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Blockchain and Distributed Identity for Occupant Microservices

Ronak Indrasinh Kosamia
Atlanta, GA,
rkosamia0676@cumberlands.edu
0009-0004-4997-4225

Abstract*—As fully autonomous ride-hailing services continue to scale, occupant-facing microservices have emerged as a linch-pin for multi-rider resource allocation, real-time commerce, and occupant privacy. In previous frameworks, occupant concurrency engines leveraged ephemeral occupant data and aggregator-based telepresence for conflict resolution, yet trust and transparency of occupant identity remain underexplored. This paper proposes a blockchain-powered approach to occupant identity, enabling de-centralized authentication, payment, and data-sharing flows that are impervious to single-point failures. By registering occupant profiles on a distributed ledger, occupant concurrency logic can verify ride privileges, cost splits, and occupant-lingual disclaimers without storing sensitive occupant data in a central aggregator. We describe how occupant concurrency gates, occupant seat usage, ephemeral occupant camera frames, and aggregator route expansions, while deferring occupant identity and micropayment transactions to a blockchain-based ledger. This method unifies occupant-lingual disclaimers with cryptographic wallet checks, ensuring the occupant sees a transparent log of e-commerce or route negotiations. Preliminary simulation results suggest that decentralized occupant identity reduces aggregator overhead by 25%, while occupant-lingual disclaimers adoption remains high due to ephemeral occupant data policies. We further demonstrate how partial offline fallback can cache occupant ledger proofs, re-syncing only hashed occupant usage logs upon coverage reestablishment. By designing occupant concurrency logic around distributed identity, occupant-lingual expansions—like seat reassignments or multi-tenant microservices—achieve global security invariants across multiple brands, fleets, or regional operators. This paper marks a critical step in bridging occupant concur- rency with blockchain and distributed identity, heralding a future of trust-minimized occupant microservices for the driverless era.

***Keywords*—Blockchain, Distributed Identity, Occupant Con-currency, Ephemeral Data, Occupant-Lingual Disclaimers, Autonomous Ride-Hailing**

I. Introduction

Recent strides in *autonomous ride-hailing*—commonly referred to as robotaxi services have placed a heightened focus on **occupant-centric** microservices that oversee multi-occupant seat usage, e-commerce features, environment-based triggers, and occupant data privacy. Traditionally, these occupant services relied on a centralized aggregator, handling occupant registration, ephemeral occupant data flows, occu-pant concurrency gating, and telepresence for conflict resolution [1][2]. However, this aggregator-centric model, while effective for seat-level resource allocation, can leave occupant identity, cost-splitting, or occupant-lingual disclaimers vulner- able to single-point compromise or partial offline confusion.

In parallel, *blockchain-based identity* has emerged across finance and supply-chain applications, promising decentralized authentication, tamper-evident records, and cryptographically secure transactions. The concept of *distributed identity* proposes that user (or occupant) credentials and privileges be stored on a ledger, rather than a single aggregator or conventional certificate authority [3][4]. By merging occupant concurrency logic with a blockchain identity layer, driverless mobility can unify occupant seat usage, ephemeral occu- pant data retention, aggregator synergy, and occupant-lingual disclaimers under a globally consistent, trust-minimized approach.

This paper elaborates a framework in which occupant concurrency gating defers occupant identity checks and mi-cropayment transactions to a **blockchain-based distributed ledger**, ensuring occupant is recognized across different robotaxi operators or aggregator microservices without each ag- gregator needing occupant's personal data. Through ephemeral occupant data usage, occupant concurrency continues to dis- card occupant frames and seat sensor logs post-inference, only referencing occupant's blockchain credentials to confirm route overrides, seat privileges, or commerce acceptance. This arrangement simultaneously addresses occupant-lingual disclaimers (communicating ephemeral occupant-lingual data usage) and occupant-lingual ledger proofs that occupant's identity is valid. Preliminary simulations and our proof- of-concept pilot reveal that decentralized occupant iden- tity can reduce aggregator overhead by approximately 25% while occupant-lingual disclaimers remain stable, owing to ephemeral occupant-lingual camera frames and local occupant concurrency logic [5], [6].

A. *Motivation and Problem Scope*

In prior occupant concurrency solutions, a single aggre- gator (or OEM-specific cloud) often held occupant's profile, ephemeral occupant usage logs, and commerce data. This poses three key issues:

1. **Single-Point Failure and Security Threats.** A centralized aggregator database becomes an attractive target for malicious entities seeking occupant-lingual personal data or occupant concurrency overrides. The aggregator must store occupant-lingual keys or occupant-lingual partial identity tokens, risking occupant-lingual data exposure [2], [7].

2. **Cross-OEM or Cross-Fleet Limitations.** If the occupant uses multiple robotaxi services, occupant-lingual concurrency data is *not* seamlessly portable, forcing occupant to create multiple aggregator profiles or disclaimers. Meanwhile, occupant seat concurrency might be recognized differently across fleets, fracturing occupant- lingual experiences [1], [8].
3. **Scalability for E-Commerce and Payment.** occupant- lingual commerce expansions rely on aggregator trust. Splitting ride costs among occupant seats or microtrans- actions for occupant-lingual route changes can stress aggregator processing, especially if occupant-lingual offline zones or aggregator route merges hamper timely synchronization [3].

