Web3 Number Guessing Game - Technical Documentation

Project Overview

The Web3 Number Guessing Game is a blockchain-based application built with Flutter and Solidity where players guess numbers between 0-100 and earn GUESS tokens based on their accuracy. The game leverages Ethereum smart contracts to handle game logic and token distribution in a transparent and decentralized manner. **The game is completely free-to-play** - players only receive rewards when they win, and there are no entry fees.

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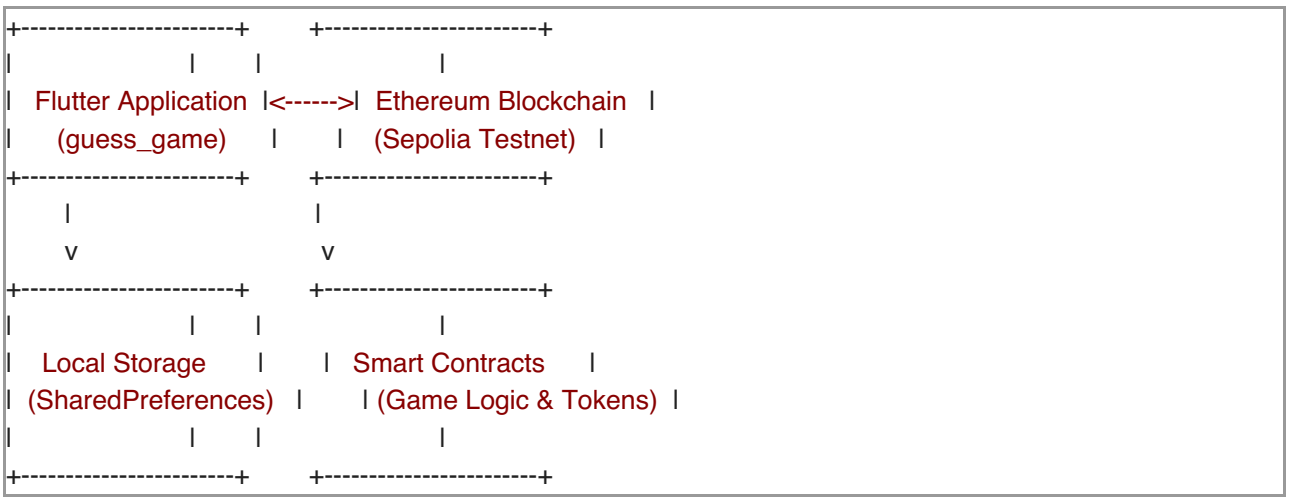
Architecture

The project follows a client-server architecture with:

- **Client**: Flutter mobile application (guess_game)
- **Backend**: Ethereum blockchain with smart contracts
- **Integration**: Web3Dart library to connect the Flutter app with the blockchain
- **Network**: Deployed on Sepolia Testnet for testing

High-Level Architecture Diagram



Frontend (Flutter)

Project Structure

```
lib/
├── constants/          # App constants and contract addresses
│   ├── app_constants.dart      # Main app constants
│   └── constants.dart          # Export file
├── contracts/          # ABI definitions and contract config
│   ├── contract_config.dart    # Contract addresses and network config
│   ├── erc20_abi.dart          # ERC-20 token ABI
│   ├── game_contract_abi.dart # Game contract ABI
│   └── contracts.dart          # Export file
├── models/             # Data models
│   ├── game_result.dart        # Game result data structure
│   └── models.dart             # Export file
├── providers/          # State management
│   ├── app_provider.dart       # Main app state provider
│   └── providers.dart          # Export file
├── screens/            # UI screens
│   ├── home_screen.dart        # Main game interface
│   └── screens.dart            # Export file
├── services/           # Business logic services
│   ├── web3_service.dart       # Blockchain interaction service
│   ├── storage_service.dart    # Local storage management
│   └── services.dart           # Export file
├── lib.dart            # Main library export
└── main.dart           # App entry point
```

Key Components

1. **Main Application** (main.dart):
    - Entry point for the Flutter application
    - Configures Material Design 3 theme (light/dark mode)
    - Sets up Provider state management
    - Initializes the application
2. **Home Screen** (screens/home_screen.dart):
    - Primary user interface for the game
    - Handles wallet connection state
    - Game play interface with number input
    - Real-time result display with performance indicators
    - Statistics display (games played, total rewards, accuracy)
3. **Game Result Model** (models/game_result.dart):
    - Represents the outcome of a single game
    - Stores target number, user guess, difference, reward amount, and timestamp

State Management

The app uses the Provider pattern for centralized state management:

