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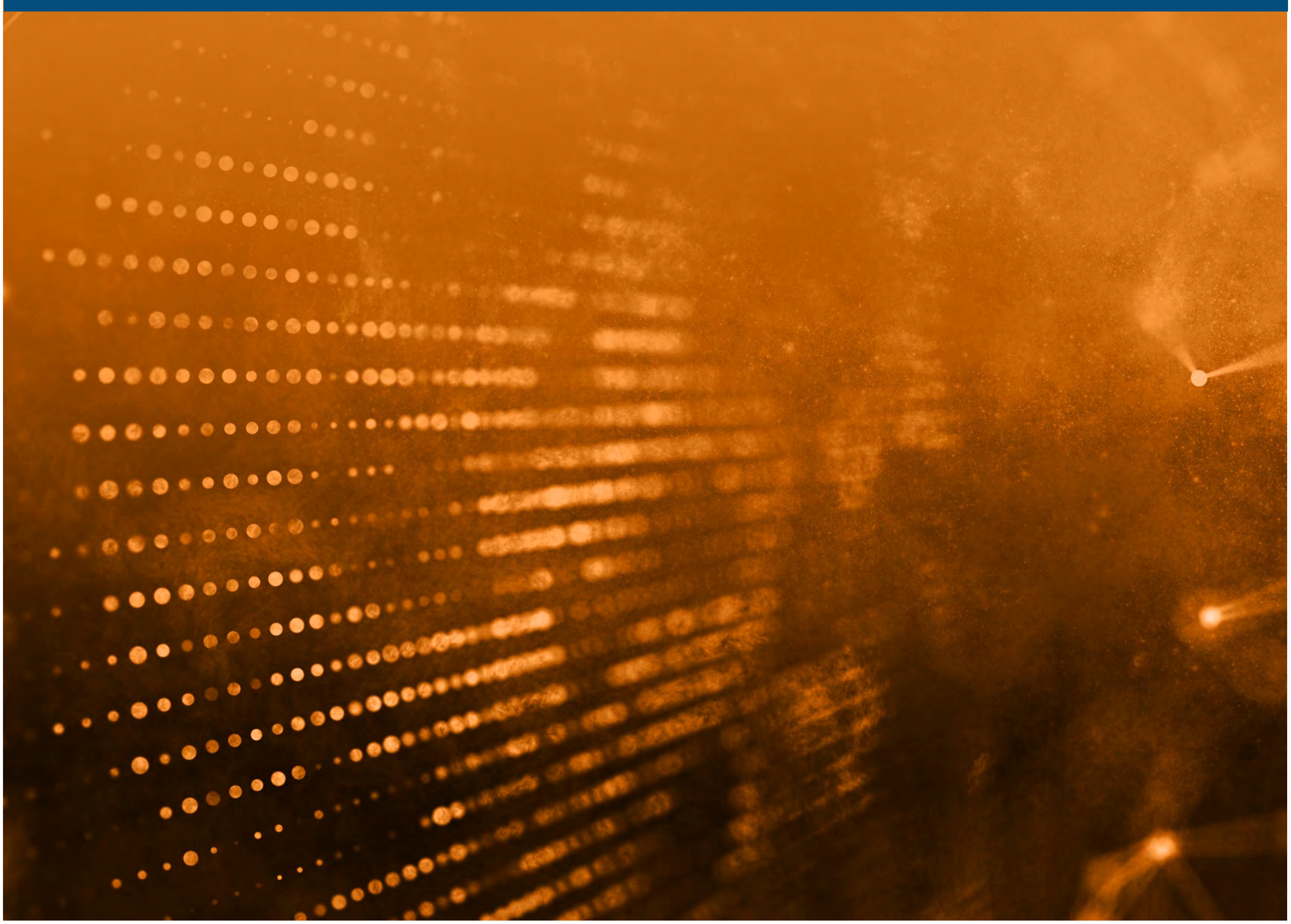
Peer-to-Peer Insurance: Blockchain Implications



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Peer-to-Peer Insurance:

Blockchain Implications

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Executive Summary

Blockchain is a technology consisting of an open ledger shared among multiple parties where business transactions are recorded in a verifiable and immutable way (Iansiti & Lakhani, 2017). This technology offers increased efficiency of economic transactions through flexible and automated interactions between agents. In the insurance industry, blockchain technology applications have ranged from improved operational efficiency and claims processing to on-demand insurance and automated underwriting. The intimately related smart contract technology provides coded (business) logic. Together, the smart contract and blockchain technology have reached the level of maturity where it can empower new market entrants to quickly, and with little resources, develop new insurance products and business models of a decentralized nature.

One such example is Peer-to-peer (P2P) insurance, a business model where individuals or economic agents join together and pool their resources for mutual aid. Coupled with blockchain technology, this model allows for creating a business that does not require centralized authorities and ensures an automated and trustworthy transaction environment. Instead of case-by-case claim approval through traditional underwriting, claims can be processed automatically when appropriate conditions are met. The premium payments can be facilitated via so-called digital wallets, digital escrow-type accounts storing fixed-valued exchangeable tokens. All payments can be made using platform-specific tokens, further reducing transaction costs while ensuring that no user carries an exposure greater than the amount they put into their digital wallets. Both raising of claims and claim payment can be automatically enabled, executed, and recorded by the blockchain technology. Thus, the practical need for an intermediary insurance company is removed.

In this context, in addition to the efficiency and automatization of transitions, the drivers of value for consumers may be relevant and open communication, which currently are areas of low satisfaction for policyholders. Communication includes transparency in how premiums are set and where customer money goes, concepts that may be confusing or unfair to the average policyholder. Use cases such as P2P insurance offer a unique response to these criticisms by allowing a return to the community values of historical mutual aid, while providing explicit transparency by maintaining a transparency about the ledger, business logic, all pool contributions, and claims. Going forward, it is conceivable that mass accessibility of powerful and simplified blockchain development tools will empower many non-institutional new market entrants to experiment with alternative risk-sharing arrangements.

Thus combined, technological processes and consumers' desire for new and more social models can be disruptive to the insurance industry. At the same time, they might pose unprecedented opportunities. The goal of this report is to empower the insurance community in this new context. That is why, in this paper, we showcase the development of a P2P insurance model and analyze it from a technological and product perspective. This provides an opportunity not only for start-ups but for traditional insurers who would like to offer such a platform. While there are many possible design choices one can investigate, this work proceeds by making intuitive choices with an overall goal of guiding the reader through all the developmental stages of a particular implementation. For our example, we use Hyperledger Fabric technology, an enterprise grade distributed ledger that supports smart contracts. Step by step, we show how a traditional insurer could be part of the development of this use case process. We run simulations and stress testing to understand aspects of this novel product better. Ultimately, our intent is to empower insurance industry practitioners to envision new opportunities and gain insights into the sharing economy.

Section 1: Introduction

1.1 BLOCKCHAIN TECHNOLOGY

Blockchain is a technology consisting of an open ledger shared among multiple parties where business transactions are recorded in a verifiable and immutable way in cryptographically protected blocks (Iansiti & Lakhani, 2017). Blockchain technology came to the public stage in 2008. It was introduced alongside the then esoteric Bitcoin digital currency, with its foundational underpinnings formulated in the seminal work of Satoshi Nakamoto. In recent years, the already significant proliferation of blockchain technology applications have only been accelerating across various industries (CB Insights, 2016). This comes as no surprise as this technology offers increased efficiency of economic transactions through automated interactions between agents. It also provides novel resource utilization and monetization, all while maintaining data integrity and privacy (Swan, 2015; Shrier, Wu, & Alex, 2016; Rijmenam and Ryan, 2018).

Notable companies exploring blockchain uses include Amazon, Comcast, Facebook, Microsoft, and Google (Castillo, 2019). Acceptance in the finance industry has been widespread, drawing the involvement of companies such as Citigroup, Fidelity, ING, JPMorgan Chase, and Mastercard. Meanwhile in the healthcare industry, companies such as Ciox Health and CVS Health have implemented blockchain to improve the handling of health data and medical records, increasing transparency and security, while removing data redundancy. Within the realm of the food industry, companies such as Nestle, Bumble Bee Foods, and Golden State Foods are employing blockchain to track ingredients throughout the supply chains to ensure better food safety and ethical food sourcing.

In the insurance industry, applications of blockchain technology have ranged from increased operational efficiency and claims processing, to on-demand insurance and automated underwriting (Gatteschi, Lamberi, Damertini, Pranteda, & Stamaria, 2018; Hans, Zuber, Rizk, & Steinmetz, 2017). For example, the solutions of blockchain consortium, B3i, remove the need for traditional tracking of data via paperwork, phone calls, and email by keeping a single updated source of insurance information on a distributed ledger (B3i, 2021). Citigroup has invested in start-ups aiming to build distributed ledgers for insurance payments. Another example of industry implementation is the maritime insurance platform launched by Guardtime together with Maersk, which ensures trust in transactions by relying on immutable ledgers of logistics data (Guardtime, 2018). However, the most enticing use of blockchain technology may be in the development of completely new business models and products. This is especially true due to the zeitgeist of the times with changing consumer preferences evident in the rise of the sharing economy.

1.2 PEER-TO-PEER INSURANCE

Peer-to-peer (P2P) insurance is one such business model where individuals or economic agents join together and pool their resources for mutual aid. The most characteristic feature of this model is that it allows for the creation of businesses that do not require centralized authorities. While there may have been an interest in these forms of business models in the past, the question of trust in transactions between unmediated parties has not successfully been resolved until recently. Blockchain technology is the solution that ensures an automated and trustworthy transaction environment. Today, when putting the business model and technology together, as the practical need for an intermediary insurance company evaporates, P2P insurance has the potential to be truly disruptive and may only be a harbinger of things to come.

Specifically, in the case of P2P insurance, in lieu of case-by-case claim approval through traditional underwriting, claims would be processed automatically when appropriate conditions are met. The premium payments would be facilitated via so-called digital wallets, which are digital escrow-type accounts storing fixed-valued exchangeable tokens. All payments in this model would be done using platform-specific tokens, further reducing transaction costs, all while ensuring that no user carries an exposure greater than the amount they put into their digital wallets (Laurent, Chellet, Burke, & Seers, 2018). Both the raising of claims and claim payments would be automatically enabled, executed, and recorded by the blockchain technology.

Going forward, it is conceivable that the mass accessibility of powerful and simplified blockchain development tools will empower many non-institutional new market entrants to experiment with alternative risk-sharing arrangements. Clearly, blockchain-powered insurance models will significantly remove the barriers of entry to new entrepreneurs. We have seen technology play such a revolutionary role in the recent history of other industries, particularly exemplified by Amazon in the context of book retail. In this new reality in the case of P2P insurance, premium collection, claim processing, and traditional underwriting are all transformed. Today, there are only a small number of early market entrants with some form of implementation of a P2P model, with surprisingly only a few reaping the benefits of blockchain technology. Currently, when combined with maturing blockchain technology, the opportunities provided by this business use case are within the reach of many. That is why it is beneficial for those in the insurance industry to understand the nuances of this application along with the underlying technology.

For this reason, the aim of this project is to showcase the development of a P2P insurance model and analyze it from both technological and product perspectives. While there are many possible design choices one can investigate, we proceed by making certain intuitive choices with an overall goal of guiding the reader through all the development stages of a particular implementation. Throughout this report, we succinctly give the minimum necessary technological background. Our intent is to empower insurance industry practitioners to envision new opportunities, as well as gain insights into the sharing economy as it applies to insurance.