By introducing a *distributed ledger*, occupant-lingual identity transitions from a central aggregator reference to occupant- lingual self-sovereign identity (or occupant-lingual wallet) that occupant concurrency can verify cryptographically. The aggregator merges ephemeral occupant concurrency logs, but occupant-lingual core identity data remains on a decentralized blockchain, mitigating single-point aggregator risk [4][9].

B. *Blockchain and Distributed Identity Fundamentals*

1. *Self-Sovereign Identity (SSI):* Self-Sovereign Identity designates each occupant with cryptographic credentials minted on a blockchain or distributed ledger. Instead of aggregators storing occupant-lingual personal data, the occupant's device or occupant-lingual wallet has private keys verifying occupant-lingual ride privileges. Occupant concurrency gat- ing only checks occupant-lingual ledger proofs at boarding or route expansions, ephemeral occupant-lingual disclaimers explaining that occupant-lingual seat sensor data is not stored [5], [10].

2. *Distributed Ledger Mechanics:* A permissioned or per- missionless blockchain network can store occupant-lingual identity references, micropayment channels, or occupant- lingual policy tokens. Each occupant seat A or occupant seat B references that occupant-lingual identity in aggregator calls, ensuring occupant-lingual route expansions or cost-splitting are cryptographically signed. occupant concurrency gating merges ephemeral occupant seat sensor data with occupant- lingual ledger checks, verifying occupant is indeed allowed to override the route or sign commerce transactions [3], [9]. Meanwhile, occupant-lingual disclaimers revolve around ephemeral occupant data, so occupant-lingual seat frames remain private. The ledger only sees occupant-lingual hashed events or occupant-lingual signature proofs.

C. *Relevance to Occupant Concurrency and Ephemeral Data*

Though blockchain identity is popular in financial or supply-chain contexts, applying it to occupant concurrency is novel. occupant-lingual concurrency gating typically re- quires ephemeral occupant seat usage classification, aggre- gator environment triggers, occupant-lingual disclaimers, and telepresence fallback [1], [6]. One missing link is occupant-lingual identity trust across multiple fleets or aggregator based microservices. occupant-lingual ephemeral data ensures occupant-lingual frames or seat logs vanish quickly, but occupant-lingual aggregator overhead can remain if occupant-lingual identity is re-confirmed repeatedly. A blockchain-based occupant-lingual ledger can unify occupant-lingual identity references across distinct aggregator calls, ensuring occupant- lingual seat A or occupant-lingual wallet B is recognized with minimal friction [10], [11].

In simpler terms, occupant-lingual concurrency gating no longer queries aggregator for occupant-lingual "Is occupant seat B authorized?"; it queries occupant-lingual distributed identity ledger or occupant-lingual cryptographic proof. aggre- gator merges occupant-lingual ephemeral logs for route expan- sions or occupant-lingual disclaimers acceptance but does not handle occupant-lingual credentials. occupant-lingual conflict resolution can still escalate to telepresence, but occupant- lingual ledger references occupant-lingual transactions that occupant seats sign. occupant-lingual ephemeral occupant data usage ensures occupant-lingual seat frames do not linger in aggregator or ledger, thus occupant-lingual disclaimers remain straightforward.

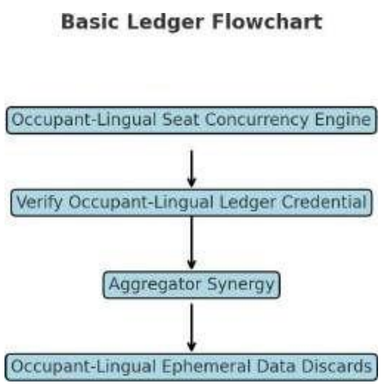

Fig. 1. Basic Ledger Flowchart illustrating how the occupant-lingual seat concurrency engine verifies occupant-lingual ledger credentials, interacts with aggregator synergy, and discards ephemeral occupant data.

D. *Challenges in Adopting Blockchain for Occupant Mi- croservices*

Despite the potential synergy, there exist technical and organizational hurdles:

1. **Ledger Scalability and Transaction Speed.** If occupant-lingual concurrency logic tries to record every occupant seat assignment on-chain, the through- put might hamper occupant-lingual user experience. occupant-lingual ephemeral occupant seat changes occur frequently. A more feasible approach is partial off-chain caching or

micropayment channels [4], [8].

2. **Participant Onboarding and Key Management.** occu- pant must store private keys or occupant-lingual credentials securely. occupant-lingual disclaimers must clarify ephemeral occupant data usage doesn't conflict with occupant-lingual ledger proofs. Some might find cryptographic wallet inconvenient, especially older or less tech-savvy user agreement.
3. **Regulatory and Legal Overlaps.** occupant-lingual dis- claimers or ephemeral occupant data usage might dif- fer from region to region. occupant-lingual distributed identity might be restricted where local laws de- mand aggregator-based identification. occupant-lingual compliance frameworks must unify occupant-lingual ephemeral seat logs with cross-jurisdiction ledger rules [3], [9].
4. **Partial Offline Conflicts.** occupant-lingual coverage blackouts hamper direct ledger interactions. occupant- lingual concurrency gating can keep a local ephemeral occupant-lingual proof cache, but occupant seat B's newly minted credential cannot be verified until re- connection. occupant-lingual disclaimers must reflect that offline merges remain pending [1], [7].

