PropChain: A Blockchain-Based Framework for Automated Property Transfers and Smart Contract Integration

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Abstract

Real estate transactions traditionally involve complex, time-consuming processes that require multiple intermediaries, extensive paperwork, and prolonged settlement periods, resulting in increased costs and inefficiencies for all parties involved. Although previous attempts to digitize real estate transactions have improved document management and communication, they have failed to address the fundamental issues of trust, transparency, and the need for centralized intermediaries in the transaction process. Our research demonstrates how blockchain technology and smart contracts can transform property transactions by creating a decentralized, trustless system that automates property transfers between buyers and sellers while maintaining legal compliance and transaction security. The proof of concept implements common real estate actions in a distributed ledger, such as title search, property transfers, and property reviews. The system is also connected to sample banking and escrow services through back-end servers to simulate loan processing and escrow holding for properties. In addition, an authentication system is set up to allow an internal ERC-20 coin to be awarded for user actions, such as property verification. Finally, in order to showcase the viability of this system, the interface has been created in a way that is compatible for both computer and mobile users, reducing friction to using the service.

Website: https://b17-blockchain-capstone-q2.vercel.app/

Code: https://github.com/is-patel/B17-Blockchain-Capstone-Q2

1 Introduction

1.1 Introductory Overview

Real estate transactions represent one of the largest and most complex forms of value exchange in the modern economy. In 2023, just over 4 million homes in the U.S. were sold, with the total value of the real estate market increasing by 2 trillion dollars to a total of 47.5 trillion dollars Hyatt (2024) NAR (2024). Despite this scale, the industry continues to rely on outdated processes that create significant inefficiencies, security risks, and unnecessary costs for all parties involved. Our research solves this problem through a blockchain-based solution that fundamentally transforms real estate transactions by implementing smart contracts and distributed ledger technology. Initial results demonstrate the potential to reduce transaction times from months to days, lower costs by eliminating unnecessary intermediaries, and enhance security through cryptographic verification and immutable record-keeping.

1.2 Prior Work and Literature Review

The digitization of real estate transactions has evolved through several distinct phases over the past decade. Initial efforts focused on creating online listing platforms and property databases, exemplified by services like Zillow and Redfin, which primarily addressed information asymmetry in the market. Subsequent developments introduced electronic document signing and digital payment processing, as seen in platforms like DocuSign and various property management systems. However, these solutions merely digitized existing processes rather than addressing fundamental inefficiencies.

Recent attempts to implement blockchain in real estate have shown promise but remain limited in scope. Blockchain is decentralized in nature, and provides an immutable ledger

that can be viewed by all parties that are on the chain. This provides a unique advantage in real estate by ensuring validity of transactions on the chain, while making downstream tasks like title searching much faster and cost effective PixelPlex (2023).

Over the last few years, several projects like Propy and RealT have demonstrated the feasibility of tokenizing real estate assets, but their focus on investment properties rather than traditional home sales has limited their impact. Additionally, research has been done on potentially allowing fractional ownership of real estate assets through property tokenization, which would increase market liquidity and democratize real estate investment Saari, Junnila and Vimpari (2022). Similarly, efforts to create smart contracts for real estate transactions have typically addressed only specific components of the process, such as payment processing or title recording, rather than providing an end-to-end solution. The previous years' blockchain project EthStates provided buyer and seller interfaces with transactions, but did not provide other critical services like escrow Yin Lam Lai (2023).

The key limitations of previous approaches centers around their failure to integrate all necessary components of a real estate transaction—including mortgage origination, title searches, and escrow services—into a single, cohesive system. A notable shortcoming in current blockchain-based solutions for real estate is the lack of a straightforward mechanism for transferring and rewarding ERC-20 tokens to incentivize user participation and maintain system integrity. Existing platforms often do not include robust incentive structures or reward mechanisms for participants who keep the system honest like through validation, reporting errors, or flagging fraudulent activities. Additionally, these solutions have limited or non-existent integrations with traditional banking services, which complicates the bridging of fiat transactions and token-based activities. This gap in banking connections prevents seamless onboarding of new users and hinders the broader adoption of blockchain in real estate. Consequently, while blockchain technology holds great promise for addressing

inefficiencies in real estate transactions, current solutions fall short of delivering a comprehensive, integrated system that includes banking connections and incentivizes honest participation with a native ERC-20 reward mechanism. Balancing the transparency benefits of blockchain with privacy requirements remains another ongoing challenge Yeoh et al. (2024).

1.3 Data and Implementation Context

In developing new methods for a blockchain-based real estate ecosystem, our focus is on data that represents critical aspects of property transactions encoded within smart contracts. This includes comprehensive data types such as property ownership records, which detail the current and historical owners of a property, providing transparency and traceability in ownership transfers. Loan application details encompass applicant credentials, financial statements, loan amounts, interest rates, and repayment schedules, essential for automating loan approvals and managing repayment processes. Identity verification statuses involve KYC (Know Your Customer) data, ensuring that all participants are authenticated and comply with regulatory standards to prevent fraud and money laundering. Title histories record all past transactions, liens, and claims associated with a property, crucial for verifying title clarity and resolving disputes. Insurance policies data include coverage amounts, policy durations, and terms, offering protection against potential title defects or ownership challenges. By structuring this diverse set of data to function seamlessly within a decentralized environment, we mirror real-world entities and processes in a secure and efficient manner.

Our methods are applicable to this kind of data because they enable automation, enhance security, and ensure transparency in complex real estate transactions through the use of smart contracts. By leveraging blockchain technology, we can automate processes such as

verifying property ownership, approving loans based on predefined criteria, and transferring titles only when all conditions are met, which significantly reduces manual intervention and the potential for human error. This approach minimizes the risk of fraud by eliminating unnecessary intermediaries and creates immutable records that enforce compliance with legal and financial regulations. Additionally, smart contracts facilitate real-time updates and notifications to all parties involved, improving communication and trust within the transaction process. Our methods demonstrate how innovative blockchain solutions can effectively manage and utilize complex, interrelated datasets in the real estate sector, addressing long standing challenges such as inefficiency, lack of transparency, and vulnerability to fraud, thereby enhancing overall industry efficiency and reliability.

In addition to these core data points, an ERC-20 coin transfer and rewarding system requires its own set of data to function effectively. Specifically, the platform must maintain token holder addresses, which serve as unique identifiers tied to each participant for sending and receiving ERC-20 tokens, along with account balances that track the number of tokens each participant holds at any given time. The system also needs clear reward logic—smart contract rules that incentivize honest behavior and contributions to the ecosystem, such as staking tokens for validation or reporting fraudulent activities. Transaction records logging all token transfers and reward allocations ensure transparency and immutability in how incentives are distributed. Finally, secure banking connections are crucial for bridging the token-based ecosystem with traditional financial institutions, enabling efficient onboarding of users and smooth conversion.