Section 2: Background

2.1 HISTORICAL CONTEXT

Many conceptions of mutual aid throughout history have relied not solely on financial agreements, but also social ones. One of the earliest documented precursors to insurance was recorded in the code of Hammurabi, a code which was highly dependent on the social structure of the Babylonian culture (Trenerry, 2009). The collegia of the Roman empire not only supported burial costs to their members, but also extended charitable services and held social gatherings (Ginsburg, 1940). In the realm of maritime insurance, the "Rhodian Sea-Law" stated that financial loss would be distributed among fellow shipmates if an individual had to throw cargo overboard to save the ship (Britannica, 2021). The guilds of the middle ages required visiting the sick, attending funerals, and regular social events in addition to their common *alms* payments (Gorsky, 1998). The friendly societies in the early modern period encouraged "solidarity between members, they promoted civic engagement and acted as nurseries of democracy, and they cultivated an attitude to social welfare founded on independence and self-help" (Gorsky, 1998).

The successors to these organizations, namely modern mutual and capital insurance companies, have added structure that can benefit policyholders. The central entity maintains historical data and actuarial practices that calculate what premiums will be sufficient to cover expected claims. Heavy regulation of these central insurance companies ensures sufficiency of these funds and mandates payment of claims as agreed in the insurance contract. Large scale adoption of modern insurance means insurers can rely on the law of large numbers when making these calculations, stabilizing the variability of losses from year to year. Overall, this arrangement is designed to instill confidence in policyholders in the ability of the central entity to cover their claims.

However, the current centralized structure has led to dissatisfaction with the insurance industry. According to the Reputation Institute's study of the U.S. insurance industry in 2018, public sentiment regarding the industry is declining. Value alignment is an area of particularly low satisfaction in property and casualty insurance (US Insurance RepTrack, 2018). In fact, one of the most common criticisms of the capital insurance industry is the conflict of interest when paying claims as premiums not used to pay claims are considered profits for the insurance company (Berardinelli, 2008; Feinman, 2010). Mutual insurance aims to alleviate this concern by transferring ownership of the company to the policyholders. However, even in the case of mutual insurance, the same report lists relevant and open communication as areas of low satisfaction for policyholders. Such communication includes transparency of how premiums are set and where customer money goes, concepts that may be confusing to the average policyholder. P2P insurance offers a unique response to these criticisms by allowing a return to the community values of historical mutual aid, while providing explicit transparency by maintaining a public ledger of the business logic, pool contributions, and claims. Thus, in a community of individuals where there is a shared sense of care for other members of the P2P group, P2P insurance is a way to protect the community and, in a way, make each insured bear responsibility of the risk.

2.2 DECENTRALIZED MARKETS AND INSURANCE

The expansion of the internet in the 1990s led to internet-based, decentralized, peer-to-peer markets such as Craigslist and eBay. Over time, these marketplaces have evolved from being primarily goods-based to proving services such as ridesharing through Uber and Lyft and home-sharing through Airbnb. Peer-to-peer lending emerged in 2005 with Zopa and entered the U.S. market with Lending Circle in 2010. In 2017, the decentralized marketplace for AI technology, SingularityNET, was launched, further integrating blockchain into the peer-to-peer economy (SingularityNet, 2021). Benefits of P2P markets include matching buyers with sellers, implementation of novel pricing mechanisms, and the creation of trust and reputability (Einav, et al., 2016). A natural extension of these technologies is to a P2P-style insurance. As in other P2P marketplaces, a central entity must facilitate the infrastructural underpinnings for such a product. This provides an opportunity not only for start-ups, but for traditional insurers who would like to offer such a platform. Early market entrants in P2P insurance have implemented decentralization to varying degrees and with differing levels of success.

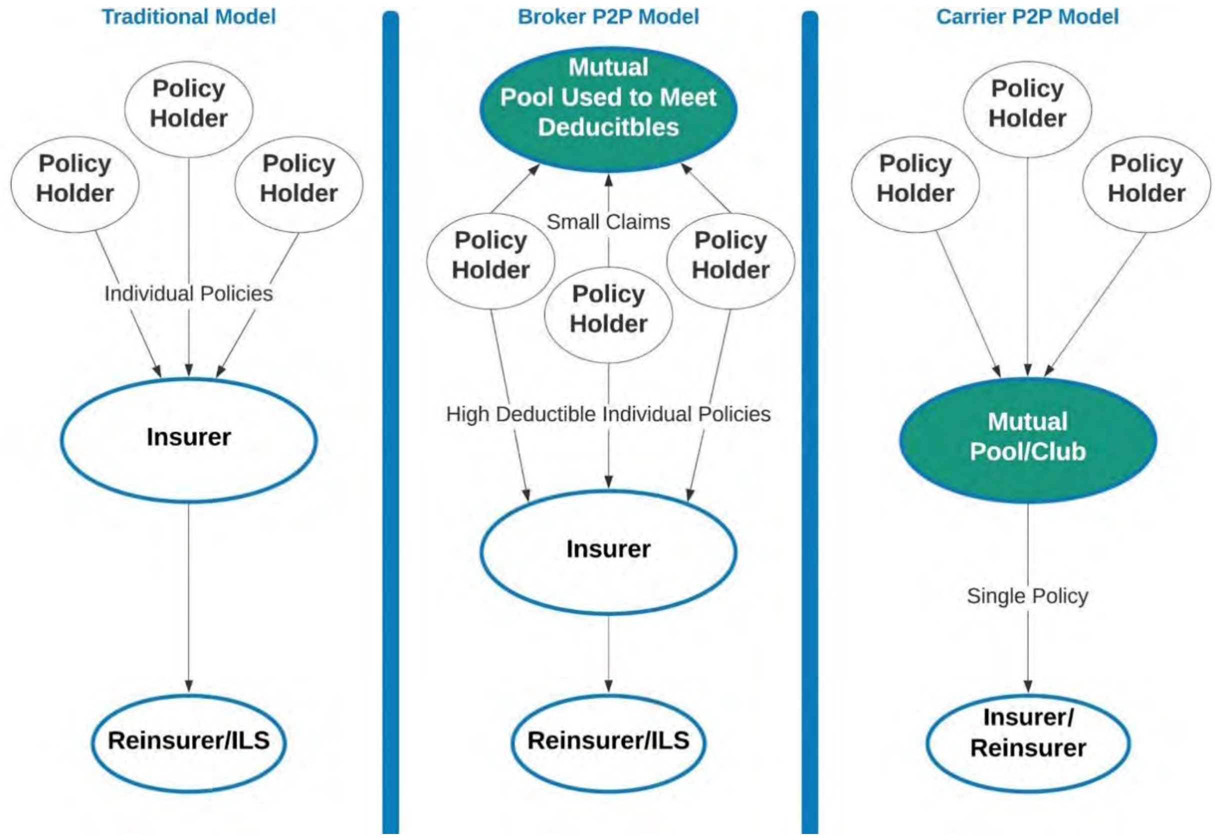
In 2010, the first successful P2P insurance model was launched in Germany with Friendsurance. On this company's platform, users can browse and purchase a high deductible insurance product from an established insurance company. Then, individuals are assigned to a pool with members of a similar risk profile who purchased similar policies. These individuals all contribute to a common pool that covers small claims until applicable deductibles have been met, while individual insurance policies cover larger claims. If only a small number of claims are raised, pool members receive a portion of their premium back at the end of the coverage period (Friendsurance, 2021). Because Friendsurance operates as a broker in this transaction, this business application is referred to as a broker P2P model. As of early 2021, Friendsurance has expanded to offer vehicle, homeowners, legal and liability, and electronics insurance. It is worth noting, however, that this particular implementation does not achieve true decentralization as typical insurance products are being sold rather than individuals contributing to a decentralized pool owned and managed by all group members.

After the success of Friendsurance, a large number of insurtech companies followed suit. In 2013, UK start-up Guevara developed a P2P model for vehicle insurance. However, they dissolved in 2017 as vehicle owners were wary to leave their trusted traditional carriers (Carey-Evans, 2017). Yet, in 2015, Lemonade Inc. launched in the U.S. and, as of early 2021, the company has a market cap above nine billion USD, and a daily trade volume of around five million USD (Google Finance, 2021). As opposed to Friendsurance, Lemonade sells their own products, implementing a so-called carrier P2P model. Lemonade offers homeowners, renters, pet, and life insurance, taking only a flat rate from the premium for profit, and using the remainder to pay claims and purchase reinsurance. Any unused premium is donated to the policyholder's chosen cause, building a sense of community (Lemonade, 2021).

In contrast to these partially decentralized models, U.S.-based Teambrella, which launched in 2016, harnesses the strength of blockchain technology to build a platform based on cryptocurrency. Teambrella does not sell any insurance products; rather, users automatically send P2P payments for claims from their Etherium wallet. For each raised claim, users vote on a reasonable amount of coverage to give and, when approved, funds are automatically transferred. This model encourages generosity, as those who vote not to approve other's claims will likely not have their own claims covered in return (Teambrella, 2021). Their model achieved a new level of decentralization by completely removing the need for an insurance provider. Alipay's Xiang Hu Bao platform, launched in the Chinese market in 2018, operates in a similar manner. The P2P platform has over 100 million users who share the costs of medical care. In light of the pandemic in 2020, COVID-19 was added to the list of covered illnesses (Insights, 2020).

Other companies in the P2P marketplace include Besure, Axieme, Etherisc, Laka, Insurepal, AIgang, Rega Life, Bit Life and Trust, and Unity Matrix Commons. What these companies have in common is the desire to disrupt the current insurance industry by harnessing the benefits of this cutting-edge technology and/or novel business models. With all of the above considered, these industry examples point to the opportunities for true decentralization in P2P insurance, which is technologically feasible through implementation on a blockchain system. Even more importantly, the growing success of these companies suggests that the market is increasingly ready for these decentralized products. Yet, established insurance companies have a unique advantage in creating such a P2P marketplace due to their pre-existing company trust.

Figure 1
P2P INSURANCE BUSINESS MODELS



Section 3: Technological Background of Hyperledger Fabric

In its full complexity, a blockchain network contains numerous components, protocols, and interacting elements. Deep understanding of this technological solution requires dedication and continued learning, resulting in a considerable time investment. However, for actuarial practitioners, a conceptual level of understanding of a few key components may go a long way towards inspiring new business use cases. With this knowledge, professionals may confidently communicate ideas to developers and move rapidly in a new world of opportunities provided by this new technology. That is why the goal of this chapter is to empower the readership by briefly explaining key elements of not only blockchain technology, but also related technologies such as smart contracts, oracles, and external software applications.

3.1 ASSOCIATED TECHNOLOGIES

Alongside blockchain technology is the intimately related smart contract technology. Smart contracts are merely coded logic and, more specifically in the case of enterprise applications, coded business logic. Given the current state of a ledger and external information, smart contracts trigger new changes on a blockchain. The traditional definition of smart contracts says they are "a set of promises, specified in digital form, including protocols within which the parties perform on these promises" (Szabo, 1996). In engineering terms, smart contracts are self-executing scripts that can be coded in high-level programming languages and run on a blockchain platform.

Although some blockchain systems are self-sufficient and need no external information, others need constant access to outside data. For example, a vehicle insurance smart contract may access real-time weather information to determine its contribution to an accident. Smart contracts collect this external information via "Oracles." An oracle is a piece of hardware or software that assigns facts about the state of the outside world. Decentralized oracles are gateways for smart contracts to interact with the outside world while, at the same time, limiting their reliance on a single source of truth.