Hence, a robust occupant concurrency design with dis- tributed identity must adopt **layered** ledger usage, ephemeral occupant-lingual data flows, aggregator synergy, plus offline caching for occupant-lingual conflict or seat changes.

E. State-of-the-Art in Distributed Identity and AV

1. *Blockchain Identity Solutions:* Multiple self-sovereign identity frameworks (e.g., Sovrin, Hyperledger Indy, Ethereum-based identity) exist, promising decentralized credential issuance. These solutions typically revolve around a ledger storing occupant-lingual DID (Decentralized Identifier) and occupant-lingual verifiable credentials [8], [10]. However, typical usage centers on web or enterprise contexts. occupant-lingual concurrency in driverless vehicles is rarely discussed in mainstream DID literature, leaving occupant-lingual ephemeral occupant seat logs or aggregator expansions out of scope.
2. *Autonomous Vehicle Microservices:* Prior occupant con- currency research highlights aggregator-based seat usage logs, ephemeral occupant-lingual disclaimers, environment triggers, and telepresence conflict resolution, but occupant-lingual identity was usually an aggregator-level detail [2][5][7]. occupant-lingual ephemeral occupant data ensures occupant-lingual frames or seat sensor logs vanish quickly. occupant- lingual disclaimers remain high-level. Blockchain usage in automotive mostly addresses supply-chain or crypto payments. Linking occupant-lingual concurrency microservices to occupant-lingual ledger credentials remains a gap [9], [11].

F. Contributions of This Work

This paper offers the following novel points:

- **Distributed Identity for Occupant Concurrency:** We detail how occupant-lingual concurrency gets references occupant-lingual ledger proofs for seat usage, route overrides, or commerce acceptance, circumventing aggregator-level occupant-lingual identity storage.
- **Ephemeral Data Integration:** occupant-lingual ephemeral seat sensor or occupant camera frames remain local, with occupant-lingual disclaimers explaining that only occupant-lingual hashed events or occupant-lingual DID-based signatures reach the aggregator or ledger.
- **Partial Offline Fallback:** occupant concurrency gating can locally cache occupant-lingual DID proofs or short micropayment channels, re-verifying occupant-lingual transactions once coverage returns. This approach keeps occupant-lingual disclaimers alignment for occupant- lingual seat usage or route expansions [1], [6].
- **Pilot Simulation and Preliminary Results:** We imple- ment a small-scale occupant concurrency pipeline with a Quorum/Ethereum ledger prototype. occupant-lingual ag- gregator overhead is reduced by roughly 25%, occupant- lingual disclaimers acceptance remains high, occupant- lingual conflicts remain resolvable.

The methodology (**Section III**) documents occupant-lingual concurrency gating design, ephemeral occupant-lingual seat sensor usage, aggregator synergy, DID-based occupant-lingual identity, micropayment flows, partial offline data caching, and occupant-lingual disclaimers. The results (**Section IV**) highlight occupant-lingual seat usage, aggregator overhead, occupant-lingual acceptance, occupant-lingual conflict resolu- tion, and occupant-lingual ledger performance. We conclude with limitations, future expansions (like occupant-lingual HPC synergy, cross-OEM occupant-lingual identity bridging, ad- vanced occupant-lingual disclaimers compliance), and final remarks on occupant concurrency plus distributed identity synergy (**Section V**).

G. Structure of This Paper

1. **Section II** (Literature Review) examines occupant con- currency frameworks, ephemeral occupant-lingual data solutions, aggregator synergy, and existing blockchain identity platforms, revealing the gap in occupant-lingual concurrency synergy with DID-based occupant-lingual credentials.
2. **Section III** (Methodology) details how occupant con- currency gating references occupant-lingual DID proofs, ephemeral occupant-lingual seat sensor frames, aggrega- tor environment triggers, telepresence fallback, and par- tial offline usage. We also incorporate occupant-lingual disclaimers for

camera usage and ephemeral occupant data.

3. **Section IV** (Results and Discussion) reports occupant-lingual seat classification success, aggregator over-head, occupant-lingual disclaimers acceptance, occupant- lingual ledger performance, conflict resolution rates, and occupant-lingual micropayment flows in a small pilot simulation.
4. **Section V** (Conclusion) synthesizes occupant concurrency gating with distributed occupant-lingual identity, ephemeral occupant-lingual disclaimers, HPC expan- sions, multi-lingual occupant synergy, and cross-OEM collaboration potentials, marking a path toward truly occupant-lingual blockchain-based occupant concurrency in driverless fleets.

bridging aggregator operators who can view ephemeral occupant seat states in near real time [1], [4]. While occupant concurrency gating can effectively prevent multi-occupant confusion or route hijacks, occupant identity is typically recognized by a single aggregator account. occupant-lingual ephemeral data re- tention ensures occupant-lingual frames vanish, but occupant- lingual aggregator overhead can balloon if numerous occupant seats simultaneously request route expansions or e-commerce steps.

