MedBlock: The Ultimate System Design & Technical Reference

Date: January 24, 2026 **Status:** Production-Ready (Testnet)

1. Abstract

MedBlock is re-engineers the traditional healthcare data model by moving from **Institution-Centric** storage (where hospitals own data) to **Patient-Centric** ownership (where patients own data).

This is achieved through a **Hybrid Decentralized Architecture**:

1. **Identity & Permissions**: Managed on-chain via **Ethereum Smart Contracts**.
2. **Data Persistence**: Managed off-chain via **IPFS (InterPlanetary File System)**.

This document serves as the definitive technical guide to the entire MedBlock ecosystem, detailing every interaction, data structure, and security mechanism.

2. Architectural Philosophy

The system is built on the principe of **"Trust through Verification"**.

2.1 The "Data Silo" Problem

Current systems fragment patient history. A patient visiting five different specialists often leaves traces of their medical history in five disconnected databases.

- **Consequence**: Incomplete diagnosis, redundant testing, and data leakage.

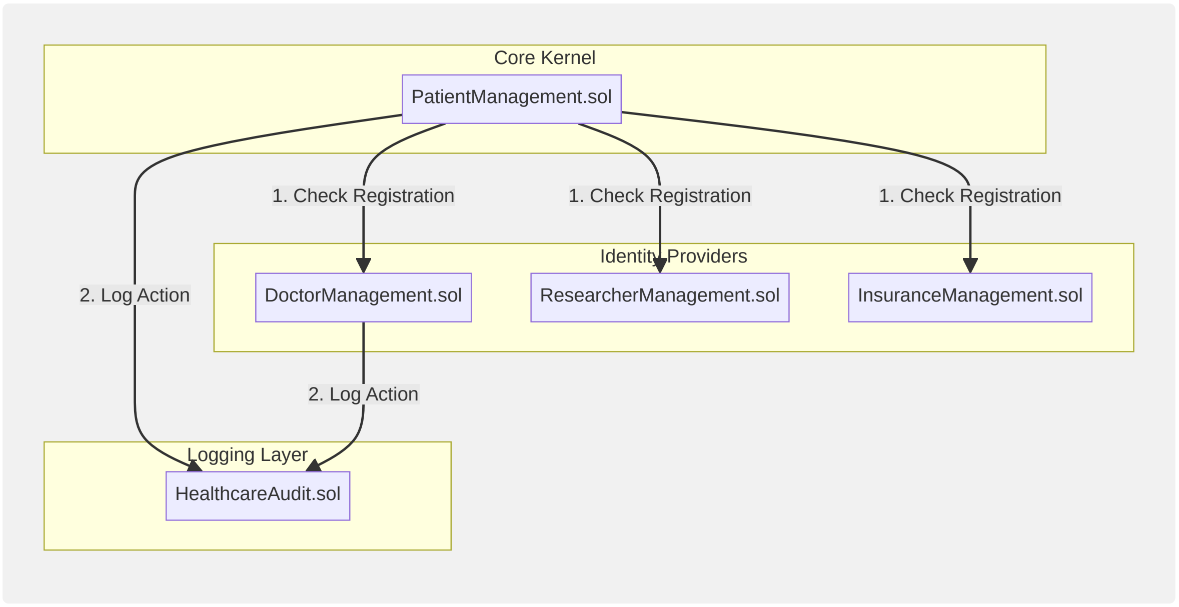
2.2 The MedBlock Solution

MedBlock acts as a **Universal Index**.

- The *File* stays distributed (IPFS).
- The *Index* stays global (Blockchain).
- The *Key* stays with the Patient.

3. System Architecture: The "Five-Contract" Ecosystem

The backend logic is not monolithic. It is a cluster of specialized micro-contracts that interact via Interfaces.



3.1 PatientManagement.sol (The Kernel)

This contract is the **Single Source of Truth** for data ownership.

- **State Variables**:
  - `mapping(address => Patient)`: The registry.
  - `mapping(address => MedicalRecord[])`: The actual data pointer.
  - `mapping(address => mapping(address => uint256)) accessExpiry`: The permission matrix.
- **Responsibilities**:
  - Validating uploader permissions (`msg.sender` == Doctor).
  - Validating viewer permissions (`block.timestamp` < expiry).
  - Routing identity checks to external contracts.