External software applications also play a vital role in business use cases of blockchain technology. These applications allow users to access a user-friendly interface to interact with the blockchain. In the case of P2P insurance, an external application would allow users to search the marketplace for friends and family and request to form a pool. This application would continue to be the access point to the blockchain for users to contribute funds and submit claims. In general, external applications that interact with blockchain platforms could be accounting software, marketing databases, enterprise risk management applications, etc.

3.2 PUBLIC AND PRIVATE BLOCKCHAIN

Technologically, blockchains can be private, public, a consortium, or semi-private. These implementations offer trade-offs in their business applications. For example, in a public blockchain, anyone can join without asking for permission; hence, we call public blockchain permissionless. Importantly, one has unfettered access to write to and read from the ledger. Among the many public blockchain platform providers, Ethereum is the largest and offers smart contract capabilities, currently hosting around two million smart contracts. The Ether (ETH) is the currency of the Ethereum platform with the most recent market capitalization of around 144.5 billion USD. As of early 2021, the platform has 24-hour volume of trade around 37.8 billion USD (Ethereum, 2021).

When it comes to private blockchains, one needs the approval of all other parties to join. Importantly, permitted actions for all approved parties are clearly specified. In this way, private permissioned blockchain is generally better suited to business applications, particularly in an insurance setting. As is the case for public blockchain, there are numerous technological platform providers for private blockchain. The most prominent is Hyperledger Fabric, initially developed by IBM. Nowadays, it is an enterprise-grade open-source project governed by the Linux foundation. In recent years, it has become the one of the fastest growing Linux Foundation projects. Allianz SE, Amazon, BNP Paribas, Intel, Microsoft, Siemens, State Farm, Visa, and Walmart are only a few of the companies that are harnessing this technology.

Simply put, Hyperledger Fabric is a distributed ledger that supports the use of smart contracts to enforce trust between multiple parties. Hyperledger Fabric has an architecture that is configured in a modular manner, allowing transactions to be executed in parallel. The result is a dramatic increase in the rate of data transfer and transactions over that achievable by public blockchains. Our specific use case of P2P insurance necessitates a secure, efficient, and private system. This is why we employ Hyperledger Fabric for our implementation, highlighting the technical aspects of this particular technology.

However, direct engineering of this open-source system requires considerable expertise and time. Luckily for practical applications, many prototyping tools have been developed. These services provide interfaces that allow for simpler blockchain configuration, exploration, and management. Examples of these proprietary development tools include Chainrider, ChainStack, Kaleido, Rockside, and FabDep. Unfortunately, there are currently no open-source prototyping tools offering blockchain services on a similar scale. Of the ones that are available, Hyperledger Composer allows for building blockchain applications through a user interface. However, streamlining the entire process from building to deployment of Hyperledger Fabric networks and smart contracts is rather complex. Minifabric is another open-source tool, however, it has no user interface and, thus, requires use of the command line. Given our objective to examine the engineering complexity of implementing a P2P insurance use case and achieve fast implementation, we use ChainRider proprietary software.

3.3 OTHER BLOCKCHAIN MODELS

As an aside, it is worth noting that more types of blockchains have recently emerged to cover a more specific range of industry scenarios. These include semi-private blockchain networks and consortium blockchains. For a semi-private blockchain, a group of individuals manages the private portion, while the public part is open to anyone's participation. This hybrid model can be used in situations where the private part of the blockchain remains internal and shared amongst known users, while anyone can access the public part of the blockchain, optionally allowing the blockchain to be secured even through mining. In terms of how they are handled, semi-private blockchain applications would be similar to private web applications. As long as users are eligible through pre-established requirements or credentials, access is granted to them. Examples of semi-private blockchains could include ones for government entities for record-keeping, land titles, or public records.

A consortium blockchain is a blockchain where a pre-selected group of nodes governs the consensus process. For example, there may be a consortium of 15 financial institutions, each of which operates a node, and of which ten must sign each block in order for the block to be considered valid. The ability to read the blockchain may be public or restricted to certain participants. Some examples of consortium blockchains include R3 (for banks) and Energy Web Foundation (for the energy sector). This way of managing permissions and transacting reduces processing costs and data redundancies and helps to upgrade legacy systems, simplify document handling, and get rid of semi-manual processes of enforcement.

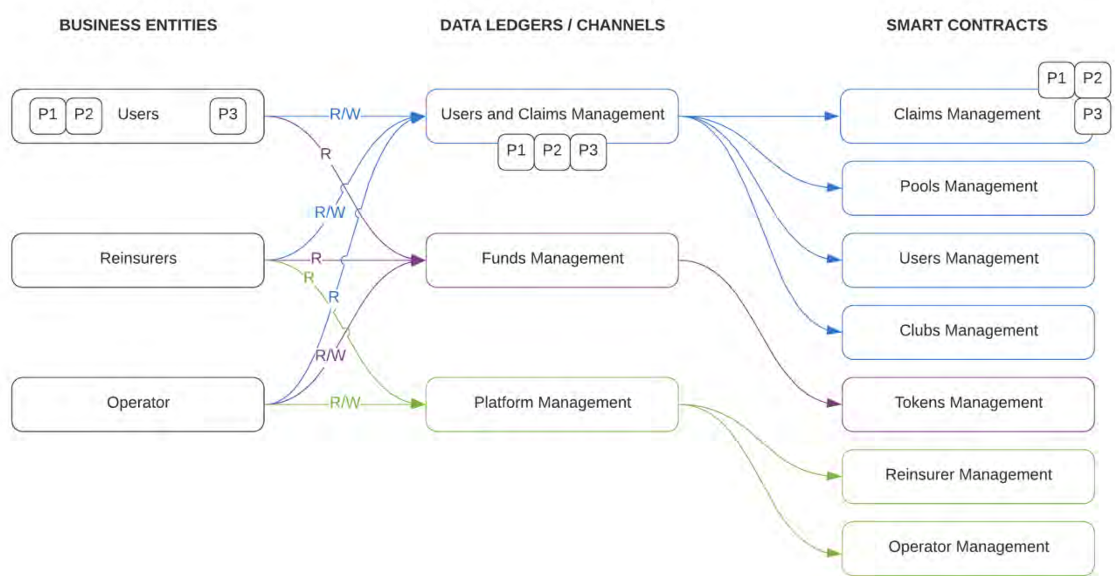
Section 4: Hyperledger Fundamentals

4.1 CONFIGURATION ELEMENTS

In this section, from a conceptual point of view, we outline the minimum technological background to understand the implementation in Hyperledger Fabric of our P2P business model. In order to introduce this important terminology, here we will reference Figure 2 as an illustrative example of a blockchain network, which is also reflective of our P2P implementation. However, our focus in this section is on the associated technological terminology, while the further specifics of the business implementation will be discussed in Section 5. The source used for this short introduction is (Hyperledger Fabric, 2021), and we gladly recommend this as your guide on further and more nuanced understanding of the blockchain framework. Here, we proceed with a description of the blockchain *network.*

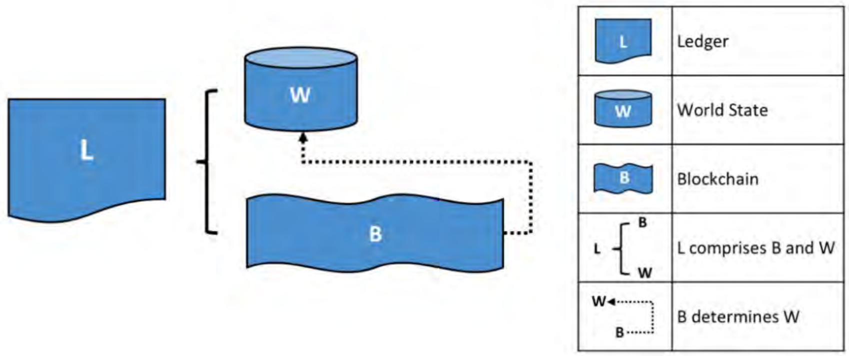
Figure 2

EXAMPLE OF A BLOCKCHAIN CONFIGURATION



- A **Blockchain Network,** such as the system depicted in Figure 2, is a technological solution that provides access to *ledgers* and *smart contracts* from external software *applications*. In the case of our P2P implementation, there are three business entities, or *organizations,* that take part in the network: the platform operator, the platform users, and the reinsurers.
- **Ledgers** hold shared information between parties. Ledgers are immutable, meaning that information can only be added to them, not deleted. Ledgers store both the current state of data, called the *world state*, as well as the entire transaction history, in a *blockchain*. Figure 3 provides a visual representation of the ledger system.

Figure 3
THE LEDGER



Source: https://hyperledger-fabric.readthedocs.io/en/release-1.4/ledger/ledger.html

- A **Blockchain** is a data structure comprised of interconnected blocks that contain grouped records of transactions. Each transaction in a block is either an update to or a query of the world state. All transactions on the blockchain are arranged sequentially in a historically compliant sequence. They are all cryptographically protected.
- **Smart contracts** are stores of shared processes or, in simple terms, business logic between parties. Smart contracts can perform operations using information from the ledgers to which they are assigned. For example, in Figure 2, the pool management smart contract can use information from the users and claims ledger in order to determine if an interested user has enough funds to join an insurance pool. If they do, the contract will facilitate the transfer of funds from the user's digital wallet to the common pool funds and write this transaction to the ledger. As seen in the previous example, smart contracts can both query information from the ledger and update the ledger's world state. It is worth noting that *Chaincode* is a computer code of smart contract(s) implemented in a high-level programming language. When it comes to Hyperledger Fabric, very often these two terms are used interchangeably.
- **Digital assets** are entities in the system that are governed by a smart contract and whose values are stored in the ledger(s). For example, platform tokens representing USD are one type of digital asset stored in the token/funds ledger and managed by the token management smart contract.
- **Peers** are physical components that store copies of the blockchain ledger(s) and smart contracts. In a blockchain network, the same information is stored on all of the peers, rather than being hosted on one server. As an example, in Figure 2, the user's organization is shown to have three peers: P1, P2, and P3. All three of these peers host a copy of the blocks of data from the users and claims ledger. All three peers also have physically deployed the claims management smart contract.
- **Channels** allow for sharing, according to prespecified rules, among a subset of parties in the blockchain network. Peers on the same channel have copies of the same ledger and have access to the same business logic captured in smart contracts on that channel. In our example network, peers P1, P2, and P3 have copies of the same smart contracts and ledgers since they share the same channel. Thus, peers on the same channel host exactly the same information and their smart contracts hold exactly the same business logic. While this structure inherently means redundancy of stored data, we also have a high degree of reliability and stability.
- A **consensus** is a process by which peers across a channel reach agreement that a ledger should be updated. In private blockchains, this process is facilitated by an **Orderer**. Once a sufficient number of peers endorses transactions, they are sent to an order. Orderers are network components whose role is to order transactions and package them in blocks. The blocks are then distributed to all of the peers to update the ledger. A peer can only endorse a transaction via the associated smart contract. While this process must be used to update a ledger, peers can query data from ledgers they host on their own. This means that, if a request is made to

the smart contract, any of the three peers can be used to send back the information. Additionally, the ordering service is in charge of specifying who has access to read and write on each channel. In Figure 2, each organization has read (R) and write (W) access to different channels and their corresponding ledgers.