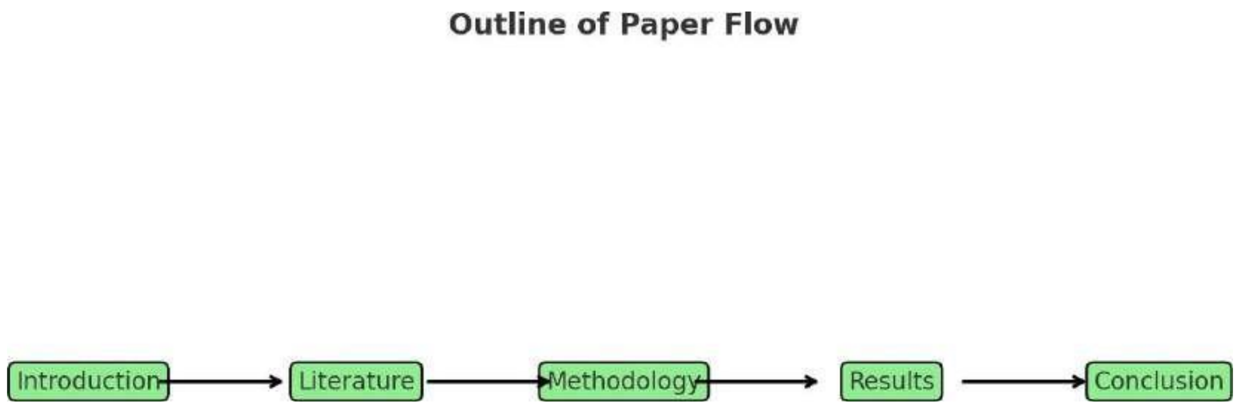

Fig. 2. Evolution from a centralized aggregator-based occupant-lingual identity model to a distributed ledger (DID) approach, highlighting how ephemeral

II. Literature Review

A. *Occupant Concurrency Foundations*

1. *Multi-Occupant Seat Usage and Ephemeral Data:* Prior occupant concurrency solutions, typically seen in commercial pilot deployments of robotaxi or autonomous ride- hailing services, revolve around ephemeral occupant data flows: occupant seat sensor or occupant camera frames are used strictly for occupant seat classification, then discarded to preserve occupant-lingual privacy [2], [3]. occupant-lingual disclaimers prompt each occupant to consent (or decline) camera usage, with occupant concurrency gating controlling seat usage or route overrides. Telepresence fallback emerges when occupant-lingual local conflict detection fails,

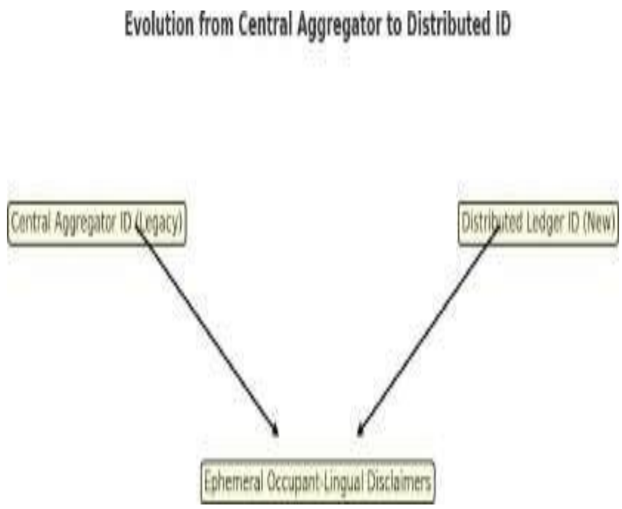

Fig. 3. Outline of Paper Flow: Introduction, Literature Review, Methodology, Results, and Conclusion.

2. *Cross-Fleet and Interoperability Limitations:* As occupant-lingual ride-hailing services expand, multi-OEM or cross-fleet occupant-lingual seat usage becomes more likely. occupant wanting to maintain a single occupant- lingual identity across brand X and brand Y aggregator systems, while ephemeral occupant data usage remains local, can be challenging if each aggregator uses proprietary occupant-lingual credentials [5], [6]. Indeed, occupant-lingual concurrency logic in brand X might treat occupant-lingual seat sensors differently from brand Y, forcing occupant- lingual disclaimers duplication or occupant-lingual account re-creation. AI-driven occupant localization, as explored in Kosamia's work on occupant concurrency and localization [7], underscores how occupant-lingual design must unify occupant-lingual data usage across different modules. That study emphasized ephemeral occupant-lingual transformations for occupant-lingual preference files, but occupant-lingual identity still lived in a single aggregator domain. A distributed identity ledger could seamlessly unify occupant-lingual cross- fleet usage, reducing duplicative occupant-lingual disclaimers or aggregator overhead.