Additionally, to establish a robust banking endpoint and escrow endpoint using a Flask server and connecting them with smart contracts, the platform needs to capture and manage several key data elements. For the banking endpoint, this includes account and routing information that securely links users' external bank accounts to the blockchain environment,

as well as verification data for KYC compliance to confirm identities and mitigate fraud risks. Transaction logs documenting deposits, withdrawals, and currency conversions are essential for auditability and tracking the flow of funds. These logs can then be reconciled with on-chain records to provide a transparent and verifiable trail of all financial activities. For the escrow endpoint, the system must store detailed terms and conditions governing the escrow arrangement, ensuring that all contractual obligations are transparent and enforceable. Additionally, locked asset details specify precisely which funds or property are being held in escrow, serving as the reference point for validating transactions. The criteria for releasing funds—such as completion of contract milestones or third-party verification—must also be clearly defined and recorded, enabling smart contracts to autonomously finalize the transaction upon meeting the specified conditions.

By structuring these diverse sets of data to function seamlessly within a decentralized environment, we mirror real-world entities and processes in a secure and efficient manner. Our methods enable automation, enhance security, and ensure transparency in complex real estate transactions by leveraging smart contracts for tasks such as verifying property ownership, approving loans based on predefined criteria, distributing ERC-20 token rewards, and transferring titles only when all conditions are met. This approach minimizes the risk of fraud by eliminating unnecessary intermediaries and creating immutable records, while also integrating directly with traditional banking systems to streamline financial operations. Ultimately, our system addresses longstanding challenges such as inefficiency, lack of transparency, vulnerability to fraud, and limited fiat on-ramps, thereby enhancing overall industry efficiency and reliability.

2 Methods

2.1 Design of Smart Contracts

The design of the smart contracts in this blockchain-based real estate ecosystem is meticulously structured to facilitate secure, transparent, and efficient property transactions by encapsulating various aspects of the real estate process. The RealEstateToken Contract (Figure A 10) serves as the foundation by tokenizing real estate properties into unique digital tokens on the blockchain, representing ownership details and property attributes. It establishes mechanisms for transferring property ownership and managing property listings, ensuring that only authorized actions are permitted through robust access controls and verification processes. This contract is directly linked to the KYCIdentity Contract (Figure A 9), which implements a system to manage participants' verification statuses, distinguishing between basic and enhanced levels to meet varying compliance requirements. By providing procedures for verifying identities before engaging in transactions, it ensures regulatory compliance and enhances trust among participants.

Complementing these are the LoanProcessing Contract (Figure A 11) and the EscrowService Contract (Figure A 12), which handle the financial aspects of property transactions. The LoanProcessing Contract manages the entire loan lifecycle, from application submission to approval or rejection, and repayment tracking. It incorporates parameters for interest rates and calculates repayment schedules based on loan terms, ensuring accurate financial tracking and amortization. This contract interacts with the RealEstateToken Contract to associate loans with specific properties and with the KYCIdentity Contract to verify borrower identities. The EscrowService Contract creates a secure escrow mechanism to hold funds during transactions, releasing them only when predefined conditions—such as successful ownership transfer and fulfillment of contractual obligations—are met. By defining clear

conditions for releasing or refunding funds, it reduces the risk of fraud and enhances trust between buyers and sellers.

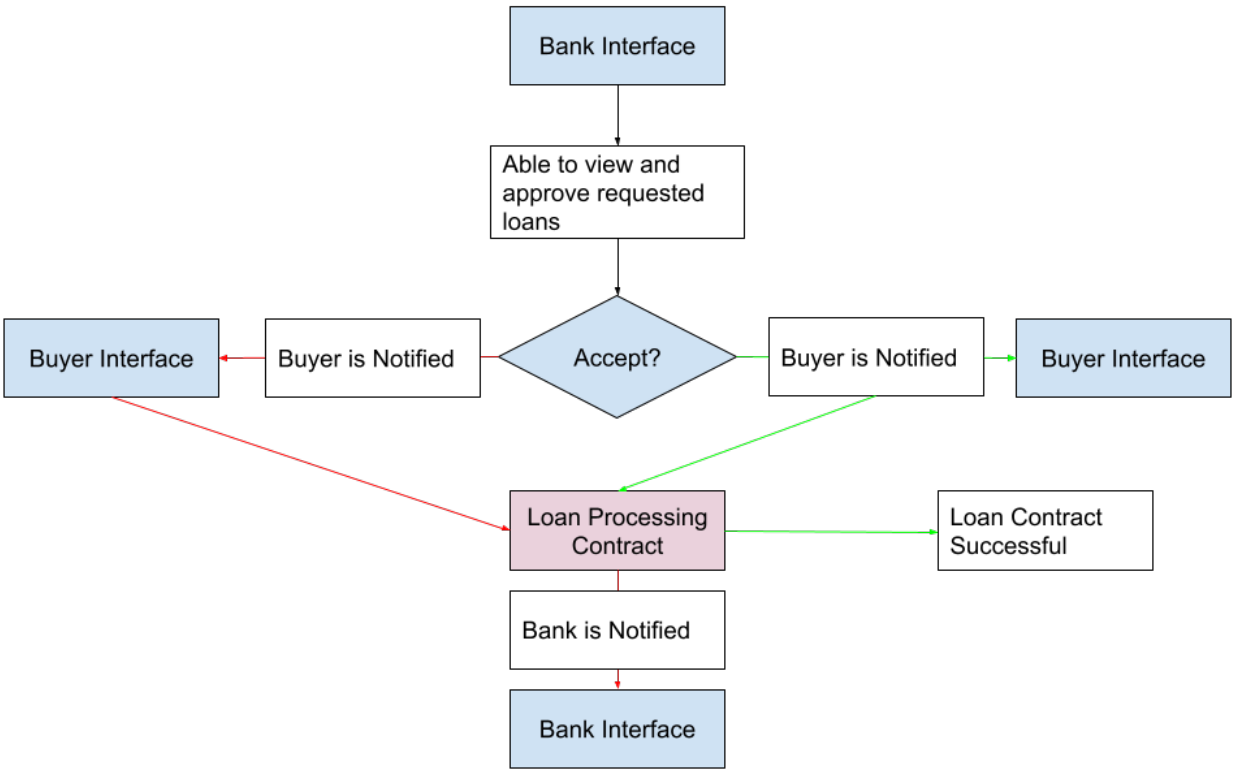

Figure 1: Bank Loan Processing Block Diagram

Ensuring the legitimacy and security of property titles are the TitleInsurance Contract (Figure A 8) and the TitleSearch Contract (Figure A 7). The TitleInsurance Contract is designed to issue and manage title insurance policies, detailing coverage amounts and validity periods to protect buyers against potential title defects. Parties can verify the validity and active status of insurance policies before proceeding with transactions. The TitleSearch Contract maintains comprehensive records of property titles, including ownership histories and any existing claims or disputes, providing a transparent and up-to-date title history. It offers mechanisms to update title statuses, such as clearing or flagging titles based on due dili-

gence findings, which is crucial for informed decision-making.