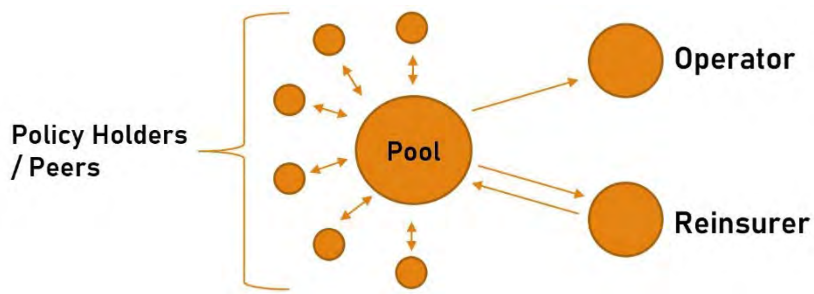
- Certificate Authorities are entities that issue digital certificates, which are used to identify and verify each peer using that peer's unique ID and security token (password). This ensures that only the peers of an organization in the blockchain network can access it.
- External software Applications owned by an organization can interact with the blockchain network through one of the peer nodes. These software applications can access information stored on a peer via API's (Application Programming Interfaces) and SDKs (Software Development Kits). These external applications allow different business entities to take part in the network, typically through a user-friendly interface.

Section 5: Business Use Case

In this section, we illustrate the application of blockchain technology deployed on Hyperledger Fabric to a P2P insurance platform. In our example, we adopt a carrier-style P2P business model, similar to that seen in Teambrella and Xiang Hu Bao. An operating company maintains a P2P marketplace platform running on blockchain technology where users can pay a fee to join the platform and form insurance pools. Users contribute funds to their pool, which are used to pay claims, with any remaining funds returned at the end of the coverage period. All transactional payments on the platform rely on platform-specific tokens in order to ensure secure transactions that can be regulated by smart contracts. While conversion to tokens is not strictly necessary for such a platform, tokens provide a universal currency that can easily be transferred within the platform, and even between different kinds of P2P pools, without needing to contact any banks or third parties for USD transfers. In addition, insurance and reinsurance entities have the ability to join the platform and sign contracts with individual pools. Then, the blockchain network has three organizations playing their roles in order for our platform to work: the users who would like to join a peer-to-peer insurance pool, the platform operator, and a reinsurer. Note that, as a decentralized model, the pool itself does not rely on an insurance license to operate. Thus, the reinsurance-like product offered would, in fact, be administered by a traditional insurer. However, we refer to this product as "reinsurance" in order to clarify its relationship with the P2P insurance pool.

5.1 ORGANIZATIONS

Figure 4
P2P ENTITIES AND TRANSACTIONS



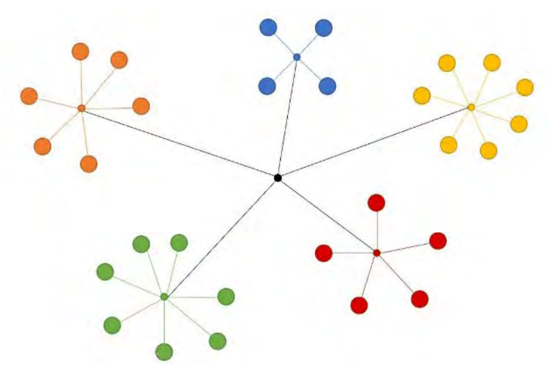
The operator deploys the blockchain and runs an external application that allows the users and reinsurers to connect to the blockchain itself through a user-friendly interface. In addition to managing the P2P platform, the operator issues tokens to be used securely as funds within the platform. In this way, the operator also acts as the regulatory body for this network by providing a way to securely handle users' tokens once they decide to contribute to an insurance pool. The operator also runs an application that allows them to track events occurring on the blockchain, giving the operating company a way to moderate the status of pools and claims. For example, if a claim is raised, the application automatically checks whether the claim is below the maximum allowed amount and if all required documentation is attached. This gives the operating company the ability to automate many of its processes.

The end-users may join the platform and deposit USD, which is converted to tokens by the operator. Users can then form pools with their friends, family, or any other users on the platform. After a brief joining period where users contribute tokens to the pool, the pool pays an operating fee and becomes active. Once a pool is active, users can raise claims. To provide self-regulation of pool funds, users can vote to approve or deny each claim raised by fellow pool members, with 50% approval needed for a claim to be approved for payment. Any remaining pool funds at the end of the coverage period are returned to the users.

To provide an extra level of protection, pools can opt to purchase a reinsurance-like contract from an insurance or reinsurance company before the pool is made active. Using smart contracts, the so-called reinsurer can stipulate specific reinsurance terms, such as photos or other documentation that must be stored on the blockchain. This novel reinsurance-like product is both profitable for insurers and beneficial to pool members. The product further distributes risk, while enticing the market segment of users who are drawn to more alternative risk-sharing methods.

One alternative to purchasing a reinsurance-like policy for the pool is to join a so-called reinsurance club. Clubs allow groups of pools to join together in order to further distribute risk by agreeing to cover excess claims within each other's pools. In this way, a relatively small group of family or friends in a pool can make contractual agreements with other pools. One downside to small pools sizes is the high variability in claims. This could be mitigated by increasing the size of the pool. However, in large pools, it may be difficult to keep track of personal trust in all members. Instead, clubs allow for pools to act as entities to interact with other pools. In practice, club contracts would likely rely on oracle-based claim approval alongside user voting in order to prevent fraudulent behavior. However, similar to the model used by Teambrella, clubs can self-regulate in a democratic manner since the non-generous pools will likely not receive help from other pools in return. In this scenario, the entire club could also purchase a reinsurance-like contract to protect itself against systemic losses.

Figure 5
REINSURANCE CLUB STRUCTURE



5.2 THE BLOCKCHAIN CHANNELS AND LEDGER

As seen in Figure 2, there are three channels corresponding to three aspects of the business logic. The first channel is for platform management, which contains the smart contracts for operator and reinsurer management. A separate funds management channel contains the smart contracts stipulating the business logic for the transfer and management of tokens. Finally, the users and claims management channel holds the smart contracts for users, pools, clubs, and claims. Each of these channels has a corresponding ledger that records all actions that take place within the channel. Each channel also has a smart contract that manages the ledger. Digital assets are the entities that have their information stored in the ledger, and that are managed by the smart contract.

The blockchain system on our platform manages seven key digital assets, outlined below and pictured in Figure 7. In this use case, the corresponding ledger stores information about these digital assets, allowing for the users, operator, and reinsurer to view details of each asset whenever needed.

1. The Operator digital asset stores information about the platform operator, and only blockchain users registered with an operator role can update this asset through the Operator Management smart contract. Stored information includes, for example, the required fees for reinsurers to join the platform or for users to activate a pool. In this system, the information can be read by the Pool Management Smart contract, hence the connection between these two smart contracts in Figure 6. Meanwhile, the Operator Management smart contract connects to the Token Management smart contract to facilitate the USD-to-tokens exchange and vice-versa. It is important to note that there can be only one operator record inside the system.

2. The User digital asset represents P2P end-users. The associated smart contract solely handles user registration. However, it is connected to Pool and Claims Management smart contracts as users can join pools and, once inside, raise claims. The User Management smart contract is also connected to the Token Management smart contract for the same reason as the operator.
3. A Token is a digital asset representing actual USD. By exchanging USD funds into platform-specific tokens, these assets can be managed via the smart contract rather than using traditional banking and verification methods. The Token Management smart contract facilitates all USD-to-token exchanges inside the system and updates the token balance ledger. This smart contract defines how many tokens equal $1 and, unlike in the case of bitcoin, the exchange rate is fixed. The exchanges are possible for the operator, users, and reinsurer; thus, this smart contract communicates with the respective Operator, Users, Pools, and Reinsurer Management smart contracts.
4. The Pool is a digital asset that is a collection of end-users. The associated smart contract interacts with the User, Claims, and Clubs Management smart contracts in order to allow users to join pools and raise claims and allow pools to join clubs.
5. The reinsurer, which in our business use can be the same as the operator, is represented by one piece of a digital record containing information about the reinsurer. Since pools and clubs can be reinsured, this smart contract connects to both associated smart contracts. The reinsurer covers specific claims, so it has access to claims information as well. In order to join the platform, the reinsurer must pay a fee in tokens to the operator, so this smart contract also connects to the Operator and Tokens Management smart contracts.
6. Claims represent digital assets specifying a claim size in tokens and a window of time in which to vote. These assets are created by end-users, hence there is a connection to the User Management smart contract. The Claim Management smart contract also interacts with the Pool Management smart contract in order to verify the user raising the claim is indeed a member of a pool. Lastly, it is important to note that the reinsurer can access any claim inside the system for underwriting purposes and to ensure the reinsurance contract is being upheld. Therefore, there is a connection from the Claim Management smart contract to the Reinsurer Management smart contract.
7. Clubs represent collections of pools inside the system, necessitating interaction with the Pool Management smart contract. Since clubs also own tokens, they also interact with the Token Management smart contract.