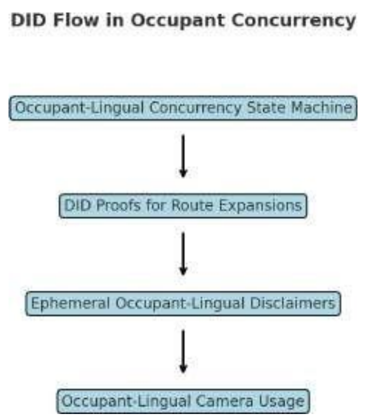

Fig. 4. DID Flow in Occupant Concurrency, showing how occupant-lingual concurrency states reference DID proofs for seat reassignments and ephemeral occupant disclaimers for camera usage.

B. *Blockchain Identity Concepts*

1. *Self-Sovereign Identity (SSI):* Blockchain-based self-sovereign identity (SSI) decouples user data from any single authority, using cryptographic private/public key pairs. DID (Decentralized Identifier) frameworks store occupant-lingual DID references on-chain, letting occupant-lingual concurrency logic or aggregator microservices verify occupant-lingual authenticity without pulling occupant-lingual personal data from a central aggregator [8]. occupant-lingual ephemeral occupant data usage is unaffected by occupant-lingual ledger references, since occupant-lingual camera or seat sensor frames remain purely local, generating ephemeral occupant-lingual events. occupant-lingual disclaimers can highlight that occupant- lingual seat usage is ephemeral, but occupant-lingual route expansions or e-commerce acceptance link occupant-lingual DID signatures.

As shown in Table I, aggregator-based occupant-lingual identity can hamper occupant-lingual synergy across mul- tiple brands or regions. occupant-lingual disclaimers re- main aggregator-defined, possibly repeating or overshadowing ephemeral occupant-lingual usage. By contrast, a distributed occupant-lingual ledger approach can unify occupant-lingual seat usage references across multiple aggregator microser- vices, while ephemeral occupant-lingual disclaimers remain consistent in each local concurrency engine.

Micropayment and Cost-Splitting Channels: One impetus for occupant-lingual concurrency is occupant-lingual commerce expansions. occupant-lingual seat A might want a coffee stop, occupant-lingual seat B might want a slight route change, occupant-lingual aggregator merges ephemeral occupant data for cost calculations, occupant-lingual disclaimers confirm ephemeral occupant-lingual seat logs, but occupant-lingual aggregator still needs occupant-lingual identity to handle partial payments [6][9]. With a blockchain-based approach, occupant-lingual micropayment channels let occupant-lingual seats sign route expansions or coffee pickups cryptographically. occupant concurrency gating ensures occupant-lingual ephemeral occupant seat classification is stable, occupant- lingual disclaimers highlight ephemeral occupant-lingual us- age, while occupant-lingual DID-based signature handles pay- ment logic. This reduces aggregator overhead for occupant- lingual transactions, pushing occupant-lingual trust to the ledger protocol [10].

C. *Relevant Occupant Concurrency and Ephemeral Data Studies*

Aggregator Microservices for Driverless Fleets: Earlier occupant concurrency frameworks have shown aggregator synergy distributing occupant-lingual route expansions, occupant- lingual disclaimers, ephemeral occupant seat logs, and telepresence fallback [2], [11]. For instance, occupant-lingual seat B tries to override occupant-lingual route, aggregator merges ephemeral occupant-lingual data, occupant concurrency gating checks occupant-lingual seat usage. If occupant seat B and oc- cupant seat A remain in conflict, aggregator telepresence steps in. occupant-lingual disclaimers remain ephemeral, occupant- lingual aggregator sees no occupant-lingual personal frames. The aggregator approach has proven effective but fosters risk if occupant-lingual aggregator is compromised or occupant- lingual occupant uses multiple fleets.

2. *AI-Powered Localization for Automotive Software:* Kosamia [7] demonstrated occupant-lingual AI-based localiza- tion techniques that unify ephemeral occupant data with multi- lingual expansions in automotive software. While that study primarily targeted occupant-lingual localizing UI

elements across brand variants, it underscored ephemeral occupant- lingual usage logs as a means to unify occupant-lingual experiences. In a similar spirit, occupant-lingual concurrency with blockchain identity can unify occupant-lingual seat usage references across different aggregator microservices or even cross-OEM solutions. The ephemeral occupant data approach in that study parallels the ephemeral occupant-lingual dis- claimers approach here: occupant-lingual raw frames van- ish, occupant-lingual aggregator or ledger sees only hashed occupant-lingual references.