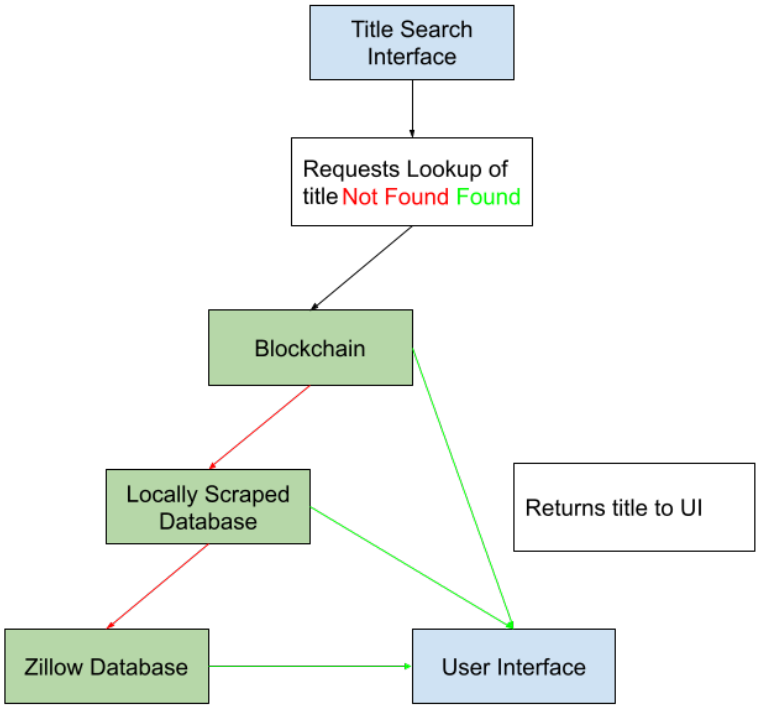

Figure 2: Title Search Block Diagram

At the core of the transactional process is the PropertyTransfer Contract (Figure A 13), which coordinates the final transfer of property ownership. It integrates with all other contracts to verify that all preconditions are met: clear title from the TitleSearch Contract, approved loans from the LoanProcessing Contract, verified identities from the KYCIdentity Contract, and active insurance from the TitleInsurance Contract. This contract utilizes interfaces or protocols to interact seamlessly with the other contracts, ensuring data integrity and consistency across the ecosystem. By orchestrating the inter-contract communication and verifying all necessary conditions, the PropertyTransfer Contract enables a seamless, secure, and efficient property transfer process, embodying the collaborative functionality

of the entire smart contract architecture.

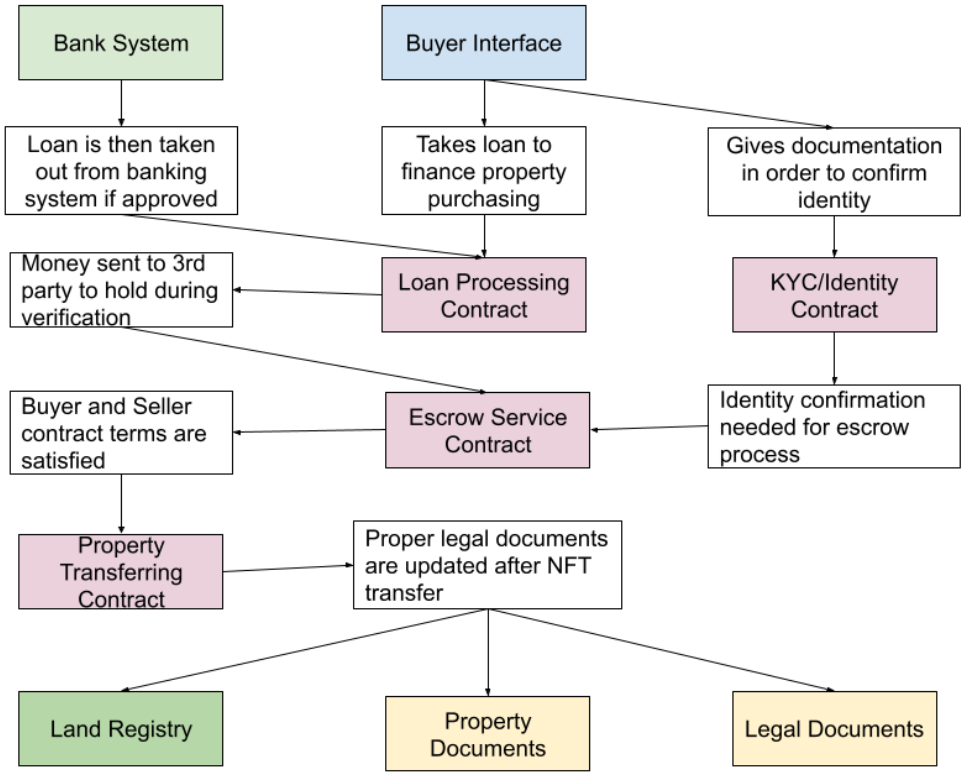

Figure 3: Buyer Processing Block Diagram

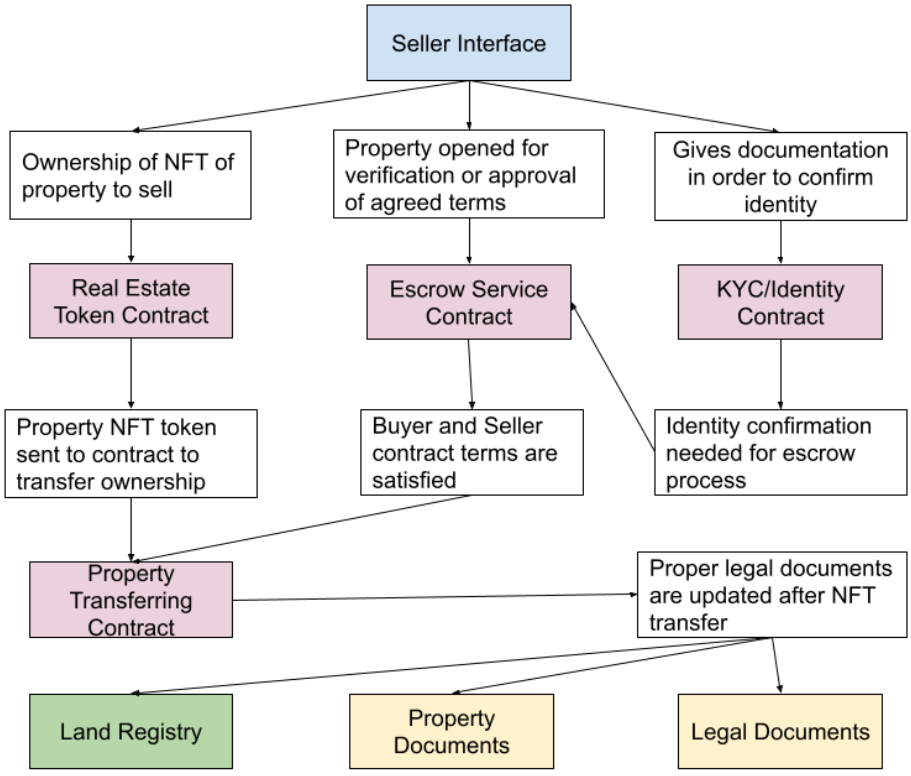

Figure 4: Seller Processing Block Diagram

2.2 Setting Up the Test Net Environment

Setting up the test net environment is a critical phase in developing a blockchain program, as it allows developers to test and refine smart contracts in a controlled and risk-free setting. By employing Ganache, we create a local Ethereum blockchain that simulates a real network environment. This simulation provides immediate transaction confirmations and eliminates the need for real Ether, making it safe and cost-effective to test smart contracts extensively. Integrating Ganache with Hardhat, a powerful development framework, further enhances the development process. Hardhat simplifies compiling, deploying, and testing smart contracts by offering a suite of tools that streamline these tasks. Configuring Hardhat to connect with the local Ganache network enables seamless interaction between the contracts and the test net, ensuring that any issues can be identified and addressed promptly. Utilizing Hardhat's compiler ensures that the contracts are syntactically correct and adhere to Solidity compiler requirements, catching errors early in the development cycle and promoting code quality.