Figure 6
CHANNELS OF THE BLOCKCHAIN NETWORK

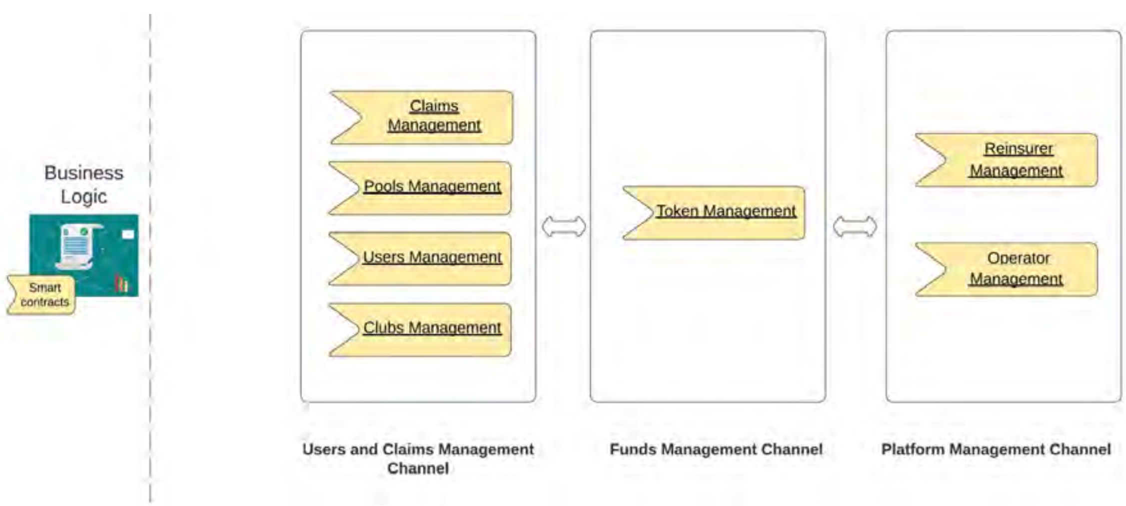
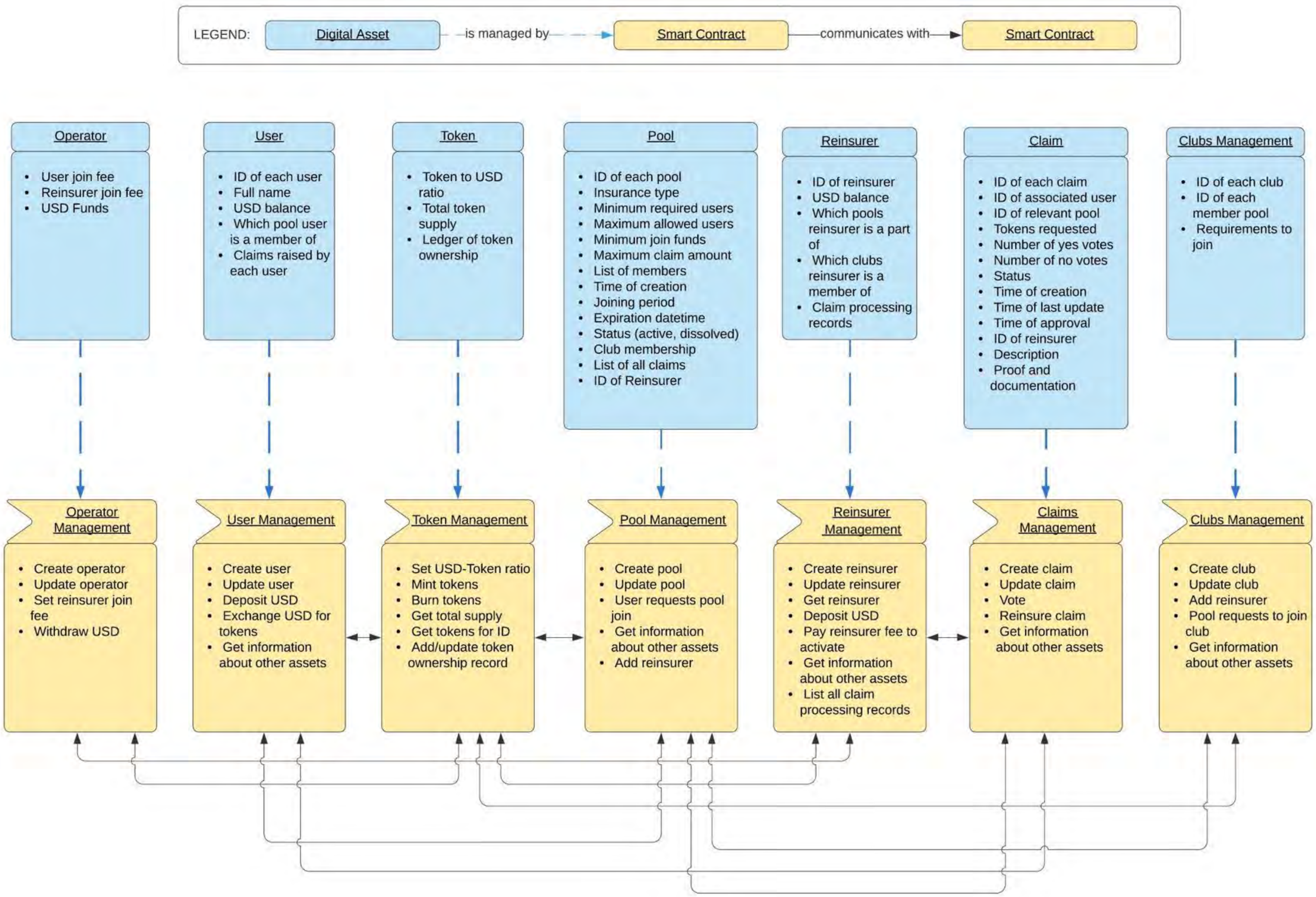


Figure 7
ASSETS OF THE BLOCKCHAIN NETWORK AND THEIR RESPECTIVE SMART CONTRACTS

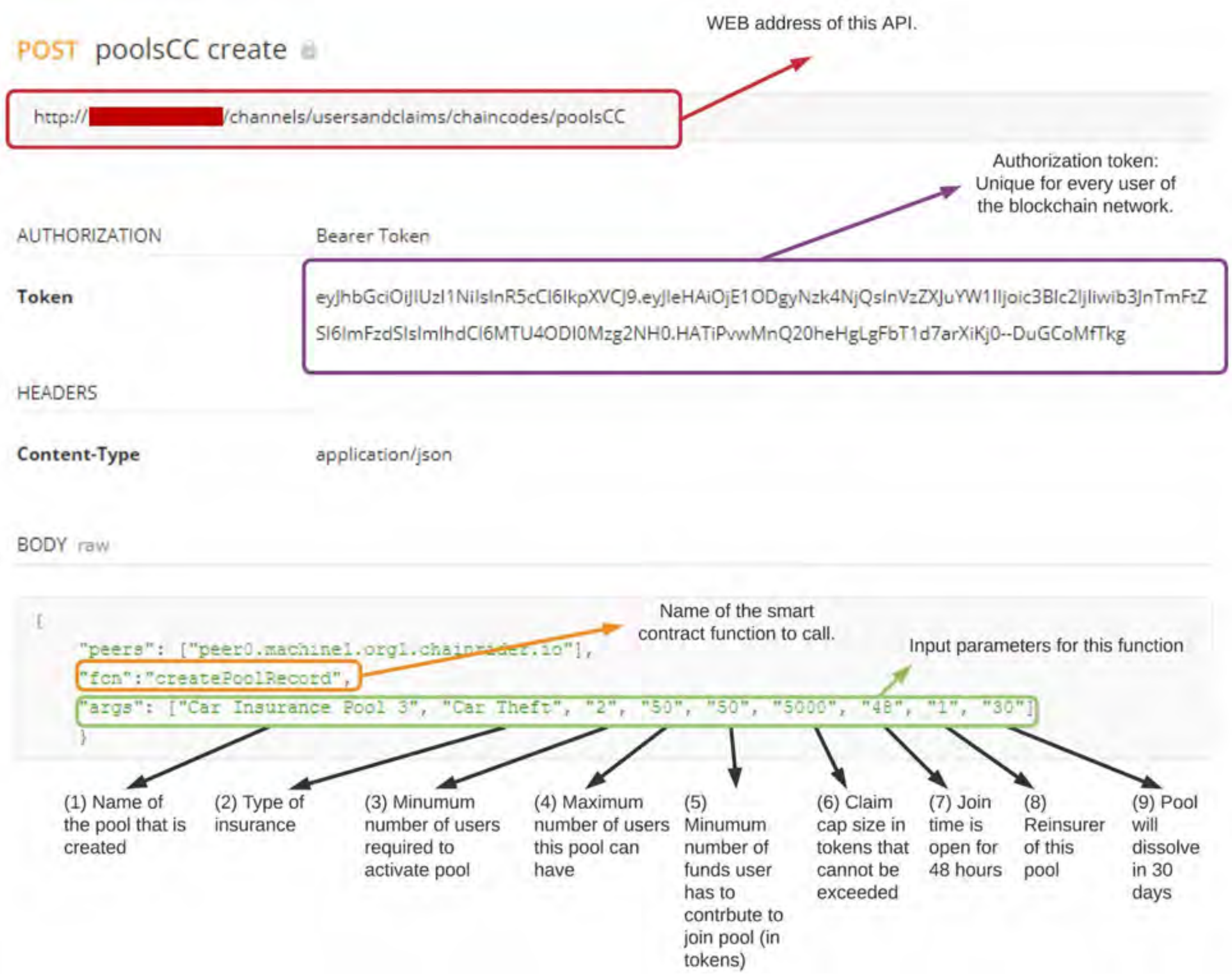


5.3 P2P SYSTEM EMULATION

The implemented blockchain network itself cannot serve the requests coming from the outside: low-level interaction with the blockchain requires using command line tools which external users do not have access to. That is why we have built another layer on top of the blockchain network. This layer, which we call the blockchain emulator, is an application that allows any authenticated external users to interact with the blockchain network, its smart contracts, and data.

This interaction between users and the emulator happens through web-standardized REST API requests. REST APIs define a set of rules for communication between two parties and, in our case, between the user and the emulator. In our implementation, the APIs stipulate that each request to interact with the blockchain requires an authorization, which is specific to the user performing the action. An external user can contact the blockchain emulator, and the blockchain emulator will first contact the blockchain network to verify this user's identity using their authorization token. If the identity is verified, the user can carry out his or her action on the blockchain.

Figure 8
EXAMPLE API

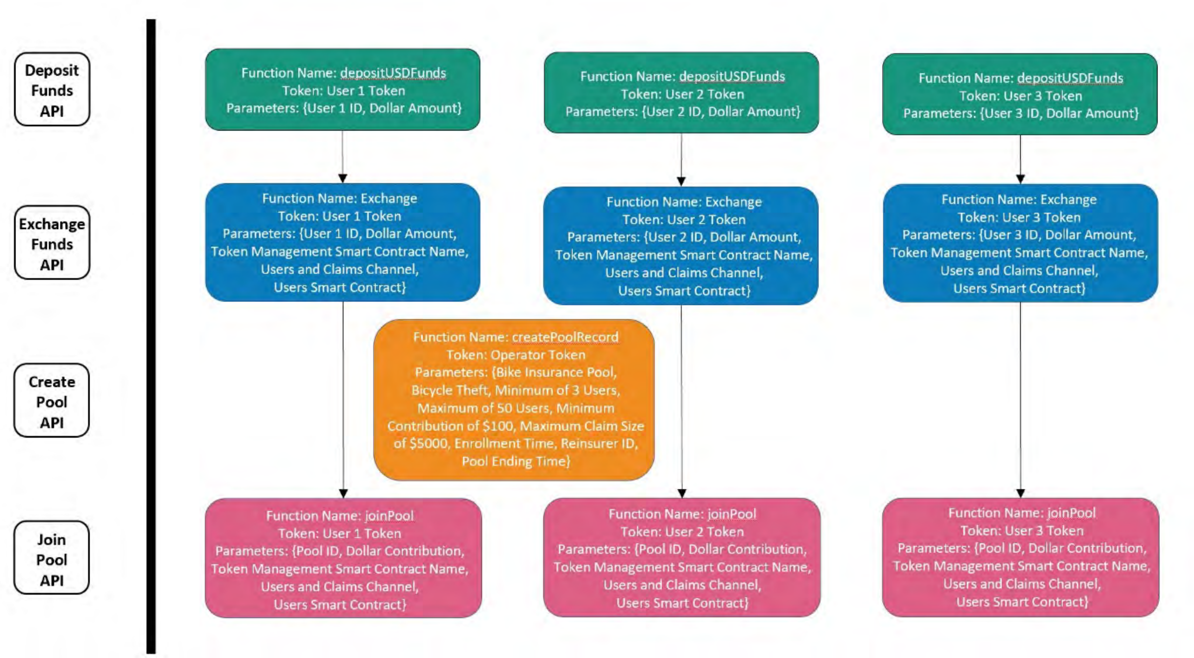


This emulator enables all of the actions discussed in section 5.1, such as the creation of pools and clubs, raising claims, and voting on claims. To illustrate usage of the emulator, consider the following set of actions depicted in Figure 9.

1. A number of users deposit USD.
2. Users exchange their USD for tokens.
3. A pool is created, which the users join.
4. All users deposit tokens into the pool fund.

Each of these actions require the use of an API request from a specific smart contract. First, a registered blockchain user deposits USD through the Users Management smart contract. This first API call requires the user to provide their user information, identification token, and dollar amount to be deposited. Next, the user calls a function from the Tokens Management smart contract to exchange these USD funds for platform tokens. This API request requires not only the user information and amount to be exchanged, but also specifies which channel is being used and which associated contracts to contact. This adds an additional layer of authentication to ensure the user can perform the action, and to verify that the user has the amount of USD they want to exchange. Separately, the operator uses the Create Pool API to form a pool and sets the pool structure, such as the minimum number of pool members and the length of the enrolment period. Finally, to join this pool, a registered blockchain user needs to request to join a pool and contribute *K* tokens through the Pool Management smart contract. This smart contract then communicates with the Tokens Management smart contract to confirm that the user owns the required number of tokens and, if so, the contract allows the user to join the pool.