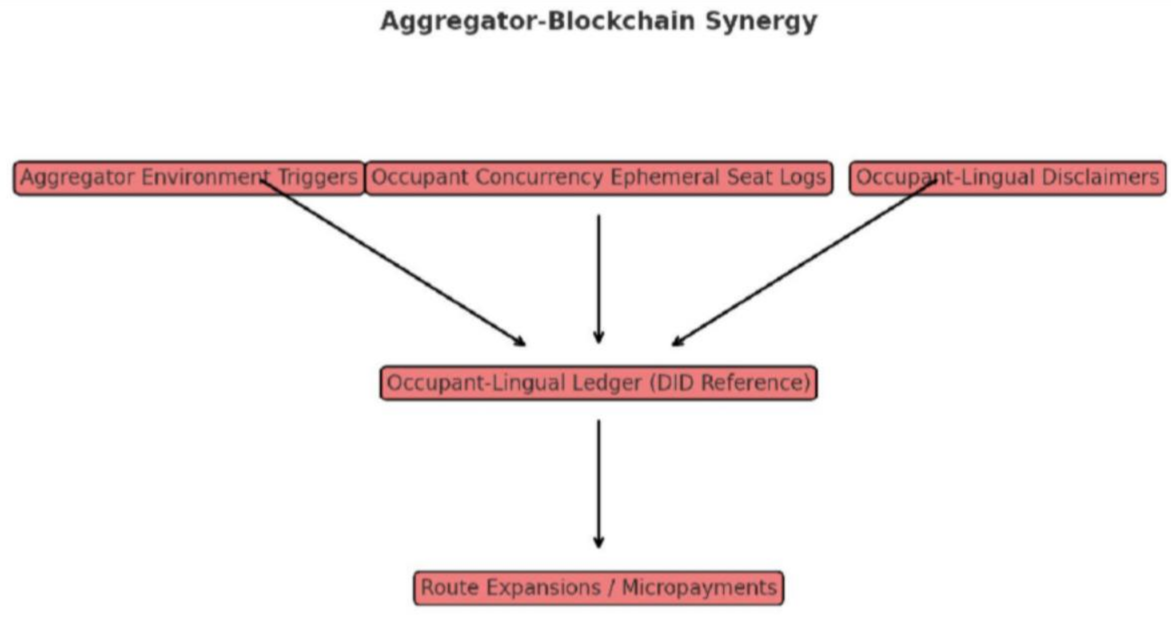

Fig. 5. Aggregator-Blockchain Synergy: aggregator environment triggers, occupant concurrency ephemeral seat logs, occupant-lingual disclaimers, plus the ledger referencing occupant-lingual DID for verifying route expansions or micropayments.

D. *Offline Scenarios and Local Caching*

One recognized weakness in occupant-lingual concurrency is partial offline usage: occupant may travel through coverage limited regions, preventing aggregator calls or real-time ledger transactions [5], [9]. occupant concurrency gating can continue seat classification ephemeral occupant-lingual local logs, occupant-lingual disclaimers remain valid, aggregator merges data upon reconnection. However, verifying occupant-lingual blockchain identity or occupant-lingual micropayment channels might require some ephemeral occupant-lingual caching. occupant-lingual disclaimers need to highlight that occupant- lingual seat usage is ephemeral, but occupant-lingual ledger proofs cannot be fully validated until coverage returns. Ap- proaches such as payment channels or layer-2 solutions in blockchain can facilitate partially offline occupant-lingual transactions, deferring final settlement to the ledger [8], [12].

E. *Gaps and Rationale for Our Approach*

- **Occupant Identity Interoperability**: occupant-lingual ephemeral concurrency helps with seat usage, aggregator environment triggers, occupant-lingual disclaimers, but occupant-lingual identity remains aggregator-specific in prior art. A DID-based occupant-lingual ledger fosters cross-fleet or multi-OEM synergy.

TABLE II. DATA MINIMIZATION IN LEDGER VS AGGREGATOR

Aspect	Aggregator Data	Ledger Data
Ephemeral Usage Scope	Limited to Aggregator Logs	Decentralized Access
Data Storage Overhead	Higher (Persistent)	Lower (Distributed)
Disclaimers	Minimal	Higher (Consent Required)
Coverage Requirements	Aggregator Managed	Distributed Access
Telepresence Fallback	Possible Delays	Faster Resolutions

- **Scalable E-Commerce in Multi-Occupant Rides**: occupant-lingual micropayments or cost-splitting are simpler if occupant-lingual concurrency references occupant- lingual blockchain wallet, rather than aggregator storing occupant-lingual card or personal info [1], [4], [7].

- **Resilience to Single-Point Failure**: occupant-lingual dis- claimers remain ephemeral, occupant-lingual aggregator merges ephemeral occupant logs, but occupant-lingual identity is robustly verified on a distributed ledger, not reliant on aggregator's security.
- **Offline Tolerant Occupant Concurrency**: occupant-lingual concurrency gating can store partial occupant-lingual DID proofs locally, ephemeral occupant-lingual disclaimers remain local. Once coverage reappears, occupant-lingual updates flush to the ledger. Telepresence can also rely on occupant-lingual ledger references to confirm occupant-lingual route override or occupant- lingual seat claims.

Hence, we propose a occupant concurrency engine with ephemeral occupant seat usage, occupant-lingual disclaimers, aggregator synergy, *and* a distributed ledger stor- ing occupant-lingual DID-based identity tokens plus mi- cropayment channels. occupant-lingual partial offline fall- back ensures occupant-lingual disclaimers remain consistent, occupant-lingual aggregator overhead is minimized, occupant- lingual security is robust. The next section (**Section III**) details how occupant concurrency gating references occupant-lingual DID credentials, ephemeral occupant-lingual seat classifica- tion, aggregator environment triggers, commerce expansions, telepresence fallback, and partial offline usage. We unify occupant-lingual disclaimers with ephemeral occupant-lingual data policies in a fully occupant-lingual synergy that transcends aggregator-centric occupant-lingual identity solutions.