3.2 DoctorManagement.sol (The Gatekeeper)

- **Responsibilities**:
  - Curates the list of valid Doctors.
  - Maintains `authorizedPatients` mapping for Doctors (Quick-access list).
  - **Security**: Only the `Admin` can verify/add new doctors, preventing Sybil attacks.

3.3 HealthcareAudit.sol (The Black Box)

- **Responsibilities**:
  - The "Flight Recorder" of the blockchain.
  - Stores `struct AuditLog { address actor; string action; address target; ... }`.
  - **Immutability**: Once written, logs cannot be deleted, providing a forensic trail for malpractice or data misuse.

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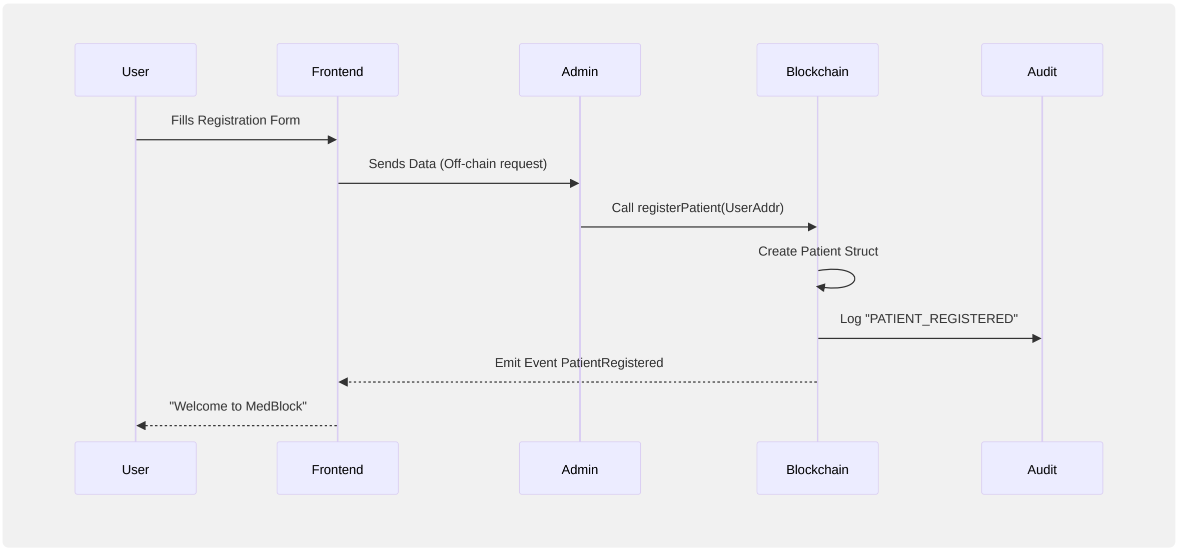
4. Visual Workflows

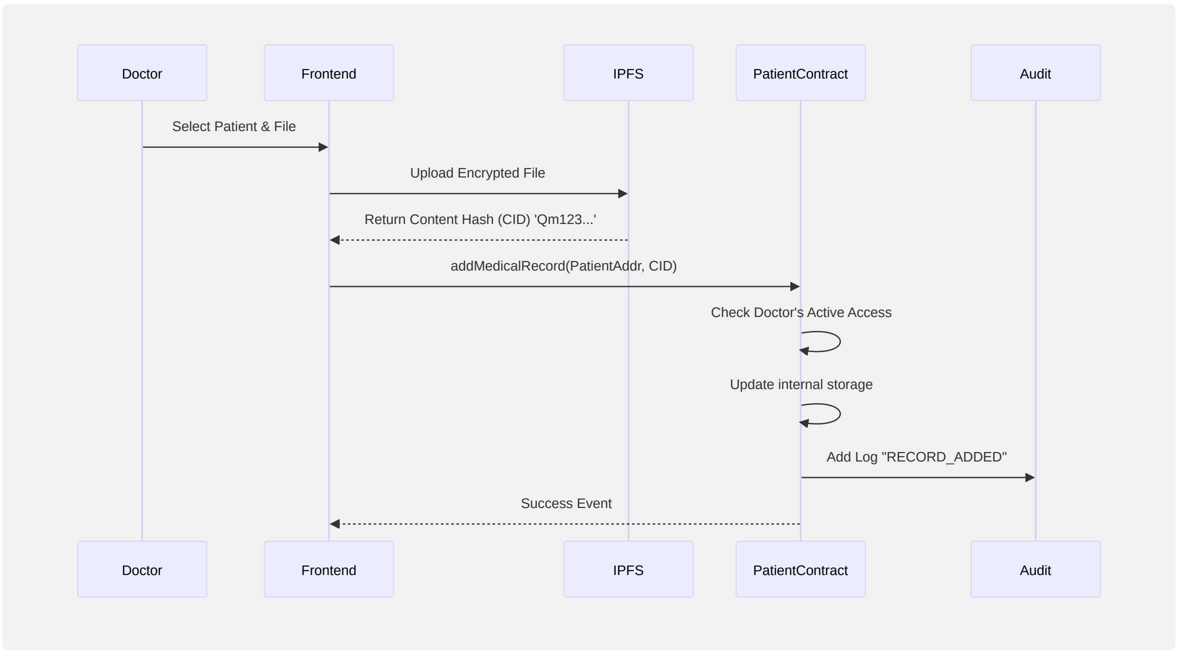
4.1 Workflow: Patient Registration (The Onboarding)