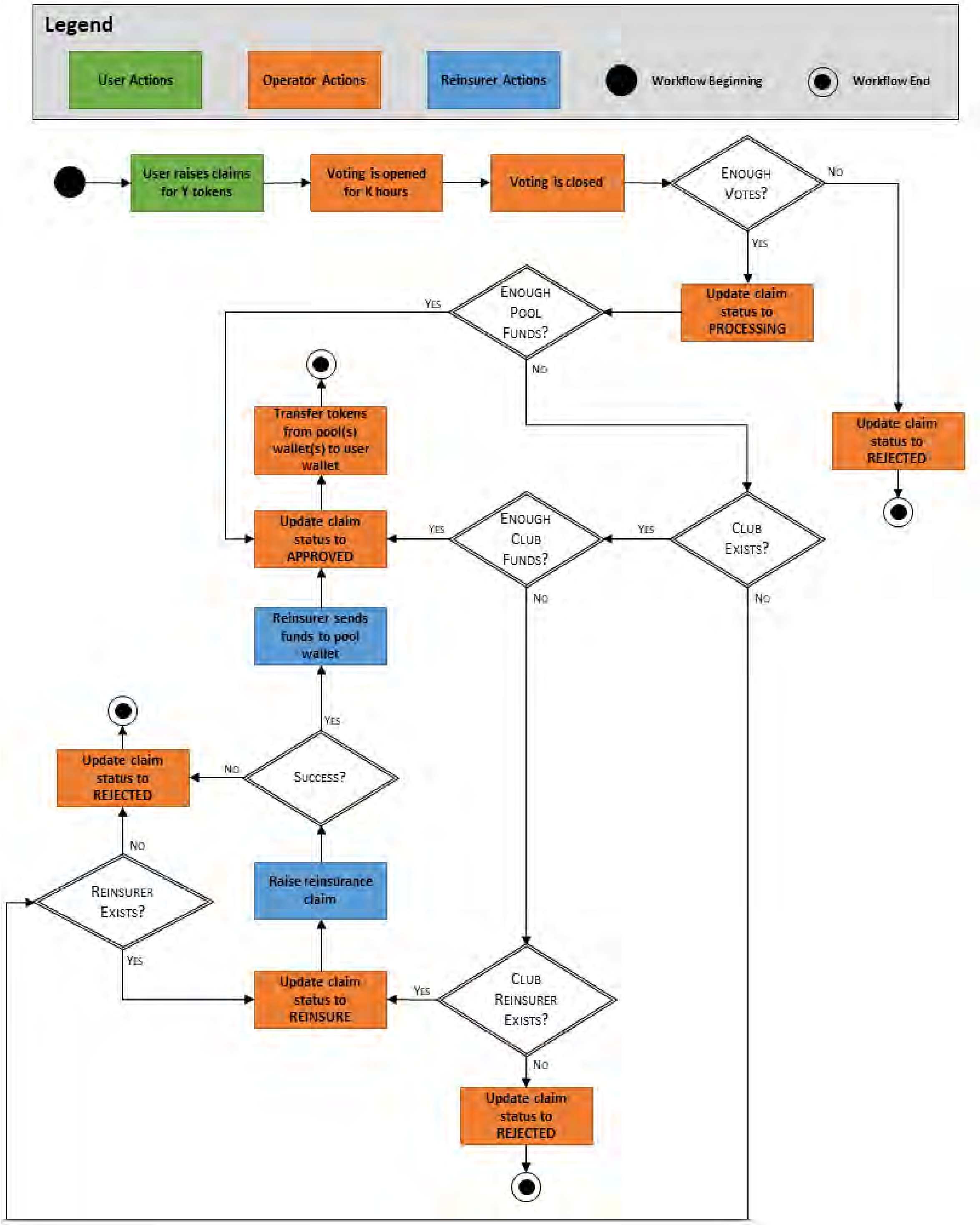
Figure 9
FOUR APIS AS CALLED BY THREE USERS WITHIN THE SYSTEM



Once a pool has been formed and users have joined, an important system process occurs when a claim is raised. First, a voting period is activated. After voting closes, if over half of the users who voted have cast their votes to approve the claim, the claim state is changed to "Processing." Next, there is an attempt to secure funds for payment, either from the pool, a club, or a reinsurance contract. With each executed action by an entity within the system, APIs allow us to interact with the emulated blockchain network as the operator, user, or reinsurer.

Figure 10

CLAIMS PROCESSING

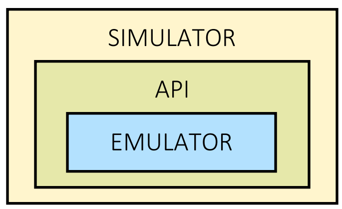


Section 6: Simulated Examples

The novelty and appeal of the P2P business model might bring new market segments to brokerages and insurers who choose to actualize this technological platform. The P2P platform enables profitability for insurers or brokerages, not only through platform membership fees, but also through the issuance of reinsurance products offered to the P2P insurance pools. For this reason, we simulate interactions on the platform with a focus on a potential reinsurance product offered to the P2P insurance pool. To facilitate the simulations, we randomly generate pools and their claims, which then can be carried out on the blockchain network via the emulator by applying the corresponding APIs. Figure 11 shows how key parts of our implementation are connected.

We consider a stop-loss policy, with the attachment point equal to the initial pool balance. The aim of the following examples and simulations is to understand the relationship and impact of various pool dimensions on reinsurance claim frequency and severity. Understanding the frequency and severity of losses allows for profitable pricing of potential reinsurance policies.

Figure 11
COMPONENTS OF OUR APPLICATION



6.1 PRIMARY APPLICATION TO PROPERTY AND CASUALTY

In a P2P environment where individuals primarily join with their friends and family, raising significant amounts of capital can be a concern. Thus, a fully decentralized P2P platform is naturally suited to small Property and Casualty contexts. In light of this, we first investigate a platform for sachet bicycle insurance, which would enable users to protect against theft or accidental damage. High-end bicycles typically cost from $1,000 to $3,000, but prices range from a few hundred up to $5000. Pools last for one year. In this example, a randomly drawn number of users n join a pool, each contributing simulated d dollars. Raised claims are simulated from a compound frequency severity model with a maximum claim amount of $5,000. Then, users can vote to approve or deny the raised claims, with 50% required for claim approval. These votes are simulated from a binary generator, where 1 represents a yes vote, and 0 represents a no vote. Approved claims are paid out of the common pool so that the cost is shared. Distributional assumptions for each of these simulated aspects are provided in Table 1.

Table 1
ASSUMPTIONS OF SIMULATIONS

Dimension	Distribution
Claim Frequency (per year)	Poisson(.1)
Claim Severity	Exponential(1000)
Individual’s Vote	Bernoulli(p)

6.1.1 MATHEMATICAL ASSUMPTIONS OF CORRELATION STRUCTURE

Of particular interest is the impact of the proposed voting system on claims and subsequent reinsurance pricing. While each individual in the insurance pool has the ability to vote, we allow that members of a pool are often friends or family and may discuss their voting choice with each other. Thus, votes for or against a claim's approval may have some level of correlation. In order to account for this, we use a $Beta - Binomial$ structure to model voting, where:

$$p_i \sim Beta(a,b) \text{ and } V_i|p_i \sim Binomial(n,p_i).$$

The random variable V_i gives the number of yes votes on claim i, while p_i represents the probability of an individual voting yes after taking the other users' votes into account. The parameters a and b can be chosen in an interpretable way to separately represent the correlation between users' votes and the marginal probability of an individual's yes vote. Explicitly, if we set $a = \gamma/\rho$ and $b = a/\gamma - a$, then the probability of an individual voting yes is given by γ, and the correlation between users' votes is given by ρ (Hisakado, Kitsukawa, & Mori, 2006). Finally, the probability of a risen claim being approved is given by the cumulative distribution function for the $Beta - Binomial$, where:

$$p^* = \sum_{j=\lfloor\frac{n}{2}\rfloor}^{n} P(V = j|n,a,b).$$

Suppose then that n individuals decide to form an insurance pool. Since we assume a $Poisson(\lambda)$ claim frequency per individual, the resulting claim frequency for the entire pool is $Poisson(n\lambda)$. However, the number of these claims that are approved is $Binomial(p^*)$. By the properties of these two distributions, this results in a $Poisson(n\lambda p^*)$ approved claim frequency. Of interest is the interrelated impact of pool size n, individual voting probability γ, and voting correlation ρ on claim frequency, severity, and subsequent excess loss. While the parameter p^* can be obtained using numerical approximations of the rather complex cumulative density function, instead we adopt a simulation approach to illustrate the direct impact of these dimensions on claim approval.

6.1.2 POOL SIZE SIMULATION

In our first simulation, we aim to observe the impact of pool size on claim frequency and severity. We allow the pool size to vary between 1 and 100 individuals, with 1,000 pools sampled for each pool size, giving 100,000 total simulated pools. We fix the contribution amounts and voting structure in order to clearly observe the effects of pool size. The voting probability is set to 70% and the correlation between users' votes to 50%. These settings imply that users are relatively cautious about approving claims and that users weigh their own opinion and those of their peers equally. Initial contribution amounts are fixed at \$100, resulting in a reinsurance attachment point of $\$100 * n$.

Table 2
POOL SIZE SIMULATION ASSUMPTIONS

Dimension	Assumption
Pool Size	Uniform(1,100)
Initial Individual Contributions	\$100
Yes Vote Probability	70%
Voting Correlation	50%

Figure 12 gives the Poisson distribution of approved claims for varying pool sizes. Intuitively, as the pool size n increases, the approved claim frequency $n\lambda p^* = np^*/10$ increases linearly. This is also the case for expected total pool claim severity with mean $1000 * n\lambda p^*$. Similarly, mean excess loss increases with pool size. Excess loss frequency, however, has a slightly more complicated relationship to pool size.

The spirit of this business implementation focuses on mutual aid of trusted individuals who would vote on each other's behalf. In pools with more than around 100 people, it becomes more difficult for individuals to personally know everyone in their pool. Smaller pools, however, have a high variance in claims. This naturally results in self-regulated pool sizes based on both trust and risk. In this manner, we see excess loss frequency peak at around 20-30 people (see Table 3). Luckily, on the reinsurer's end, a large portfolio of pools gives stability to expected losses regardless of individual pool size.