Deploying the contracts to the test net involves writing deployment scripts that automate the deployment process to the Ganache network. Running these scripts through Hardhat not only streamlines the deployment but also reduces the potential for human error, ensuring consistency across testing iterations. Developing and running tests is an essential component of creating a robust blockchain program. By writing comprehensive test cases, we validate the functionality of each contract across various scenarios and edge cases, which helps in identifying logical errors and vulnerabilities. Executing these tests within Hardhat's testing environment verifies that the contracts behave as expected, with correct state changes and event emissions during interactions. This rigorous setup, deployment, and testing process is crucial for creating a better program, as it enhances reliability, security, and performance before deploying the application to a live network. It ensures that the smart contracts are battle-tested and ready to handle real-world usage, thereby instilling

confidence in users and stakeholders.

2.3 Flask Banking and Escrow Endpoint

To simulate real-world financial transactions within our blockchain-powered platform, we developed a Flask based banking and escrow system. This system provides endpoints that facilitate secure transactions between buyers, sellers, and escrow agents. The banking component enables users to apply for loans, check loan statuses, and repay loans, while the escrow service ensures that funds are held securely until transaction conditions are met.

By integrating these Flask endpoints with our smart contracts, we created a simulated banking and escrow system that allows us to test and refine financial interactions within our platform. This simulation enables us to model real-world scenarios, such as loan approvals, repayments, and escrow-based transactions, ensuring that our smart contracts function as expected before deployment. By handling deposits, fund releases, and transaction verifications in a controlled environment, we can validate the integrity and security of our contract logic while maintaining flexibility for future enhancements. This approach allows us to iterate on contract functionality efficiently, ensuring seamless integration between traditional financial processes and blockchain-based property transactions.

2.4 Front End Application Development

In developing the front-end application, we focused on integrating scraped property listings to provide users with a rich and interactive experience. We collected detailed property data for La Jolla from Zillow, targeting listings that are most relevant and appealing to potential buyers in the market. This involved using web scraping techniques to extract information such as property descriptions, prices, images, locations, and broker details. After acquiring the data, we parsed and formatted it to be compatible with our application's architecture,

ensuring seamless integration. We then designed intuitive user interface components to showcase these property listings attractively and informatively. By implementing effective data binding, we ensured that the property details are accurately displayed to users, with real-time updates reflecting any changes in the data. Emphasizing responsive design principles, we made sure that the listings are accessible and visually appealing across various devices and screen sizes, enhancing the overall user experience.

For the title search functionality, we developed a robust search interface that allows users to find properties based on multiple criteria such as property name, city, ZIP code, and broker name. This involved creating user-friendly input fields and filters that enable users to input search parameters effortlessly. We implemented dynamic search results that provide real-time feedback, updating the displayed properties as users modify their search criteria. This functionality enhances the usability of the application by allowing users to quickly narrow down their options and find properties that meet their specific needs. By handling search queries efficiently and displaying results promptly, we improved user engagement and satisfaction with the platform.

To simulate the property purchase process, we established a workflow using a local testnet connected to the deployed smart contracts. By integrating the front-end application with the testnet, we enabled users to experience the end-to-end process of purchasing a property within our blockchain ecosystem. This involved connecting the application to the smart contracts responsible for property tokenization, ownership transfer, escrow services, and KYC verification. Users can initiate a purchase by selecting a property and proceeding through the necessary steps, such as identity verification and fund deposition into the escrow service. The application interacts with the smart contracts to execute transactions, update ownership records, and handle funds securely. This testnet workflow allows us to create a realistic simulation of a purchase, demonstrating how the smart contracts facili-

tate secure and transparent transactions. It also enables us to test and refine the purchase process, ensuring that the interface guides users smoothly through each step and that all components of the system function cohesively.

To facilitate a seamless and secure user authentication experience, we integrated Clerk authentication into the front-end application. This enables users to sign in using their Google accounts, ensuring a straightforward and accessible login process. This also allowed us to track user activity and personalize the experience while maintaining robust security. Beyond authentication, we implemented an internal coin system within user accounts. This feature enables users to accumulate and transact virtual coins as part of the platform's incentive structure. Coins can be earned through property verifications, image uploads with geolocation verification, and other engagement-driven actions. Users can transfer coins between accounts, or exchange them for platform-specific rewards. The transactional logic was designed to be intuitive, ensuring users could manage their coin balances efficiently. We used Clerk's API to store and retrieve coin balances, allowing seamless integration between the authentication system and the internal economy of the platform. Peer-to-peer transactions were enabled within the app interface, ensuring that users could engage with one another with ease.

To enhance the reliability and integrity of user-submitted property images, we incorporated EXIF metadata extraction and geolocation tagging within the image upload system. Users can capture and upload photos directly through the mobile interface, with EXIF data automatically parsed to retrieve geolocation coordinates with the OpenStreetMap api. This information is used to verify the authenticity of the uploaded images by cross-referencing them with the property's registered location, ensuring that users are genuinely contributing accurate property information. Once an image is uploaded, the geolocation data is extracted and stored within the platform's database alongside the associated property list-

ing. This allows for a verification process that rewards users with internal coins when they upload images from a verified property location. The storage system was designed to ensure efficiency and security, leveraging cloud-based storage solutions for scalability.

Each listed property has a dedicated subpage where users can access detailed information, submit public reviews, and initiate the purchase process. These subpages allow users to evaluate properties through publicly visible reviews, providing transparency and additional context for potential buyers. The purchase functionality is integrated directly into the subpage, connecting to the escrow and banking simulation to handle transactions securely. This setup ensures that property purchases follow a structured workflow while allowing users to engage with listings through reviews and feedback.

