantially larger bankroll does not completely protect you from risk of ruin. It makes bankruptcy less likely but it does not eliminate the risk.

The only way to offer unlimited zero edge bets with no risk of ruin is to have an infinite bankroll. Curiously, this can be achieved on a blockchain by allowing the smart contract to mint new native tokens as required to payout bets. Any bet that cannot be paid out from the initial bankroll (or previous winnings), can simply be paid out by newly minted tokens.

A fixed odds platform built on this basis has fatal economic value incentives. Allowing the contract to mint new tokens on demand means the token supply cannot be fixed, and indeed must be able to increase indefinitely as required in an unpredictable manner. Newly minted tokens would devalue existing tokens through inflation, and uncertainty of the future token supply would entirely undermine the token’s value proposition. Token holders and users alike would be discouraged from holding these tokens, and the platform is unlikely to succeed.

Therefore, a smart contract accepting unlimited zero edge bets on the blockchain is not feasible in the long-term. It can be concluded that a firm requirement for the native token of any such fixed odds platform is that the total supply of tokens must be fixed, and this must be provable and transparent. Given that the total token supply is fixed, an infinite bankroll is not possible, and unlimited zero edge bets can never be accepted against the decentralized bankroll.

It is worth noting that betting restrictions could be put in place which would allow for no platform edge even without access to an infinite bankroll. To reduce or eliminate their risk of ruin, one or more of the following restrictions could be implemented:

- Only offering zero platform edge occasionally with ‘profits’
- Designing games such that obtaining the zero edge is nearly impossible
- Matching bets to other users (a peer-to-peer betting exchange)

None of these restrictions are desirable, and they do not allow the operator to truly state that they are offering unlimited zero edge bets against the platform.

3.3. The Lowest Platform Edge

For blockchain based smart contracts to be provably fair, the full source code must be publicly available. This is essential for any betting application, as users need to trust the contract will do exactly what the developers claim. The requirement for developers to make their code open source leads to an interesting side-effect. If the economic incentives behind a specific smart contract can be improved (for example to lower the platform edge charged on bets), then it is trivial for another developer to copy the source code, modify it, and redeploy as their own.

Any fixed odds betting platform that charges an edge above the mathematically minimum possible edge can be beaten, and it is only a matter of time before another platform modifies their code and destroys the business model.

Given that it is not possible to offer zero edge bets with a token of fixed total supply without severe restrictions as previously discussed, the smart contract must offer the mathematically minimum possible edge. The rewards for the winner of this race to the lowest platform edge are significant. The perfect smart contract would accept the widest range of fixed odds bets at the lowest mathematically possible platform edge, ensuring all profits are returned to token holders to maximize the network effects of the platform.

3.4. The Kelly Criterion

The Kelly Criterion [3] is a mathematical formula traditionally used by a bettor to determine the optimum bet size when the odds are in his favor (i.e. he has a positive edge). The Kelly Bet is a bet size which satisfies the Kelly Criterion formula, and sizing all bets like this is known as the Kelly Strategy (and is the optimum strategy in most scenarios). Kelly Strategy will outperform any other strategy in the long-run.

Our smart contract will calculate the lowest possible platform edge it needs to charge for each bet, based on the Kelly Criterion. This is a function of several factors: the current bankroll of the smart contract, the bet size, and the desired payout odds.

Using the formula in this way allows the smart contract to accept the maximum range of bet sizes and odds with a very low platform edge, while still protecting the bankroll. These parameters are calculated dynamically for every bet to ensure the decentralized bankroll has zero risk of ruin. Indeed, the smart contract will expect to accumulate a bankroll of its own native tokens over time. As the bankroll increases, the platform profit is effectively returned to token holders (game operators and speculators) by allowing the circulating supply to reduce over time as deflation.

The Kelly Criterion was originally derived by John Kelly, Jr. in 1956 during his time at Bell Labs [3]. For a given bet, where the probability of winning and payout odds are both known, the formula returns what the bet should be as a fraction of the bettor's current bankroll to optimize long-term profit.

The equation below is the commonest form of the Kelly Criterion, and is often described by the phrase 'Edge over Odds'.

$$f^* = \frac{pb - 1}{b - 1}$$

The Kelly Criterion basic formula
f—bet as a fraction of the current bankroll (bet size / bankroll)*
b—decimal payout odds received on the bet (b>1)
p—probability of winning (0<p≤1)

The formula above provides several interesting results. If the odds are fair for the probability of winning, the Kelly Criterion states you should not bet at all. For example, evens payout (b = 2) on a coin flip (p = 0.5) would cause f* to be zero. This demonstrates that no matter how big your bankroll or how small your bet, you cannot make a Kelly Bet without there being a positive edge. A smart contract following this rule therefore must have a positive platform edge to be able to accept any bets.