Users cannot simply "exist"; they must be explicitly registered to prevent spam.



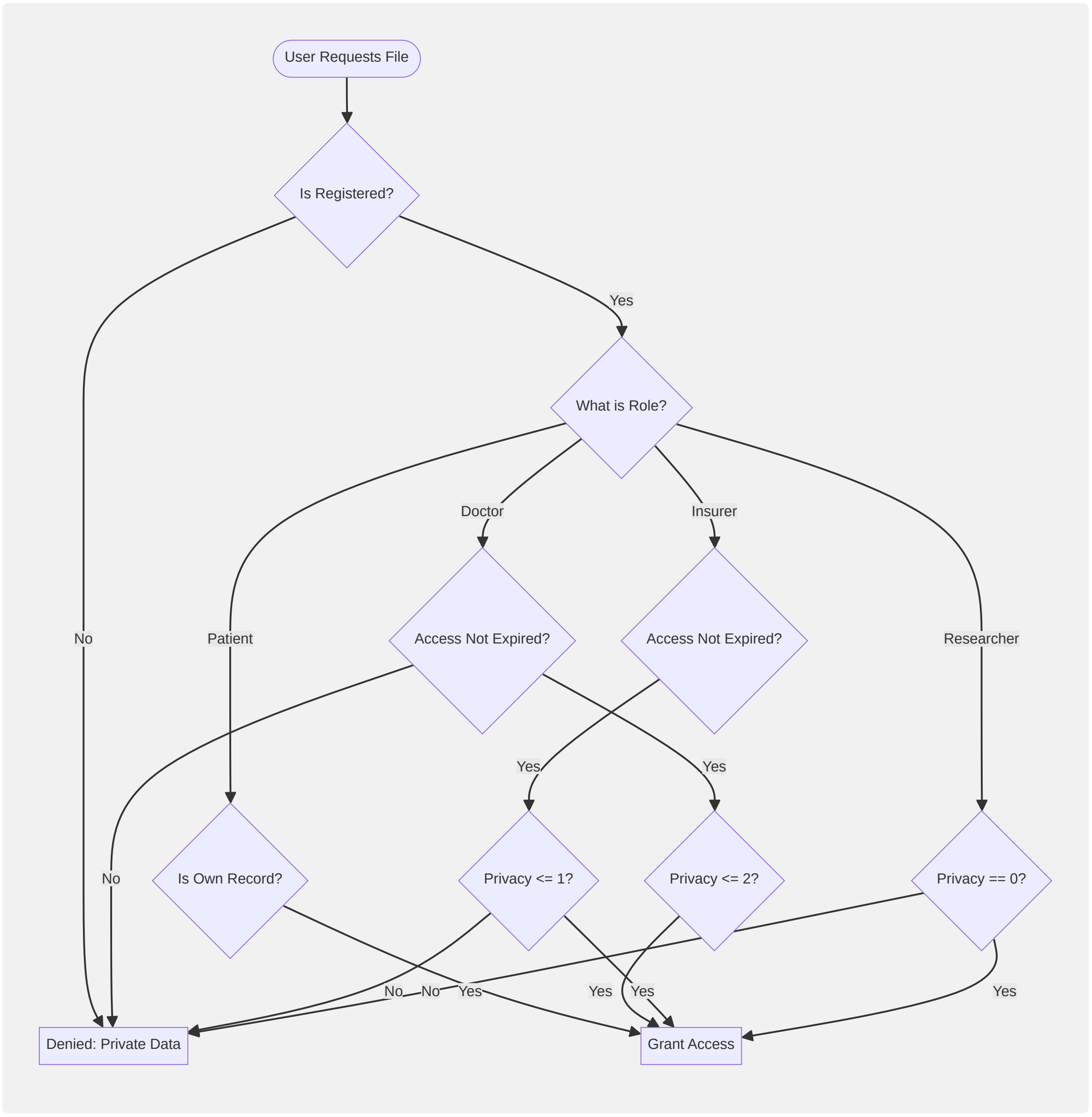
4.2 Workflow: The Secure Upload Lifecycle