3 Results

4 Discussion and Conclusion

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Appendices

Quarter 2 Project Proposal

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1 Broad Problem Statement

Real estate transactions represent one of the largest and most complex forms of value exchange in the modern economy, with annual U.S. home sales exceeding 4 million transactions in 2023. Additionally, the real estate market is valued at around 47.5 trillion dollars, making up almost 18 percent of the U.S. GDP. Despite this scale, the industry continues to rely on outdated processes that create significant inefficiencies, security risks, and unnecessary costs for all parties involved. In light of this issue, how can we utilize blockchain technology to reduce inefficiencies in the current real estate transaction space? Inefficiencies which include, but are not limited to, escrow processing, mortgage approval times, and expensive and restricted title searches. If these issues can be solved, transaction cost for real estate properties can be reduced by thousands of dollars

2 Domain Specific Problem Statement

More specifically, the real estate sector is notorious for its inefficiencies stemming from reliance on intermediaries, fragmented record-keeping systems, and opaque processes. Current solutions for property transactions, such as escrow, mortgage approvals, and title search require significant time and expense. Despite advancements in technology, previous attempts to digitize real estate processes have either failed to address these inefficiencies or have introduced their own challenges, such as centralization risks and data tampering vulnerabilities. Our research introduces a blockchain-based solution that leverages its properties of decentralization, trustlessness, and immutability to fundamentally transform real estate transactions. We aim to implement smart contracts and distributed ledger technology to facilitate this transformation. Initial results demonstrate the potential to reduce transaction times from months to days, lower costs by eliminating unnecessary intermediaries, and enhance security through cryptographic verification and immutable record-keeping. In our Quarter 1 Project, we laid the groundwork by implementing smart contracts on local blockchain networks to emulate essential real estate transactions. These included escrow agreements, loan contracts, and purchase/sale transactions. While this approach demonstrated blockchain's potential for reducing transaction times and improving security, key challenges remain: user-focused features, our quarter 1 implementation was primarily technical, leaving gaps in usability and scalability for end-users; interoperability with existing systems, the current implementation operates in isolation and lacks integration with legacy property databases or legal frameworks; tokenized incentives and interaction models, while we proposed introducing tokens to encourage user participation and verification, this feature remains undeveloped and untested in real-world scenarios; transaction cost optimization, deploying smart contracts incurs gas fees, which may offset some cost savings. We have yet to explore mechanisms to minimize these fees. Prior work has explored digitized solutions for escrow and mortgage approvals, such as centralized platforms, like DocuSign or Zillow. However, these systems fail to leverage blockchain's decentralized nature and are limited in addressing fraud risks and ensuring immutability. Similarly, research into blockchain-based property systems, like Propy, has faced challenges with regu-

latory adoption and scalability, as well as demonstrating tangible benefits for smaller scaled transactions.

3 Primary Output

Our Quarter 2 Project will expand upon the foundation established in Quarter 1 by addressing these deficiencies:

- User-focused features, we will develop an intuitive interface that simplifies interaction with smart contracts, and a mobile application which facilitates the use of the title search and property verification features.
- Tokenized user engagement, we will design and implement a token system to incentivize user participation, such as verifying property data and facilitating peer-to-peer transactions.
- Enhanced cost-efficiency, through optimization of smart contract execution, we will analyze how to minimize gas fees and further lower the cost barrier for adoption.
- Integration setup for third party services, via simulated endpoint calls to banking, escrow, and title search services