It can be demonstrated that in simple fixed odds betting scenarios, the Kelly Bet will increase bankroll faster than any other strategy in the long-term. The downside of the Kelly Bet is short-term volatility that can often be severe. If avoidance of short-term volatility is important, then some long-term gains can be sacrificed to reduce short-term volatility by employing a 'Fractional Kelly' system. In Fractional Kelly, the bets are sized as a proportion of the Kelly Bet (e.g. 50% of the Kelly Bet is known as 'Half Kelly').

The equation below incorporates a factor, K, which is the fraction of the Kelly bet to use (0 < K ≤1).

$$f^* = K\frac{pb - 1}{b - 1}$$

Fractional Kelly Criterion (including a K factor)

3.5. Using Kelly to Calculate Minimum Edge

The Kelly Criterion formula is useful for sizing bets when a bettor has a positive edge. However, in a normal fixed odds betting scenario, it is the house which has the positive edge. Therefore, the Kelly Criterion can be used by casinos when deciding if their bankroll is large enough to accept certain bets. This is especially relevant for small game operators, who may not have a large bankroll.

For a unit bet, the minimum edge can be calculated from the probability of winning (*p*) and payout odds (*b*) as shown below. It can be thought of as simply the probability of winning (*p*) multiplied by the sum won (*b-1*), plus the probability of losing (*1-p*) multiplied by the sum lost (*-1*).

$$Edge = p(b-1) + (1-p)(-1)$$

$$Edge = pb - 1$$

Edge based on probability of winning and payout odds

The term '*pb-1*' in the Kelly Criterion formula can now be replaced by '*Edge*'. Rather than comparing the probability of winning to the payout odds, we now have a single term '*Edge*' by which to describe how favorable a bet is compared to its payout odds.

$$f^* = \frac{K.Edge}{b-1}$$

Including 'Edge' term into the Kelly Criterion

Our core philosophy is that our smart contract will accept any bet size at any payout odds, assuming it can satisfy the Kelly Criterion. If so, the smart contract will take the bet at the requested payout odds, and it will use the Kelly Criterion to calculate the lowest platform edge it can charge. If we rearrange the above formula for '*Edge*', we have a formula to calculate the minimum acceptable platform edge for a given bet and payout odds.

$$Edge = \frac{f^*(b-1)}{K}$$

Re-arranging for 'Edge'

We now have a method for calculating the minimum possible platform edge that can be offered, whilst protecting our bankroll from risk of ruin. The only inputs required for the formula are the requested bet size relative to the current bankroll (*f**), the requested payout odds (*b*), and the fractional Kelly factor (*K*).

3.6. Options to Charge an Edge

We now need to put the above method into practice and use the Kelly Criterion to calculate lowest mathematically possible platform edge for any bet size at any requested payout odds.

A fair bet would be one where the payout odds exactly reflect the probability of winning (the win odds). An example of a fair bet is offering a payout of even odds (traditional odds of 1/1, or decimal odds of 2) for a 50% probability event such as the flip of a fair coin. The edge in this case would be 0%. To price in a platform edge, the actual bet must deviate from a fair bet. There are three primary ways that a smart contract could incorporate an edge:

1. Have a lower than fair payout.

2. Have a lower than fair probability of winning.
3. Charge an up-front fee.

Assume a game operator wants to place a $1,000 bet at even odds, and the smart contract's current bankroll is $1,000,000 and a K Value of 1 is being used. Using the Kelly Criterion, the smart contract calculates that a platform edge of 0.1% must be charged. A zero-edge payout would be $1,000 with a probability of 50%. Three ways a smart contract could price in a 0.1% platform edge in this example are described below::

1. Reduce the payout on a winning bet to below the requested payout odds (a winning bet pays $998 with a probability of 50%).
2. Reduce the probability of winning to below the fair odds probability (a winning bet pays $1,000 with a probability of 49.95%).
3. Charge an up-front fee of 0.1% / $1 (bet becomes $1,001, a winning bet pays $1,000 with a probability of 50%).

Paying winning bets at less than the quoted payout odds as per (1) is unorthodox. Almost all fixed odds bets in casinos are paid out in full, and the house edge is incorporated into the difference between the probabilities implied by the win odds and the payout odds. In this example, the win odds would imply a probability of 50%, and the 'payout' odds 49.95%.