How a static file becomes a secured blockchain asset.



4.3 Workflow: Granular Access Retrieval

The decision tree for "Can I see this file?".



5. Privacy Levels & Data Taxonomy

MedBlock recognizes that not all medical data is equal. A "Sick Leave Certificate" is different from "Psychotherapy Notes".

Level 0: Public / Research

- **Definition**: Data that is anonymized or low-risk.
- **Examples**: Blood Type, Vaccination Status, Generic Allergies.
- **Access**: Open to **Researchers**, **Insurers**, **Doctors**.

Level 1: Standard / Administrative

- **Definition**: General medical history required for claims and treatment.
- **Examples**: X-Rays, Lab Reports, Prescriptions, Hospital Discharge Summaries.
- **Access**: Open to **Insurers** (for claims) and **Doctors**. **Hidden from Researchers**.

Level 2: Private / Confidential

- **Definition**: Highly sensitive data protected by stricter privilege.
- **Examples**: Mental Health records, Genetic testing, HIV/STD status.
- **Access**: **Strictly Doctor-Patient Confidentiality**. Hidden from Insurers and Researchers.

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6. Technical Deep Dive

6.1 Frontend State Management

The React application uses a **Context-free, Prop-drilling minimized** approach with `ethers.js` acting as the global state provider via the Blockchain.

- **Poll-free Updates**: Instead of polling the database, the frontend listens for **Events** (`MedicalRecordAdded`, `AccessGranted`) to update the UI in real-time.

6.2 IPFS Integration

- The system uses **InterPlanetary File System** for "Content Addressed Storage".
- We store the **CID** (Content Identifier) on-chain.
- *Why?* If we stored the PDF on Ethereum, a single transaction could cost $50,000+ in Gas. Storing the CID (32 bytes) costs pennies.

6.3 Smart Contract Security (Threat Model)

Threat	Mitigation Strategy
Unauthorized Access	`getSharedRecords` enforces a strict check of `msg.sender` against the `accessExpiry` mapping.
Tampering	Records are stored on IPFS. If a byte changes, the CID changes. The CID on-chain is immutable. Mismatch = Tampering detected.
Sybil Attack	Registration is `onlyAdmin`. Bad actors cannot flood the system with fake Doctor accounts.
Reentrancy	All external calls (to Audit, etc.) follow the Checks-Effects-Interactions pattern.
Wallet Spoofing	Frontend `useEffect` hooks constantly verify that `window.ethereum.selectedAddress` matches the internal `account` state.

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7. Operational Guide

7.1 Setup & Deployment

1. **Environment**: Requires `Node.js v16+`, `Docker` (for IPFS), `MetaMask`.
2. **Deployment Order**:
    1. Deploy `HealthcareAudit`.
    2. Deploy `DoctorManagement`, `ResearcherManagement`, `InsuranceManagement` (pass Audit address).
    3. Deploy `PatientManagement`.
    4. **Linkage**: Call `setDoctorContractAddress`, etc., on `PatientManagement` to wire the system together.

7.2 Routine Admin Tasks

- **Approving Users**: The Admin must manually approve new Doctor/Researcher accounts to maintain the "Web of Trust".
- **Monitoring**: The Admin can view the Global Log to detect anomalous activity patterns (e.g., one Doctor accessing 1000 records in 1 minute).

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8. Conclusion

MedBlock Version 3.0 represents a mature, production-grade architecture. By rigorously separating concerns, enforcing granular privacy levels, and automating audit trails, it provides a comprehensive solution to the triad of Health Tech challenges: **Security**, **Interoperability**, and **Sovereignty**.

- **For Patients**: Peace of mind and portability.
- **For Doctors**: Instant access to complete histories.
- **For Research**: Access to cleaner, verified datasets.