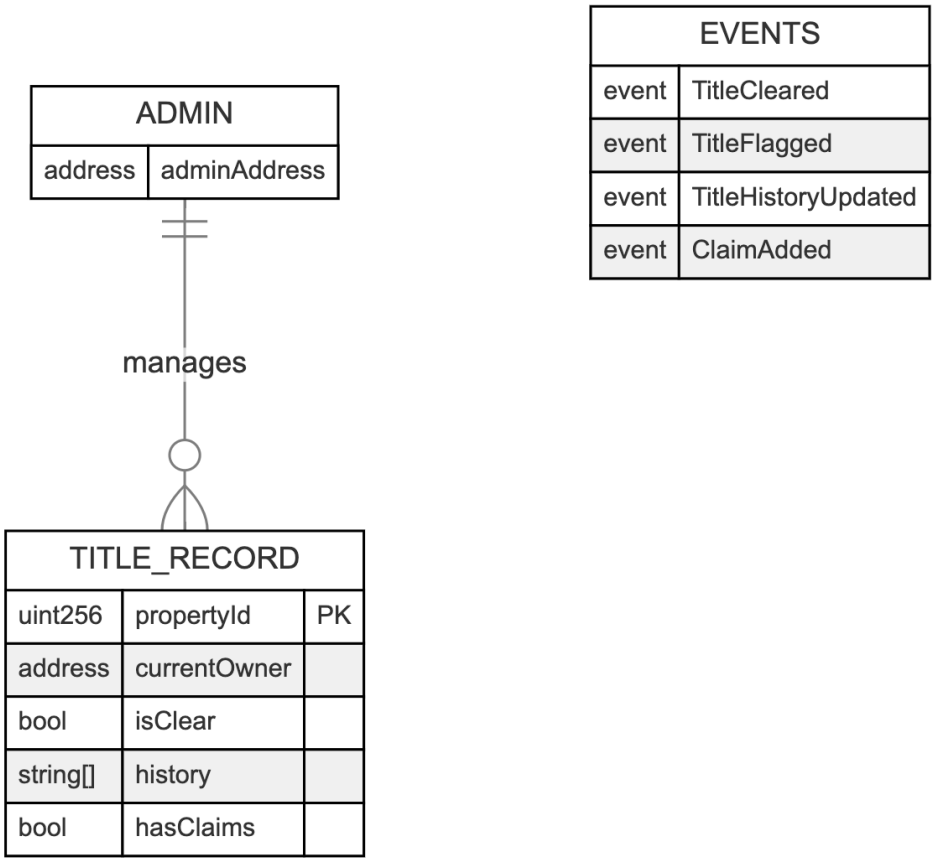

Figure A 7: Title Search Contract Entity Relationship

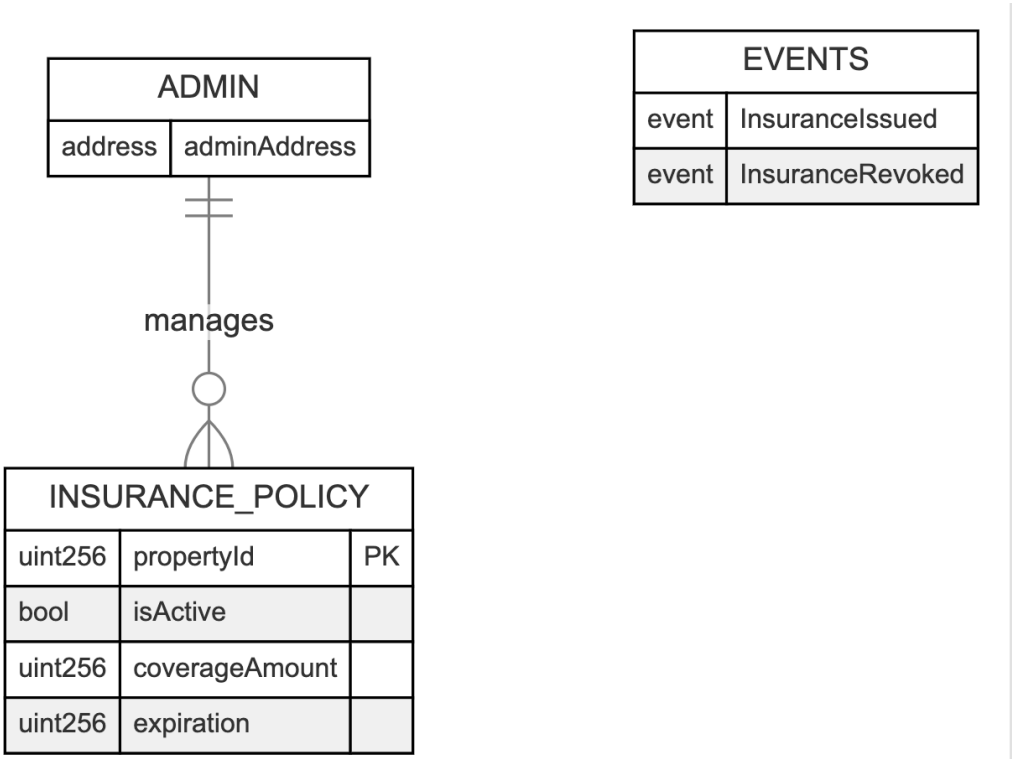

Figure A 8: Title Insurance Contract Entity Relationship

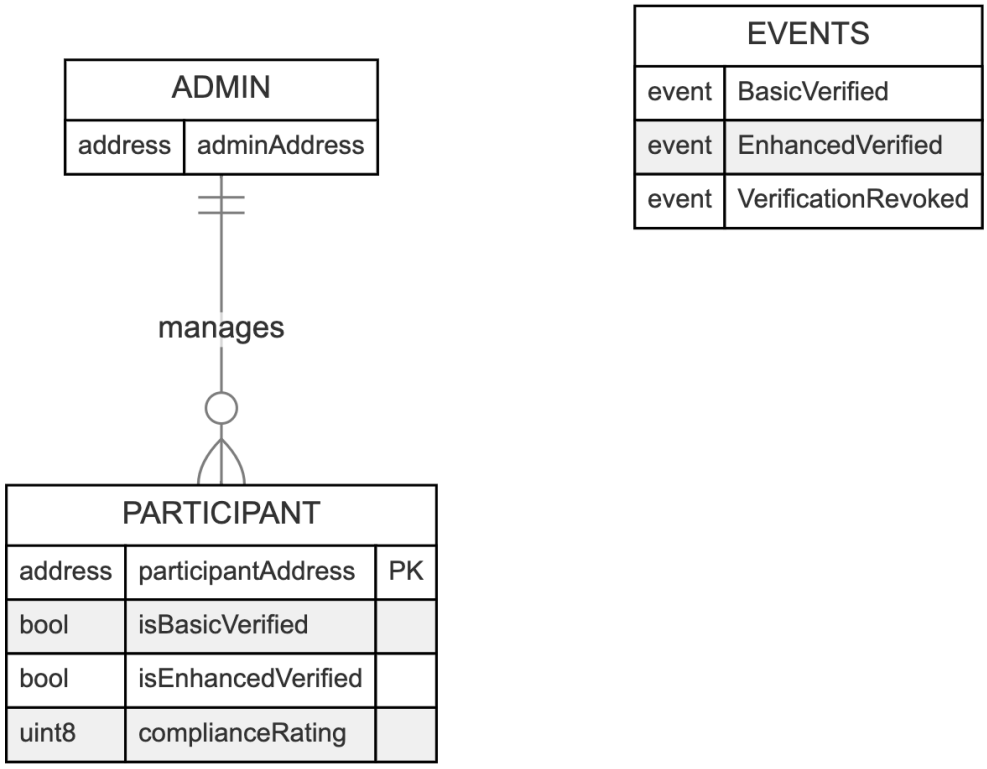

Figure A 9: KYC Contract Entity Relationship

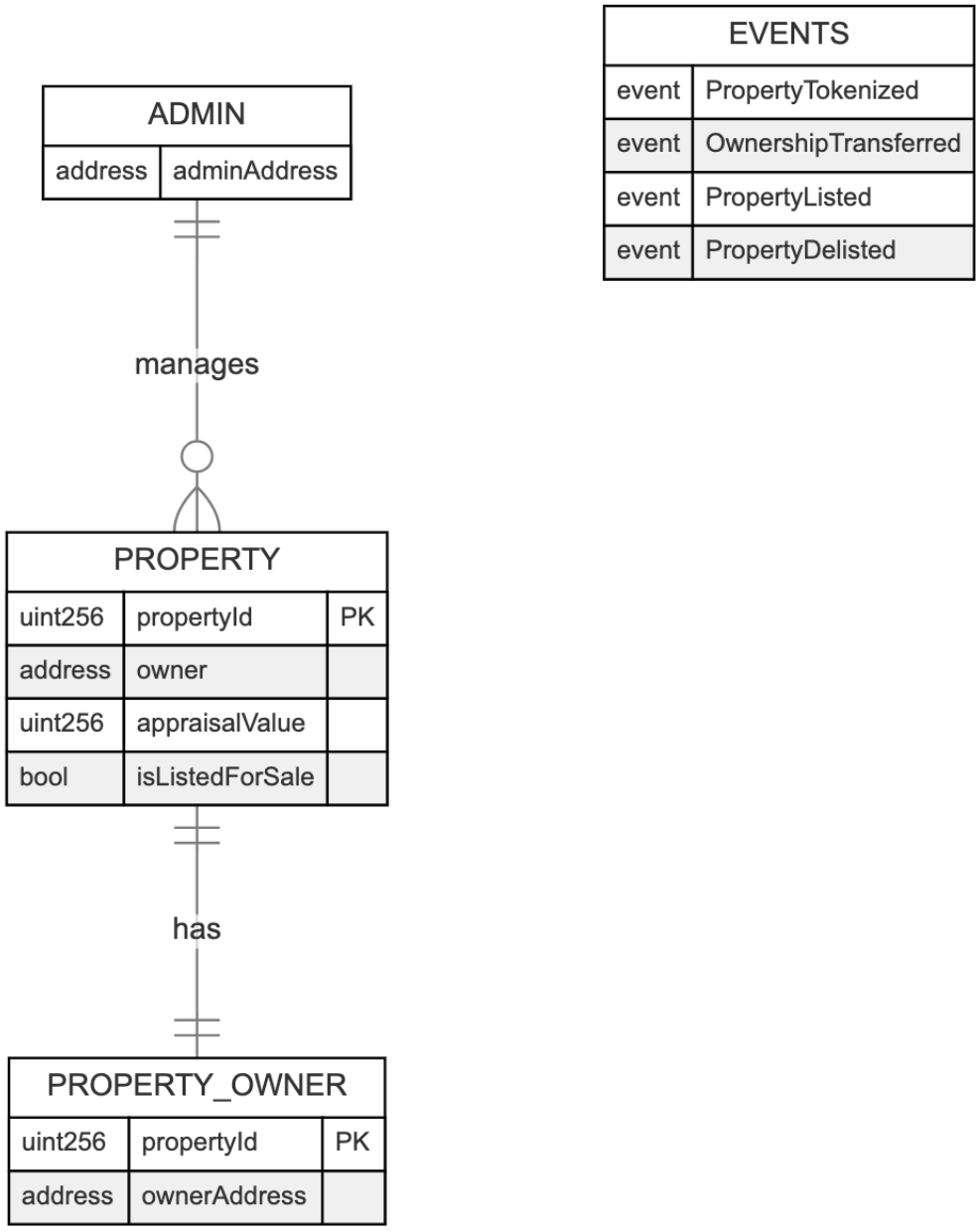

Figure A 10: Real Estate Token Contract Entity Relationship

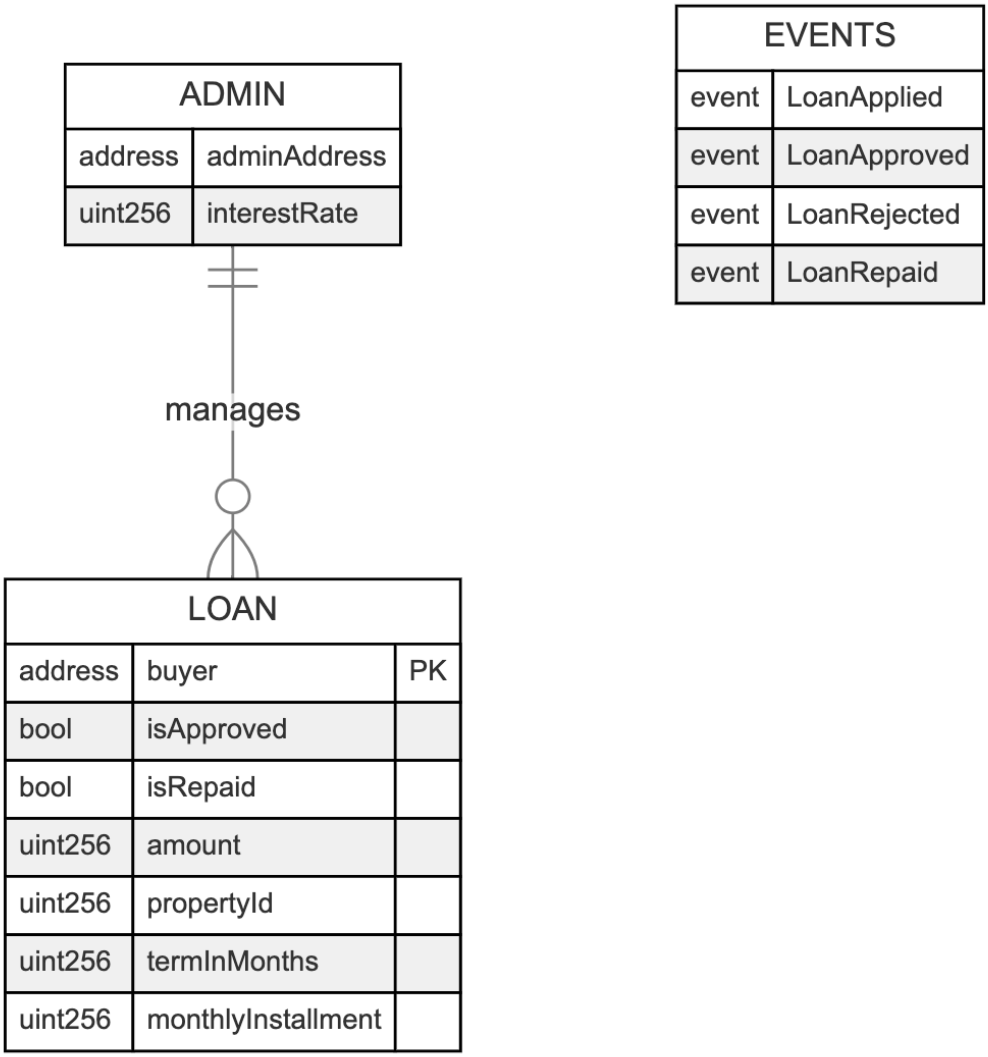

Figure A 11: Loan Contract Entity Relationship

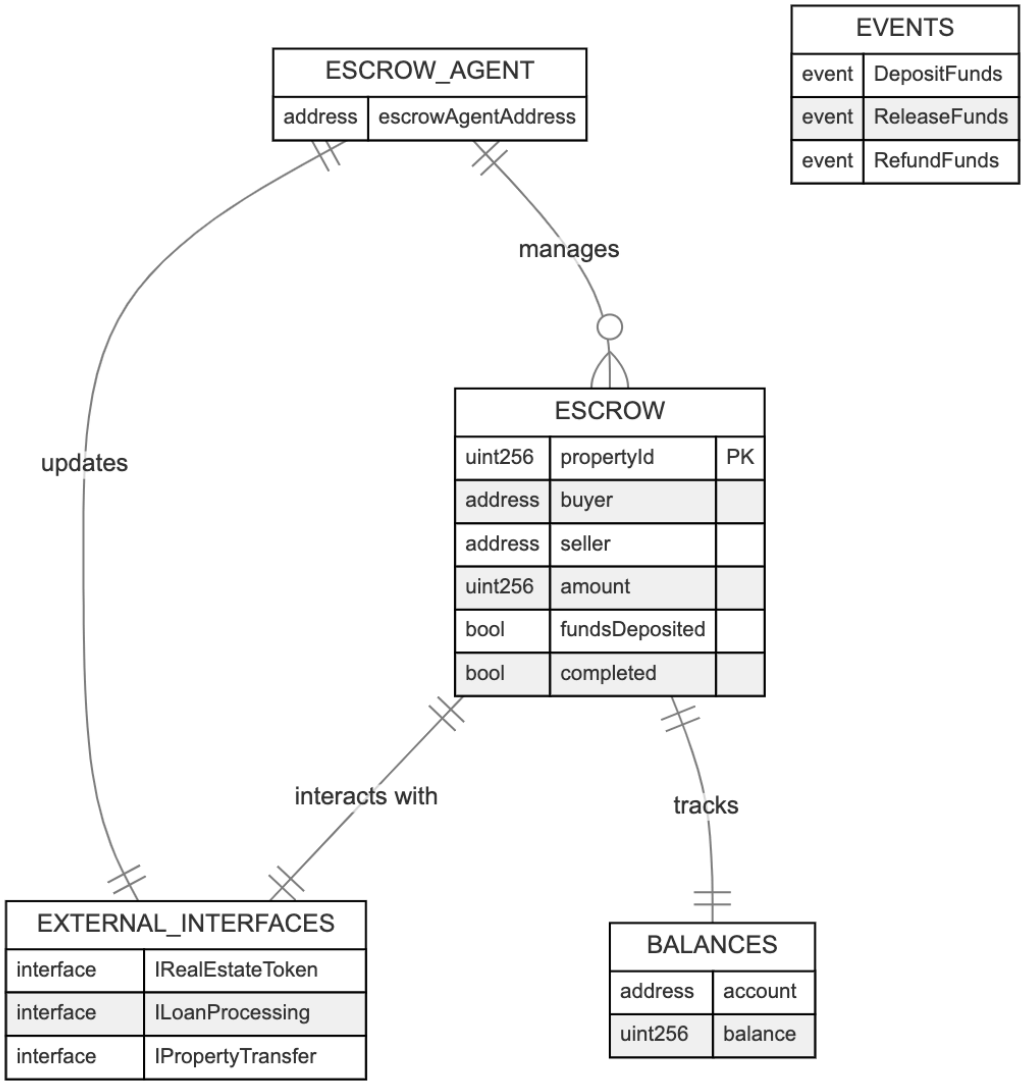

Figure A 12: Escrow Contract Entity Relationship

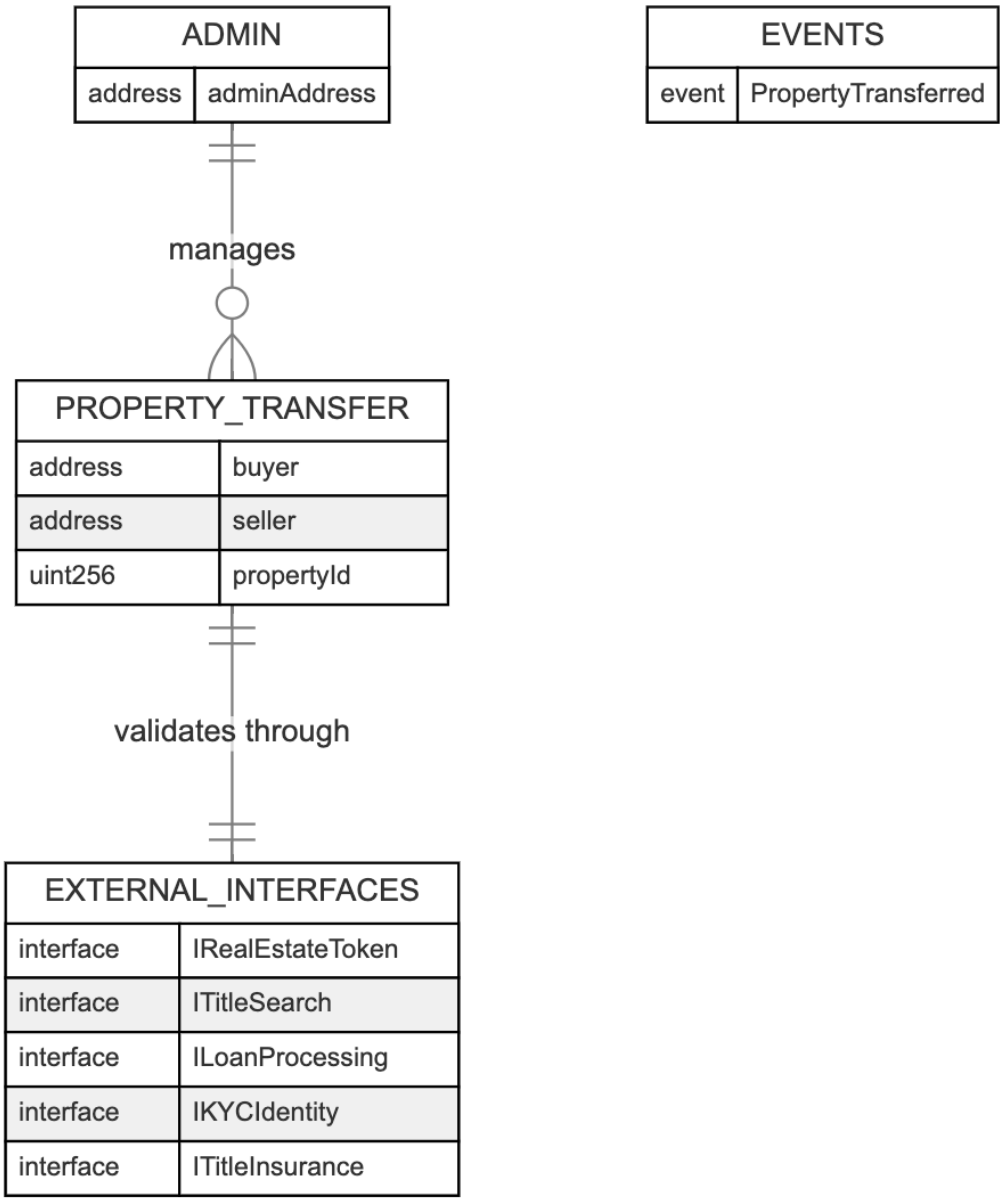

Figure A 13: Property Transfer Contract Entity Relationship

B Contributions

Dhruv Kanetkar:

- Created a new set of endpoints for escrow service processing in order to replicate how an actual escrow entity would handle common actions for a property. Endpoints created: create-escrow, deposit-funds, release-funds, refund-funds, escrow-status/<property-id>
- Set up a flask server with endpoints for bank loan processing to simulate a banking entity that the smart contracts can interact with. Here is a description of the endpoints that were created. Endpoints created: apply-loan, approve-loan, reject-loan, repay-loan, loan-status/<buyer-address>
- Set up PWA setup for access to application through mobile interface