For example, in European roulette, a straight bet on an individual number is paid out at 35/1 (decimal odds of 36). The actual odds of hitting one number are 1 in 37 which has a fair odds payout of 36/1 (decimal odds of 37). Therefore, the house edge is incorporated into the difference between the 'win' odds and the 'payout' odds and can be calculated to be 0.0270 (2.70%). It is much more common for bets to be paid out at certain agreed quoted payout odds, with the actual outcome occurring slightly less frequently than it would do under fair odds.

Charging game operators an upfront 'fee' as per (3) is not feasible, since the exact edge required for every bet is calculated dynamically and cannot be known with precision in advance. Using this method could lead to many bets being returned unprocessed due to insufficient fees.

The methodology we propose to use is as per (2): incorporate the required platform edge into reducing the win probability from the fair odds probability. Users of almost any fixed odds game are familiar with bets being paid out as a multiple (or fractional multiple) of the original bet, and accept that the total house edge is incorporated by the bets winning less frequently than the fair odds probability would dictate.

3.7. Incorporating Game Operators' Edge

We have described how the smart contract can incorporate its own required platform edge into each bet as per the Kelly Criterion requirements. We now need a method for incorporating the overall edge into the bet calculation such that game operators can charge their own edge.

The simplest way for the game operator to incorporate their own edge into each bet, is to simply keep a percentage of their user's bet (equal to their desired edge), and to only send the platform the remaining bet. However, If the game operator were to do this, they must adjust the requested payout odds upwards to ensure that the user can still expect a chance of winning the full payout. In this way, the platform can still pay the user the full winnings, only with a lower probability (because of the game operators edge).

However, the smart contract platform needs to dynamically price in its own platform edge based on the exact bankroll at the time that the bet is placed, which the game operator cannot know for certain in advance. This means the total house edge on each bet that the casino operator's users will pay can only be *estimated* before the bet is placed. This is an undesirable methodology as most fixed odds based games must have a fixed total house edge. It is generally not acceptable to only tell the user what the game operator's edge is, and not the total house edge.

In order to overcome this problem, there remain two ways to pass on the information that the smart contract needs to exactly price in the game operator's edge. The game operator can send the smart contract a bet of known value and requested payout odds and specify either (1) win odds, or (2) the total house edge.

The following example describes what we mean by this.

Assume a user of a game operator wants to place a $100 bet on a European roulette game 'straight up' on a number. The decimal payout odds of this bet are 36 (traditional odds of 35/1), and the decimal win odds of this bet are 37 (traditional odds of 36/1). Therefore, the casino wants to charge a total house edge of ~2.70%. The smart contract has a current bankroll of $1,000,000 and K Value of 1, but the bankroll changes as other unrelated bets are made. The game operator knows that the smart contract platform edge will be approximately 0.35% (calculated using the Kelly Criterion formula), but does not know the exact number before placing the bet.

In this example, the game operator has the choice of two methods to pass on the information required for the smart contract to price in both the operator's edge, and its own platform edge:

1. Send a bet of $100, with payout odds of 36, and win odds of 37.
2. Send a bet of $100, with payout odds of 36, and a total house edge of 2.70%.

Both scenarios give the same result for the same bankroll and same K value and are realistic use cases for game operators. For games such as roulette, where the total house edge is only defined by the difference between payout odds and win odds, the game operator must use option (1). For slot machine games where the total house edge is a fixed number, the game operator must use option (2). Note that there are no degrees of freedom: win odds can only be used to calculate the total house edge, and vice versa. Regardless, it is still useful to allow either of these two methods to be used to ensure simplicity between different game types, and to ensure no rounding errors.

The two methods mentioned above (rounding errors aside) are equivalent. In the case of decentralized random number generation evaluating the bet as a win, the smart contract will return $3,600 to the game operator (the user's $100 bet plus $3,500 winnings) plus $2.35 in profit (the difference between the edges: $100*(0.0270-0.0035)); Hence the game operator will receive $3,602.35 if the bet wins.

If the bet loses, the game operator will still receive the $2.35 profit. Note that the bets and payouts will be denominated in the smart contract's native token.

Here we have described a way to price in both the platform edge that the smart contract requires to protect its bankroll from risk of ruin, and two methods to ensure that the game operator can keep the remaining edge (i.e. the difference between the total house edge and the platform edge). This will enable game operators to build games which interface directly with the smart contract via these two betting functions.

4. Native Token

4.1. Requirement

Many projects have launched blockchain-based tokens over the last few years, and critics frequently question whether these tokens are actually necessary to achieve a project's goals. As a consequence, the onus is on each blockchain project to demonstrate beyond reasonable doubt that a native token is an absolute requirement.

