**High-Level System Architecture Description**

**System Overview**

The proposed **Modular Regulatory Traceability Platform** is a **cloud-native, secure, and scalable solution** designed for government use, with an emphasis on regulatory compliance and traceability of controlled substances, starting with cannabis. This platform is built to support **real-time monitoring**, **offline functionality**, and **full auditability**, ensuring end-to-end transparency from production to sale. It is structured around **modular services** that can be adapted for other substances like alcohol, mushrooms, and explosives in the future.

**Key Components of the High-Level Architecture**

**1. Users Layer**

* **Regulator:**  
  The primary users responsible for overseeing the system's operations. Regulators have full access to the system, including audit logs, reports, and real-time monitoring dashboards.
* **Operator:**  
  Operators (licensees) interact with the platform daily, performing actions such as planting, harvesting, sales logging, and product disposal. They rely on the **mobile app** for offline operations and synchronize their data once a connection is available.
* **Auditor:**  
  Auditors have read-only access, enabling them to view the entire system's audit trails, ensuring transparency and accountability.

**2. Interfaces Layer**

* **Web UI (React.js):**  
  The web interface is used by regulators, auditors, and operators to manage tasks such as data input, reporting, and compliance monitoring. The **UI is built using React** for dynamic, real-time user interactions and ease of maintenance.
* **Mobile App (Flutter):**  
  Designed for offline functionality, the mobile app is used by operators in remote areas with limited connectivity. The app integrates local storage to temporarily hold data and uses a custom sync engine to synchronize with the server once reconnected. It also supports QR/RFID scanning to identify plants and track products.
* **Offline Sync:**  
  The **offline sync** feature ensures continuous operability in environments where network connectivity is unreliable. It stores data locally in **SQLite** and uses a **custom sync engine** to process updates once connectivity is restored, ensuring that no data is lost.

**3. External Interfaces Layer**

* **POS (Point of Sale) Systems:**  
  Real-time sales data is logged and integrated through secure APIs. This data is crucial for inventory tracking and regulatory reporting.
* **LIMS (Laboratory Information Management Systems):**  
  The system supports seamless integration with **LIMS** for lab test results. When a sample undergoes testing, results are automatically logged into the system and associated with the relevant batch of cannabis.
* **IoT Sensors:**  
  Integration with IoT devices such as environmental sensors helps in tracking conditions for cultivation, providing real-time data such as humidity, temperature, and CO2 levels. This data is stored for regulatory compliance and predictive analysis.

**4. Network Layer**

* **Internet Connectivity:**  
  All components of the system, including **mobile apps**, **Web UI**, and external integrations (POS, LIMS), connect to the **API Gateway** and backend via the **internet**. Secure communications are ensured using **TLS 1.3** encryption.

**5. Core Layer**

* **API Gateway (Kong):**  
  The API Gateway serves as the primary access point for all requests to the backend services. It handles authentication, rate limiting, request routing, and security enforcement. It ensures that only authorized users and services can access the platform's core functions.
* **Identity & Access Management (Keycloak):**  
  Keycloak provides enterprise-grade **OAuth2 authentication**, **role-based access control (RBAC)**, and **multi-factor authentication (MFA)**, ensuring that each user and service has the appropriate level of access to system resources.
* **Core Engine:**  
  The Core Engine manages the **business logic** of the system, coordinating the various modules and their interactions. It ensures the smooth flow of data between the front-end interfaces, backend services, and databases.

**6. Shared Services Layer**

* **Logging (Elasticsearch/ELK Stack):**  
  All actions performed by users (e.g., operators, auditors) are logged and indexed for real-time querying and analysis. This ensures full traceability and accountability for every transaction in the system.
* **Reporting (Metabase):**  
  Provides interactive dashboards and report generation capabilities for regulators and auditors. Custom reports can be scheduled, exported in **CSV/PDF formats**, and shared with stakeholders.
* **Sync Engine:**  
  A crucial component for ensuring **offline-first** functionality. It handles the queuing and synchronization of data when the mobile app is reconnected to the internet, ensuring that all local data entries are eventually pushed to the central database.
* **Notification Service:**  
  Sends notifications and alerts for events that require attention, such as failed synchronizations or approaching regulatory deadlines. It ensures that all relevant stakeholders are kept informed in real time.
* **Analytics:**  
  Aggregates data across modules and provides actionable insights on trends, inefficiencies, and potential issues. It also enables cross-module reporting, linking lab results with farm locations, or tracking inventory movement in real time.
* **Blockchain Commit (Amazon QLDB / Hyperledger):**  
  All critical actions and data changes are committed to an **immutable ledger**, ensuring transparency and traceability. This ledger guarantees data integrity and can be audited at any time to prevent tampering.

**7. Modules Layer**

* **Cannabis, Alcohol, and Other Modules:**  
  Each regulated substance (e.g., cannabis, alcohol) is managed as a separate **module**. These modules handle the specific regulatory workflows for each substance, such as **cultivation**, **testing**, **sales tracking**, and **inventory management**. Each module has its own **database schema**, ensuring **domain separation** for clarity, accountability, and compliance.

**8. Core Database & Blockchain**

* **Core Database (PostgreSQL):**  
  The centralized relational database stores structured data for all regulated substances, audit logs, and user interactions.
* **Blockchain Integration (Amazon QLDB / Hyperledger):**  
  Critical events are hashed using **SHA-256** and committed to a **blockchain ledger** for immutable record-keeping. This ensures that all lifecycle events (e.g., plant creation, lab results, sales) are transparent and cannot be altered.

**Conclusion**

The **High-Level Architecture** enables seamless **regulatory compliance** and **data traceability** through **modular service layers**, **secure identity access management**, and **tamper-proof blockchain logging**. This modular approach not only ensures that the system is **scalable** and **flexible** for future substance integration (alcohol, mushrooms, etc.) but also guarantees **offline operability** in low-connectivity areas, which is essential for regions like **Saint Lucia**. The integration with **POS systems**, **LIMS**, and **IoT sensors** ensures that all external interfaces are securely connected, enabling a truly**comprehensive traceability platform** for all stakeholders involved.