- Specified Search feature for mobile interface to make it easier for interacting with properties
- Deployed new website to live vercel link in order to support Zillow property listings
- Added Property Routes to accommodate specific actions per property
- Feature for adding reviews and seeing reviews from other users
- Transacting properties on local blockchain
- Feature to upload more property pictures for additional information

Ish Patel:

- Integrated Clerk authentication system into the frontend, enabling secure user sign-in via Google accounts.
- Implemented token tracking for each authenticated user, allowing for the accumulation and transaction of internal coins.
- Developed and tested peer-to-peer coin transfer functionality within the platform, enabling users to exchange tokens.
- Integrated geolocation and EXIF data processing for mobile photo uploads, allowing property images to be tagged with accurate location information.
- Enabled automatic coin rewards for users uploading verified property images based on geolocation confirmation.
- Assisted in setting up property verification mechanisms, ensuring that uploaded content aligns with real-world property locations.
- Ensured cross-platform compatibility by optimizing features for both web and mobile Progressive Web App (PWA) implementation.
- Implemented cloud database system for uploaded property images, allowing users to view and access community-contributed photos for each listing.
- Integrated mobile geolocation services to display targeted property listings based on the user's current location, enhancing localized search functionality.

Raghava Bandla:

- Created a specialized escrow smart contract to manage the flow of funds, verifying conditions before releasing or refunding deposits and maintaining an immutable record of escrow states, providing functionality for the endpoints. Contract communicates with the Flask server to trigger specific escrow operations and provide real-time status updates.
- Created a dedicated banking smart contract to manage enforcing loan terms, tracking payment schedules, and updating account statuses based on approvals, rejections, or repayment milestones, to simulate a banking entity. Contract communicates with the Flask server to trigger specific banking operations and provide real-time status updates.
- Connected escrow and banking endpoints to their smart contracts and platform for end-to-end workflow
- Worked on mobile application's search interface, developing relevant contracts and functionality to allow users to discover properties
- Created an ERC-20 token for secure digital currency mechanism enabling on-platform transactions and rewarding system