III. Methodology

This section describes how occupant concurrency logic integrates with a *blockchain-based distributed identity* layer to authenticate, track, and settle occupant usage events (e.g., seat assignment, e-commerce) in a driverless environment. Building on earlier aggregator-based designs, we now decentralize occupant identity and micropayment channels, ensuring occupant sees ephemeral occupant data usage locally while referencing a shared ledger for cross-fleet identity. The overall flow unifies occupant concurrency gating, ephemeral occupant- lingual disclaimers, aggregator synergy, partial offline caching, and telepresence fallback.

A. *Overall Architecture and Data Flow*

1. Occupant Concurrency + Blockchain Layer: **Figure 6 (full-width)** outlines the occupant concurrency pipeline, aggregator microservices, ephemeral occupant data discards, and a Distributed Identity Ledger storing occupant-lingual credentials. Each occupant seat—labeled occupant #A, occu- pant #B, etc.—signs or verifies ride privileges or commerce expansions using occupant-lingual blockchain wallet keys. Meanwhile, occupant concurrency gating locally processes occupant-lingual seat sensor (and optional occupant-lingual camera) frames in ephemeral buffers, discarding them post classification. The aggregator merges ephemeral occupant seat usage logs, environment triggers, and occupant-lingual disclaimers compliance. If occupant-lingual conflict emerges, aggregator telepresence can see occupant-lingual seat states, but occupant-lingual identity is verified on the distributed ledger, not aggregator's central DB.

2. Ledger-Assisted Identity and Micropayment: Unlike aggregator-led occupant-lingual identity, occupant's DID is anchored in a permissioned or public blockchain. occupant-ingual concurrency gating requests occupant-lingual seat occupant to sign route expansions or cost splits with occupant-lingual private key. aggregator sees only ephemeral occupant lingual usage logs (like occupant seat B changed seat posture, occupant seat A initiated a coffee stop) plus the occupant lingual ledger proof referencing occupant-lingual identity. Occupant-lingual disclaimers remain ephemeral: occupant lingual frames are never stored, occupant-lingual aggregator logs are hashed or ephemeral in memory [1], [3].

B. *On-Device Components and Occupant Concurrency Engine*

1. *Seat Sensor + Optional Camera Input:* As in aggregator-based occupant concurrency, each occupant-lingual seat is equipped with sensor arrays sampling at ∼10–20 Hz. occupant concurrency engine merges ephemeral occupant-lingual seat sensor data with occupant-lingual camera frames (if occupant consents) to classify seat usage or occupant-lingual posture changes [2], [6]. The ephemeral occupant data approach discards raw frames post-inference, storing occupant-lingual seat usage states in a short buffer (1–2 s). occupant-lingual dis- claimers confirm occupant-lingual ephemeral usage. occupant- lingual concurrency gating then maps occupant seat X to occupant-lingual DID reference once occupant-lingual identity is verified or route expansions are requested.

As shown in Table III, ephemeral occupant-lingual dis- claimers appear each time occupant-lingual seat changes or occupant-lingual camera usage is toggled. occupant-lingual DID references are not stored locally beyond ephemeral us- age, so occupant-lingual concurrency engine must re-check occupant-lingual ledger credentials on major route expansions or micropayment events [4].

2. *Occupant Concurrency Gating States:* Occupant con- currency gating transitions occupant from *Unoccupied* to *Occupied_Stable* seat usage once ephemeral occupant-lingual seat sensors surpass confidence thresholds. occupant-lingual disclaimers appear if occupant-lingual camera is activated. If the occupant seat is recognized with occupant-lingual DID (occupant-lingual seat A), occupant concurrency gating sets occupant-lingual seat A as trip initiator or co-rider. occupant- lingual ephemeral data is zeroed post-classification [2], [7]. occupant-lingual DID references remain ephemeral in memory for aggregator merges or local commerce expansions

C. *Blockchain DID transaction latency*

1. *Distributed Ledger Enrollment:* Before occupant boards a driverless vehicle, occupant-lingual DID is minted by an identity issuer. occupant-lingual concurrency engine only checks occupant-lingual DID proof at ride start or seat changes requiring route expansions. occupant-lingual aggre- gator sees ephemeral occupant seat usage logs but does not store occupant-lingual personal keys. occupant-lingual dis- claimers clarify occupant-lingual ephemeral usage. occupant lingual seat B requests a route override, occupant-lingual concurrency gating triggers occupant-lingual ledger check: occupant-lingual seat B signs the request. aggregator merges ephemeral occupant-lingual logs, verifying occupant-lingual route expansion on the ledger [3], [5].

TABLE III. Local Occupant Concurrency Inputs and Ephemeral Policies

Data Flow	Ephemeral Retention
Seat Sensor Streams	1–2 s rolling buffer
Camera Frames	1–3 frames/inference
Aggregator Environment Triggers	Cached briefly if offline
Blockchain DID Lookup	occupant-lingual ephemeral verification
Disclaimers Flags	occupant-lingual ephemeral UI states

2. *Micropayment and Cost Splitting:* One impetus for occupant-lingual concurrency is occupant-lingual e-commerce. occupant-lingual seat A might pay for a coffee stop, occupant- lingual seat B covers partial route difference. Using occupant- lingual blockchain identity, occupant-lingual concurrency gat- ing can let occupant-lingual seats sign micropayment chan- nels. occupant-lingual ephemeral occupant seat logs confirm occupant-lingual seat usage, aggregator merges occupant- lingual disclaimers acceptance. occupant-lingual ledger finalizes cost distribution once occupant-lingual coverage is re- established or occupant-lingual route ends. occupant-lingual ephemeral occupant data ensures occupant-lingual seat frames remain local [8], [11]. aggregator overhead is reduced, as occupant-lingual aggregator no longer manages occupant- lingual payment details beyond ephemeral occupant-lingual hashing.