Figure 12

FREQUENCY AND SEVERITY FOR VARYING POOL SIZES

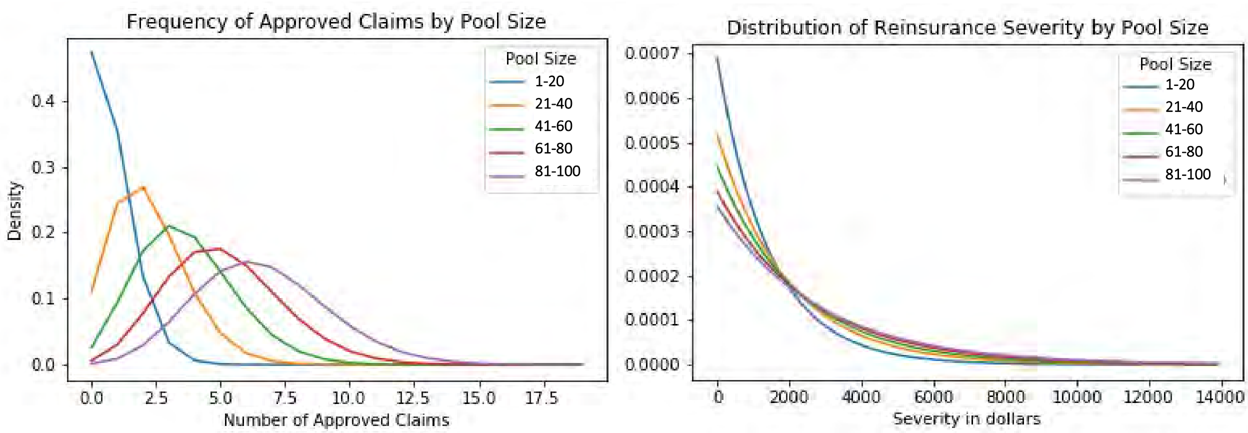


Table 3

REINSURANCE FREQUENCY AND SEVERITY FOR VARYING POOL SIZES

Pool Size	Approved Claim Frequency (per year)	Reinsurance Frequency	Mean Excess Loss
1-20	0.75	0.22	$1451.70
21-40	2.20	0.27	$1934.08
41-60	3.66	0.26	$2246.08
61-80	5.23	0.24	$2566.48
81-100	6.61	0.23	$2809.70

6.1.3 VOTING STRUCTURE SIMULATION

Next, we consider the novel P2P voting structure and its unique impacts. The individual probability of a user voting yes and the correlation between each user's vote in tandem affects the frequency of accepted claims. In these simulations, both voting aspects are explored. We consider a grid of values with a probability of an individual yes vote at 25%, 50%, 75%, and 100%, and correlation between votes of 0%, 25%, 50%, 75%, and 100%. In this case, 0% correlation corresponds to completely independent voting, while 100% correlation corresponds to unanimous consensus among pool members. The other two dimensions of pool size and contribution amount are held constant, and 10,000 pools are sampled for each voting structure combination, leading to 200,000 total pools.

Table 4

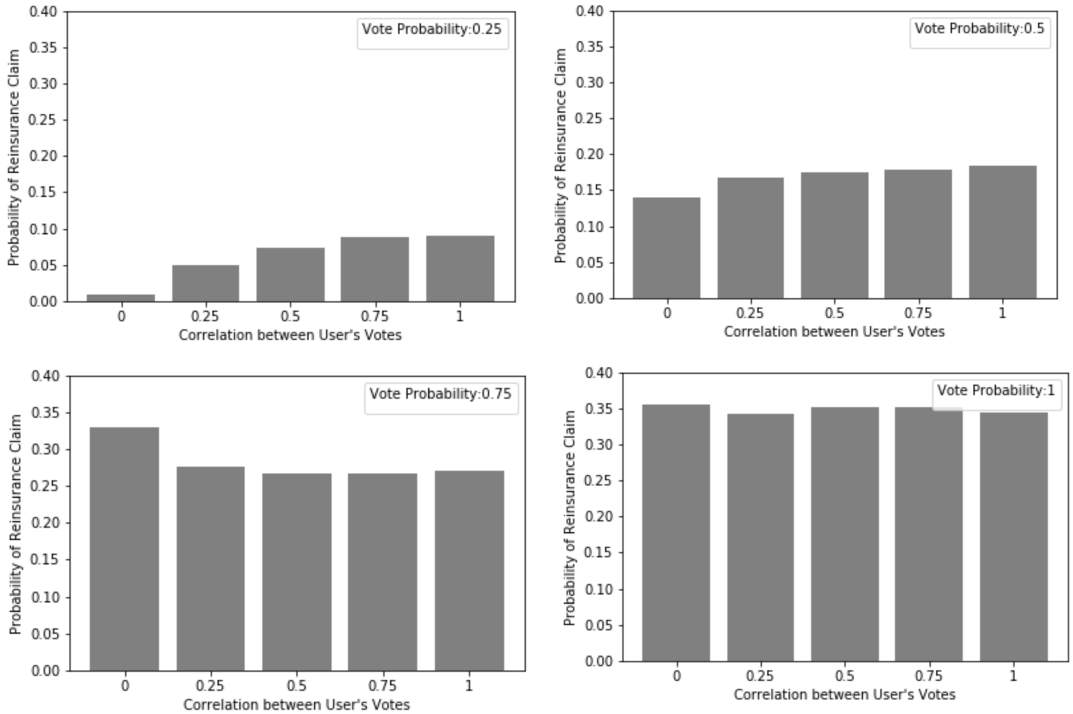
VOTING STRUCTURE SIMULATION ASSUMPTIONS

Dimension	Assumption
Pool Size	10
Initial Individual Contributions	$100
Yes Vote Probability	25%, 50%, 75%, 100%
Voting Correlation	0%, 25%, 50%, 75%, 100%

Figure 13 illustrates the interplay of voting correlation and probability on claim frequency. When the probability of voting success is high, correlation between votes has little impact because everyone will be voting favorably. These favorable votes occur regardless of whether there is independent decision-making or unanimous voting. Conversely, when users are very cautious and do not approve most claims, the impact of user correlation is much higher. Users who have greater levels of agreement lead to more claims when voting probability is low. However, the overall impact of correlation is less than that of voting probability itself.

Figure 13

PROBABILITY OF REINSURANCE CLAIM FOR VARIOUS VOTING ASSUMPTIONS



To further stress test the voting probability and show the one-dimensional impact of voting level on reinsurance severity, 100,000 additional pools are simulated. The pool size and contribution assumptions in Table 4 are followed, but with fixed correlation set to 50% and varying voting probability.

Figure 14

REINSURANCE FREQUENCY AND SEVERITY BY VOTING PROBABILITY

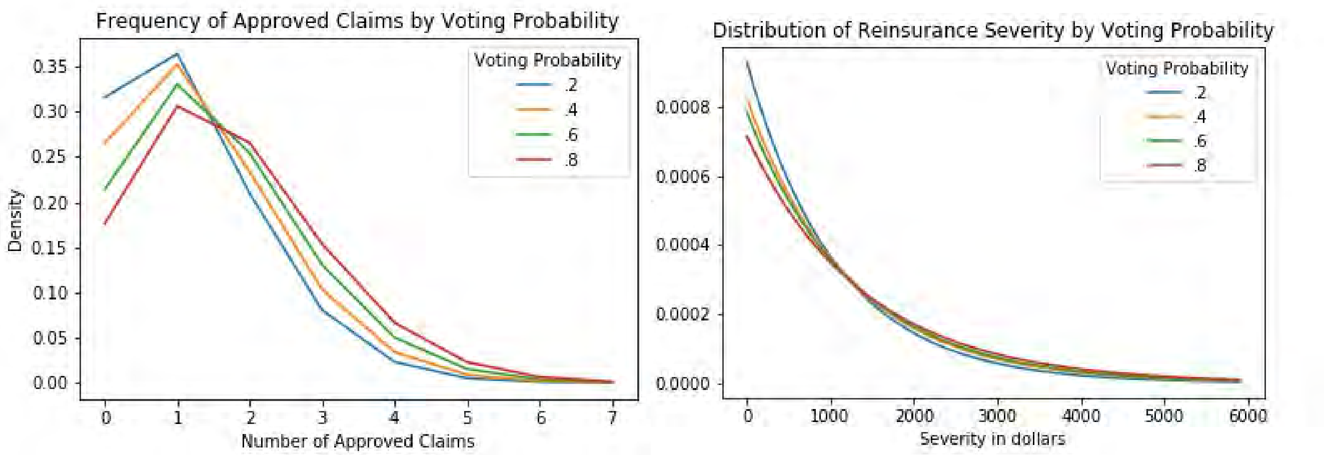


Table 5

REINSURANCE FREQUENCY AND SEVERITY BY VOTING PROBABILITY

Voting Approval Rate	Approved Claim Frequency	Reinsurance Frequency	Mean Excess Loss
20%	1.15	0.06	$1078.25
40%	1.33	0.14	$1215.52
60%	1.54	0.20	$1277.79
80%	1.74	0.28	$1402.29

6.1.4 ATTACHMENT POINT

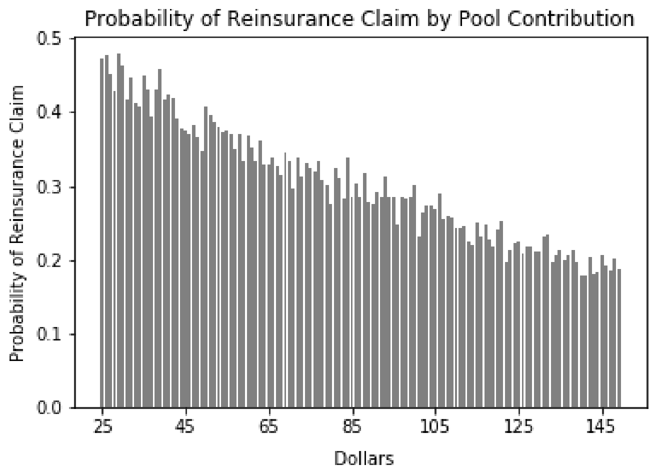
Finally, we consider the impact that differing contribution amounts have on a potential reinsurance product. The more that individual users contribute to the pool, the higher the attachment point for claims will be. In this way, the proposed reinsurance contract operates much like stop-loss insurance for self-funded group health insurance plans. Users' contribution amounts will primarily affect the frequency at which reinsurance is needed. To show this relationship, we simulate 100,000 pools with a fixed size and voting structure. Individual contribution amounts are sampled uniformly and randomly between $25 and $150.

Table 6

ATTACHMENT POINT SIMULATION ASSUMPTIONS

Dimension	Assumption
Pool Size	10
Initial Individual Contributions	Uniform(25,150)
Yes Vote Probability	70%
Voting Correlation	50%

Figure 15
ESTIMATED IMPACT OF POOL CONTRIBUTION ON REINSURANCE FREQUENCY



6.1.5 FULLY STOCHASTIC P2P PLATFORM

Thus far, stress testing has examined the individual effects of each dimension (pool size, voting probability and correlation, and pool contribution) separately. Next, we consider a fully stochastic scenario, where user's contributions, voting probability and correlation, and pool size are allowed to vary simultaneously. The resulting simulation aims to capture the random nature of a real reinsurance platform and provide a distribution of losses. This scenario allows us to see the relative importance of each pool dimension in order to aid in business decisions for insurers and reinsurers interested in offering a reinsurance product. Assumptions for this simulation are given in Table 7, with 10,000 simulated pools on the P2P platform.