- **AppProvider** (providers/app_provider.dart):
    - Manages wallet connection state and user address
    - Handles game state (idle, playing, showing results)
    - Coordinates with Web3Service for blockchain interactions
    - Manages loading states and error handling
    - Stores game statistics and history

UI/UX Design

- **Material Design 3**: Modern design system with Material You theming
- **Responsive Layout**: Adapts to different screen sizes and orientations
- **Color-coded Results**: Performance indicators with intuitive color schemes
- **Loading States**: Smooth loading animations during blockchain transactions
- **Error Handling**: User-friendly error messages and recovery options
- **Dark/Light Theme**: Automatic theme switching based on system preferences

Backend (Smart Contracts)

Token Contract

GuessToken.sol - ERC-20 token contract with enhanced features:

- **Token Details**:
    - Name: Guess Token
    - Symbol: GUESS
    - Decimals: 18
    - Max Supply: 1,000,000 tokens
    - Initial Owner Supply: 100,000 tokens

- **Key Features**:
    - **Minting System**: Role-based minting with owner control
    - **Access Control**: Minter role management (add/remove minters)
    - **Pausable**: Emergency pause functionality
    - **Burning**: Token holders can burn their tokens
    - **Supply Cap**: Hard cap at 1 million tokens
- **Security Features**:
    - OpenZeppelin standard implementation
    - Pause functionality for emergency situations
    - Role-based access control

Game Contract

NumberGuessingGame.sol - Main game logic contract:

- **Game Mechanics**:
    - **Free-to-Play**: No entry fees, players only receive rewards for winning
    - **Random Number Generation**: Pseudo-random (use Chainlink VRF for production)
    - **Winning Condition**: Guesses within 20 points of target are considered wins
    - **Automatic Rewards**: Winners receive tokens automatically
- **Key Functions**:
    - playGame(uint256 guess): Main game function (free to play)
    - getUserGameHistory(address user): Retrieves complete game history
    - getLatestGameResult(address user): Gets the most recent game
    - getUserTotalRewards(address user): Total rewards earned
    - getUserTotalGames(address user): Total games played
    - getUserAverageAccuracy(address user): Average guess accuracy
- **Reward Structure**:
    - Perfect Guess (0 difference): 50 GUESS tokens (10 base + 40 bonus)
    - Excellent (≤5 difference): 17.5 GUESS tokens (10 + 75% bonus)
    - Very Good (≤10 difference): 15 GUESS tokens (10 + 50% bonus)
    - Good (≤20 difference): 12.5 GUESS tokens (10 + 25% bonus)
    - Poor (>20 difference): 0 GUESS tokens (loss, but free to play)

Security Considerations

- **OpenZeppelin Libraries**: Uses audited, battle-tested contract libraries
- **Reentrancy Protection**: ReentrancyGuard on all state-changing functions
- **Access Control**: Owner-only functions for contract administration
- **Pausable Contracts**: Emergency pause functionality
- **Input Validation**: Strict validation of all user inputs
- **Safe Math**: Built-in overflow protection in Solidity 0.8+

Integration Layer

Web3 Service

web3_service.dart handles all blockchain interactions:

- **Connection Management**: Initializes Web3 client with Sepolia testnet
- **Contract Interaction**: Loads and interacts with deployed smart contracts
- **Wallet Integration**: Manages wallet connection state
- **Transaction Processing**: Handles game transactions and confirmations
- **Error Handling**: Comprehensive error handling for blockchain operations
- **Gas Management**: Appropriate gas limits for contract interactions

Storage Service

storage_service.dart manages local data persistence:

- **Wallet Persistence**: Stores connected wallet address
- **User Preferences**: Saves app settings and preferences
- **Session Management**: Handles user session state
- **Data Clearing**: Clean data removal when disconnecting wallet

Getting Started

Prerequisites

- **Flutter SDK**: 3.7.0 or higher
- **Node.js**: 16.0 or higher
- **Git**: For version control
- **Ethereum Wallet**: MetaMask or compatible Web3 wallet
- **Sepolia ETH**: For testing transactions (free from faucets)

Installation

1. **Clone the repository**

```
git clone <repository-url>
cd quiz_app
```

2. **Install Flutter dependencies**

```
flutter pub get
```

3. **Install smart contract dependencies**

```
cd smart-contracts
npm install
cd ..
```

Deployment

1. **Configure Environment** (edit smart-contracts/hardhat.config.js)

```
networks: {
  sepolia: {
    url: "YOUR_SEPOLIA_RPC_URL",
    accounts: ["YOUR_PRIVATE_KEY"]
  }
}
```

2. **Deploy Contracts**

```
cd smart-contracts
npx hardhat run scripts/deploy-testnet.js --network sepolia
```