The token we propose will be a utility token used to create a decentralized liquidity pool that is available to operators of online fixed odds games. A fixed total supply of tokens will be created on a smart contract supporting blockchain such as Ethereum. Some of these tokens will be sold into circulating supply, and some will be moved into a decentralized bankroll smart contract. The tokens in the bankroll will be mathematically locked into the smart contract and can only be interacted with by means of betting functions, as described earlier. Once the smart contract is fully implemented, nobody (not even the platform developers, founders, or token owners) will have any control over the tokens in the smart contract bankroll.

A decentralized bankroll smart contract could be created using existing tokens, such as the blockchain's own token (for example Ether on the Ethereum blockchain). However, creating the EdgeFund bankroll using an existing blockchain token such as Ether would prevent the platform from operating as required for the following reasons:

1. Token holders would need an incentive to place their tokens in the smart contact's bankroll, rather than hold them privately as they do now.
2. Token holders would need a method to withdraw their funds from the smart contact's bankroll.
3. Providing investors with a cut of the winnings would prevent the bankroll from growing and the tokens would not experience deflation.

There would also need to be a method for withdrawing funds built-in as a function of the smart contract. This would lead to a highly variable bankroll, and raise the possibility that it would drop too low for practical use. Game developers and operators must be able to rely on the decentralized bankroll to ensure enough liquidity to incentivize them to build games. It is a requirement that the only way tokens in the bankroll are interacted with are via the betting functions. Withdrawals from the bankroll by any means other than the betting functions must not be possible. The only way to realistically achieve this, is to configure the platform with a circulating supply of tokens counterbalanced with a cryptographically protected bankroll created at the outset of platform development, and protected by the smart contract code.

By building this platform using its own native token, we can both incentivize investors to fund the platform, and allow them to withdraw their investment whenever they please via any number of cryptocurrency exchanges. As the value of the individual tokens in circulating supply can be expected to

increase in proportion to the number of tokens in the bankroll, these profits are effectively shared with token holders.

In this way, we will have created the world's first decentralized and fully trustworthy bankroll. This utility token opens a world of opportunities for game developers and operators to create new and interesting fixed odds betting games.

4.2. Value Proposition

In creating the optimum solution for accepting fixed odds bets on the blockchain, our smart contract can attract token holders and token users faster than any other platform due to four key network effects.

1. The Kelly Criterion will ensure no platform can accept fixed odds bets with a lower platform edge, ensuring our smart contract has the fastest user growth rate of any fixed odds smart contract.
2. This increased use will cause the smart contract to have the most valuable liquidity pool, which will allow us to offer the largest bet size range and lowest platform edge, further increasing our user growth rate.
3. As platform use increases, tokens will accumulate inside the smart contract's decentralized bankroll, increasing the value of the remaining circulating tokens through deflation.
4. Token holders seeing the first three network effects in action will be drawn to hold further decentralized bankroll tokens in the platform, as they will expect larger value gains than can be found elsewhere.

Game operators can start businesses with no requirement to hold a bankroll themselves and are immediately able to offer bets with large potential payouts. The smart contract takes the risk, so game operators make a return on every bet. Once interest in the smart contract begins, a positive feedback loop is created whereby as use increases, the value of the tokens increases, allowing for larger bets to be accepted, and for the platform edge to decrease even further. As the value of the bankroll builds, even larger established game operators will find it more profitable to use this platform once the bankroll value is higher than their own.

We see the combination of these network effects being incredibly powerful and ultimately leading to Edgefund being the de facto decentralized fixed odds platform. Once the bankroll has sufficient value, it will be near impossible for any other decentralized fixed odds platform to provide cheaper odds or a larger bet range.

As the smart contract will charge a platform edge on every bet, on average the tokens will migrate from the circulating supply pool into the bankroll over time. Since the bankroll tokens are only accessible through the smart contract betting functions, the tokens that migrate towards it are effectively burned (permanently removed from circulation). As the platform is used for placing bets, over time the value of circulating tokens will increase as they become scarcer. This creates a unique and fascinating economic outcome, whereby we have created a token that is inherently deflationary. Its value increases in proportion to the volume in which it is used for betting.

Over time the total number of tokens in circulation will tend towards zero. However, tokens will be numerous and divisible to many decimal places. If the average fiat currency denominated bet remains constant over time, the number of tokens that represent that bet will decrease over time, and the nominal rate of accumulation into the bankroll will slow.

Holders of many cryptocurrency tokens do not currently have any way to obtain a return even given steady use of the token. If they were to instead purchase native tokens in this smart contract, those users could expect an increased return assuming the platform experiences use. This platform will be attractive to both token holders looking for increasing value, and to fixed odds game operators. It will allow for start-ups all over the world to have access to liquidity that they would never be able to achieve on their own.

5. References

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