Table 7
FULLY STOCHASTIC SIMULATION ASSUMPTIONS

Dimension	Assumption
Pool Size	Uniform(1,50)
Initial Individual Contributions	Uniform(25,150)
Yes Vote Probability	Uniform(0,1)
Voting Correlation	Uniform(0,1)

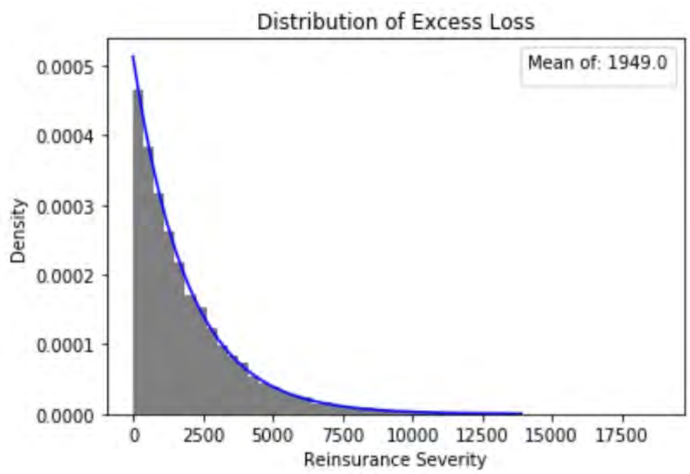
The distribution of excess loss resulting from the simulated P2P platform are shown in Figure 16, with a Mean excess loss of $1,949 from a typical pool. Then, expected reinsurance loss is given by the product of the mean excess loss and the reinsurance frequency, which is estimated to be $1,949*0.219 ≈$427 given the assumptions of our simulation.

Pearson correlations suggest that an individual's probability of voting yes is the dimension with the largest impact on reinsurance frequency. When it comes to mean excess loss, pool size is the dimension with the largest impact. Meanwhile, the level of dependency between users' votes had little correlation with reinsurance frequency and severity. This mirrors the findings of section 6.3.1, which shows the voting correlation impact is much lower than the other pool dimensions. This implies that potential insurers and reinsurers interested in offering a reinsurance product to pools have little reason to be concerned about the impact of so-called "group-think" within a pool. Instead, pricing should primarily be segmented by pool size and contribution levels. However, observing the voting behaviors of individuals on the platform would allow for more accurate projections of reinsurance claim frequency. The most conservative reinsurance pricing structure would assume 100% voting probability; however, discounting premiums to account for reasonably lower expected loss as observed on the platform early on may entice platform users who, otherwise, would be unwilling to purchase a standard insurance product.

Table 8
PEARSON CORRELATIONS

Dimension	Correlation with Reinsurance Frequency	Correlation with Mean Excess Loss
Pool Size	0.08	0.24
Contribution Amount	-0.23	-0.08
Voting Probability	0.35	0.17
Voting Correlation	0.01	-0.04

Figure 16
FULLY STOCHASTIC SIMULATED EXCESS LOSS



6.2 EXTENSION TO LIFE INSURANCE

Next, we consider an application to one-year term life insurance. Blockchain technology can offer a significant improvement in current business practices by automating confirmation of death certificates with hospitals, funeral homes, and government agencies. By removing the issues of trust and fraud, pool members do not need to rely on any form of voting or pre-approval for claim payments (Prabhakar, Shukla, & Ratan, 2017). In this scenario, we assume a group of individuals decide to mutually insure each other for a fixed amount d, so that each group member contributes d/n total dollars. Note that, at the end of the coverage period, if no deaths within the group occur, each member receives their funds back. If a member chooses to renew their policy, they may use any remaining funds from the previous years or contribute a smaller amount to increase coverage.

Of interest is the potential profitability of a reinsurance product that will cover claims in the event of death of more than one individual. This situation is quite similar to group life, with the caveat that the first death within a pool is covered by the pool rather than the insurer. Given the mortality rate ${q^i}_x$ for life i age x in the pool, the probability of survival for the entire group is given by $1 - \Pi_{i=1}^{n} q_x^i$. However, in practice, mortality for individuals in a group may not be independent as they may be friends or family who engage in many of the same life activities.

Let X_i be an indicator variable signifying death of individual i. Then, the expected total number of deaths in the pools is given by $E(\sum_{i=1}^{n} X_i) = \sum_{i=1}^{n} q_x^i$. The variance in the observed number of deaths is $\mathrm{Var}(\sum_{i=1}^{n} X_i) = \sum_{i=1}^{n} Var(X_i) + \sum_{i \neq j} Cov(X_i, X_j)$. In the case where deaths are considered independent, $\sum_{i \neq j} Cov(X_i, X_j) = 0$, we say the number of deaths is distributed Poisson-Binomial. For small probabilities q_x, the Poisson-Binomial distribution can be approximated by the Poisson distribution with mean $\lambda = \sum_{i=1}^{n} q_x^i$ (Hodges & Le Cam, 1960).

One extra layer is added when we take the number of deaths to be correlated. In this case, we have a similar mathematical setup to the voting system in the bicycle insurance model. We consider a beta distributed random variable p_i with parameters $a = q_x^i/\rho$ and $b = a/q_x^i - a$, where ρ gives the correlation between pool members' deaths. Then, a $Bernoulli(1, p_i)$ random variable will simulate an individual pool member's death.

Here we provide simulations to illustrate the impact of this dependent mortality on variance in the number of deaths. In this example, mortality is taken from the joint gender U.S. mortality table for 2018 from the Human Mortality Database (Shkolnikov, Barbieri, & Wilmoth, 2020). We simulated 10,000 pools with ten individuals whose ages ranged from 25 to 60. Figure 17 plots the simulated expected number of claims, with equivalent variance under the assumption of a Poisson distribution. These initial results suggest that, for such small pool sizes, dependency between mortality has a negligible impact on reinsurance claim frequency, allowing for standard pricing of insurance premiums for the reinsurance-type product. However, future work investigating increased pool sizes and reinsurance clubs may reveal deeper patterns of dependent mortality.

Table 9

LIFE INSURANCE SIMULATION ASSUMPTIONS

Dimension	Assumption
Pool Size	10
Age of Individual	Uniform(25,60)
Mortality of Individual	From Human Mortality DB
Correlation of Mortality	[0,0.1,0.3]

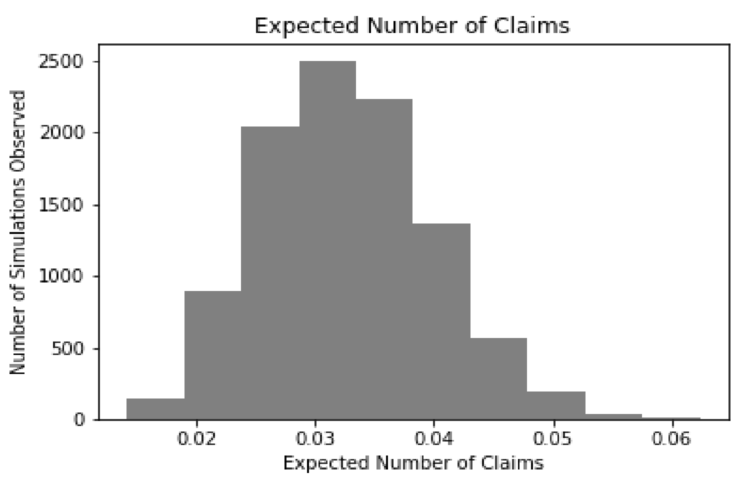
Table 10

REINURANCE FREQUENCY AND SEVERITY BY VOTING PROBABILITY

Mortality Correlation	Expected Payment per Claim
0%	0.030
10%	0.026
20%	0.031

Figure 17

MODELED CLAIM FREQUENCY



6.3 BLOCKCHAIN ENGINEERING INSIGHTS

We note that, due to constraints of computational resources, the blockchain implementation we created did not have the throughput that would allow us to conduct sensitivity analysis in a satisfactory timeframe. That is why we have developed a simulator of our blockchain emulator and supplemented the emulations with simulations. In a corporate setting where computational resources are available, this choice may not be necessary. However, to move from our prototype to enterprise grade software, several steps are required.

Our current blockchain system for the emulator is fully automated and equipped with blockchain events and client applications that listen to those events. For example, when a claim has been made, every time a pool user votes on that claim, a blockchain event is fired. This triggers a number of steps that are carried out automatically without "user intervention." In this instance, the first step is to check if there are enough votes to process this claim. If there are, and enough of these votes are *yes* votes, tokens are transferred from pool/club/reinsurer to user and the claim status and claim approval time are updated. This is only one of the many automated workflows that eliminates manual inputs. The high level of automation creates a small delay in claim processing (3-5 seconds), however, it enhances the potential user and operator P2P insurance platform usage experience significantly.

To upgrade our built emulator to a production grade platform, one would need to do several things, including:

- Identify and benchmark blockchain system performance metrics,
- Identify best endorsement policies per smart contract
- Research the impact of the number of channels on resource allocations
- Look into resource allocation per peer components
- Experiment with transaction block sizes

In our case, the above-mentioned performance metrics were not fine-tuned for the P2P insurance blockchain system, but default best practices were used. To make the currently developed system handle large amounts of transactions, the efficient redesign of current workflows to take a small number of steps, digital asset models, and smart contract communication may be needed. For P2P insurance emulation purposes, this was intentionally avoided to have increased control over every single action in the system leading to a more careful data analysis process. Smart contracts and digital assets can be further decoupled to reduce the number of cross-channel reads. Additionally, benchmarking with Hyperledger Caliper software would be highly recommended. Specifically, this would include benchmarking the throughput of every single smart contract and every single transaction per channel to tweak channel configuration (block creation timeout, block size in transactions, and block size in KB). This is a process required for every production-grade platform; however, it was omitted for our P2P insurance prototype as it fell outside the scope of this project. Finally, parallelizing execution and deploying additional computation resources would be imperative.

Section 7: Conclusion

In this work, we demonstrated the application of Blockchain technology in building an insurance product. With this effort, we empower the readership in their own attempt to build solutions relevant to their use cases of interest. Given the maturity of this technology, with relatively few resources we demonstrated that fast deployment of this technology to gain operational efficiencies and develop new products is within reach. Ultimately, to insurance practitioners we gave tools to participate in conversations and discussions around this new and increasingly pervasive technology in the business context. Also, in this work, we shed light on the business use case of P2P insurance. Within the confines of our design choice, we provided findings relevant to insurers and eventually reinsurers. Specifically, we discussed the impact of various platform parameters on loss distribution, including the impact of voting patterns. Unlike the classic insurance products, P2P insurance pricing is dependent on the relationships among the policyholders and, thus, it encapsulates the social dimension. This work helps quantify this aspect, which is of practical use to actuaries.

When it comes to a larger practical perspective, although technology verges on being widely accessible, the legal practice and regulatory frameworks still very much lag behind the technological development. Much work remains to be done for the legal profession to catch up with technological reality. That is why insurance practitioners deploying blockchain-based solutions should stay vigilant and keep a watchful eye on the evolution of the regulatory landscape. In particular, specific regulations remain to be settled regarding liability attribution, the relation of smart contracts and contract law, data protection, and privacy. For the interested reader, an overview of the current regulatory landscape relevant to blockchain technology is provided in *Handbook of Blockchain Law: A Guide to Understanding and Resolving the Legal Challenges of Blockchain Technology* by Artz and Richter. In the case of the most recent debates concerning smart contracts and contract law, we refer to the reader to (Ferreira, 2021) and (Rühl, 2021). Methods to address accountability, particularly when applied to Hyperledger Fabric, are discussed from a mathematical perspective in (Graf, Küsters, & Rausch, 2020).

However, the most important perspective recognizes that blockchain-enabled technologies, including smart contract technology, are estimated to produce business value-add growth by 2025, reaching around 176 billion USD (Lovelock & Furlonger, 2017). The 2015 World Economic Forum survey of 800 information and communications executives and experts revealed the belief that around 10% of global GDP would be found on blockchain systems by the year 2027. Therefore, it is increasingly being accepted that blockchain technology opens new ways of organizing business activity across the vast space of everyday interactions. We hope this report will empower both the academic and practitioner communities to capitalize on the new opportunities.

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