3. **Update Contract Addresses** in lib/constants/app_constants.dart:

```
static const String guessTokenContractAddress = 'NEW_TOKEN_ADDRESS';
static const String gameContractAddress = 'NEW_GAME_ADDRESS';
```

4. **Generate ABI Files**

```
cd smart-contracts
npx hardhat run scripts/generate-abi.js
```

5. **Run the App**

```
flutter run
```

Game Mechanics

Gameplay

1. **Wallet Connection**: User connects Web3 wallet (no registration required)
2. **Game Start**: User initiates a new game (completely free)
3. **Number Input**: User enters a guess between 0-100
4. **Blockchain Processing**: Smart contract generates random number and calculates results
5. **Reward Distribution**: Winners automatically receive GUESS tokens
6. **Result Display**: Game shows target number, difference, and reward earned

Reward Structure

The game uses a tiered reward system based on guess accuracy:

Performance Level	Difference Range	Reward Amount	Description
Perfect	0	50 GUESS	Exact match - maximum reward
Excellent	1-5	17.5 GUESS	Very close guess
Very Good	6-10	15 GUESS	Close guess
Good	11-20	12.5 GUESS	Moderate accuracy
Loss	21+	0 GUESS	No reward, but free to play

Example Scenarios

Target Number: 42

Player Guess	Difference	Performance	Reward

Alice	42	0	Perfect	50 GUESS
Bob	46	4	Excellent	17.5 GUESS
Carol	51	9	Very Good	15 GUESS
Dave	60	18	Good	12.5 GUESS
Eve	72	30	Loss	0 GUESS

Development Scripts

The project includes essential development scripts in smart-contracts/scripts/:

Essential Scripts (Kept)

1. **deploy-testnet.js**:
    - Main deployment script for testnet deployment
    - Deploys both GuessToken and NumberGuessingGame contracts
    - Sets up initial token approvals
    - Provides comprehensive deployment information and next steps
2. **generate-abi.js**:
    - Generates ABI files for Flutter integration
    - Creates filtered ABIs with only necessary functions
    - Outputs Dart files for contract interaction
3. **check-balance.js**:
    - Simple utility to check account balance
    - Useful for verifying wallet funding before deployment

Removed Scripts

The following development and testing scripts have been removed to keep the codebase clean:

- All test-*.js files (18 test scripts)
- Debug scripts (debug-*.js, check-transactions.js)
- Demo scripts (demo-*.js)
- Fix scripts (fix-*.js)
- Old deployment scripts (deploy-updated-contract.js)
- Utility scripts (transfer-tokens.js, show-test-addresses.js)

Testing

Frontend Testing

- **Unit Tests**: Test individual components and services
- **Widget Tests**: Test UI components and user interactions
- **Integration Tests**: Test complete user flows

Smart Contract Testing

- **Hardhat Tests**: Comprehensive contract testing
- **Network Testing**: Live testing on Sepolia testnet

- **Security Testing**: Audit contract security features

Manual Testing

1. Connect different wallet types
2. Test various guess scenarios
3. Verify reward calculations
4. Test error handling

Known Issues & Limitations

Smart Contract Limitations

- **Pseudo-Random Numbers**: Current implementation uses block-based randomness (not production-ready)
- **Gas Costs**: Transaction fees apply for each game (use layer 2 for lower costs)
- **Centralized Rewards**: Owner must fund the contract with tokens for rewards

Frontend Limitations

- **Mobile Focus**: UI optimized primarily for mobile devices
- **Wallet Support**: Limited to Web3-compatible wallets
- **Network Dependency**: Requires stable internet connection

General Limitations

- **Testnet Only**: Currently deployed on Sepolia testnet
- **Token Distribution**: Manual token distribution to contract for rewards

Future Improvements

Short-term Improvements

- **Chainlink VRF Integration**: Implement truly random number generation
- **Layer 2 Deployment**: Deploy on Polygon or Arbitrum for lower gas costs
- **Improved UI**: Enhanced mobile and web responsiveness

Medium-term Features

- **Multiplayer Games**: Real-time multiplayer guessing competitions
- **Leaderboards**: Global and weekly leaderboards
- **Social Features**: Share results and challenge friends
- **Achievement System**: Badges and achievements for milestones

Long-term Vision

- **Tournament System**: Organized tournaments with bigger rewards
- **NFT Integration**: Special NFT rewards for top performers
- **Cross-chain Support**: Multi-chain deployment for broader accessibility
- **Advanced Analytics**: Detailed player statistics and performance tracking
- **Governance Token**: Community governance for game parameters