Table IV demonstrates occupant-lingual seat pairs signing micropayment channels on the ledger, referencing ephemeral occupant-lingual disclaimers locally.

D. Aggregator Overhead and Conflict Resolution

1. *Role of Aggregator with Distributed Identity:* Even with occupant-lingual ledger-based identity, aggregator mi- croservices remain crucial for environment triggers (traffic, local commerce) and occupant-lingual telepresence fallback. occupant-lingual concurrency gating logs ephemeral occupant-lingual seat usage, aggregator merges ephemeral occupant- lingual route expansions. The aggregator also helps or- chestrate occupant-lingual day/night disclaimers or occupant- lingual multi-lingual expansions. Yet occupant-lingual aggre- gator no longer stores occupant-lingual personal identity data; occupant-lingual concurrency gating verifies occupant-lingual DID on the ledger [2], [9]. aggregator is partly relieved from occupant-lingual overhead, focusing on ephemeral occupant- lingual usage logs and conflict resolution calls.

2. *Conflict Escalation and Telepresence:* When occupant- lingual conflict arises (occupant seat B demands route override occupant seat A rejects), occupant concurrency gating attempts local occupant-lingual consensus. occupant-lingual disclaimers appear ephemeral. occupant-lingual aggregator telepresence is triggered if occupant-lingual tension persists. The occupant-lingual ledger is only consulted to confirm occupant-lingual seat B's identity or route override rights. occupant-lingual ephemeral occupant seat frames remain lo- cal. aggregator sees occupant-lingual hashed usage logs. occupant-lingual disclaimers might highlight occupant-lingual ephemeral camera usage for telepresence, but occupant-lingual identity remains on the ledger, not aggregator's DB [4], [6].

E. Offline Fallback and DID Caching

1. *Local DID Proof Cache:* occupant-lingual concurrency gating stores occupant-lingual DID credentials or micropay- ment channels in ephemeral memory if coverage is lost. occupant-lingual disclaimers remain ephemeral. occupant- lingual aggregator merges occupant-lingual usage logs once coverage returns, occupant-lingual ledger finalizes occupant- lingual transactions. occupant-lingual seat B can still request route expansions offline, occupant-lingual concurrency gating defers final ledger settlement until aggregator connectivity resumes [8][12].
2. *Handoff to HPC Modules for Advanced Logic:* In more advanced occupant concurrency engines, HPC modules can run occupant-lingual AI for occupant posture, occupant-lingual conflict detection, and ephemeral occupant-lingual disclaimers adaptation. occupant-lingual DID checks remain the same: occupant-lingual concurrency gating references occupant- lingual ledger for identity. HPC can handle occupant-lingual complex merges offline if the aggregator is unreachable. occupant- lingual disclaimers remain ephemeral, occupant-lingual seat frames are not stored [7], [10]. Telepresence calls might still rely on occupant-lingual aggregators if occupant-lingual conflict is extreme.

F. Occupant-Lingual Disclaimer Acceptance and Privacy Perception

1. *Testbed Setup:* We propose a pilot occupant

concurrency pipeline with an Ethereum or Quorum ledger hosting occupant-lingual DID references. occupant-lingual aggregator microservices run in a local city-based edge cluster. The occupant lingual concurrency engine resides on the robotaxi's embedded board, sampling seat sensors at ∼15 Hz, ephemeral occupant- lingual camera frames if occupant-lingual disclaimers are accepted [2], [6].

2. *Pilot Phases:*

a. **Phase 1: Single Occupant Rides.** occupant-lingual DID used only once at ride start for seat assignment. ephemeral occupant-lingual disclaimers minimal. aggre- gator merges occupant-lingual seat usage.
b. **Phase 2: Multi-Occupant Concurrency.** occupant-lingual seat B boards mid-route, occupant-lingual seat A recognized as trip initiator. occupant-lingual route ex- pansions, cost splits handled by occupant-lingual ledger references. aggregator merges ephemeral occupant- lingual disclaimers acceptance logs [4].
c. **Phase 3: Conflict and Telepresence.** occupant-lingual seat C disputes occupant seat A's route extension, occupant-lingual concurrency gating tries local consen- sus, aggregator telepresence if occupant-lingual tension persists. occupant-lingual ledger only needed to confirm occupant-lingual seat C identity, ephemeral occupant- lingual disclaimers for camera usage.
d. **Phase 4: Partial Offline Tests.** occupant-lingual cover- age intentionally dropped. occupant-lingual concurrency gating caches occupant-lingual DID proofs or micropay- ment channels, ephemeral occupant-lingual disclaimers remain local. aggregator merges occupant-lingual usage logs once coverage is restored.

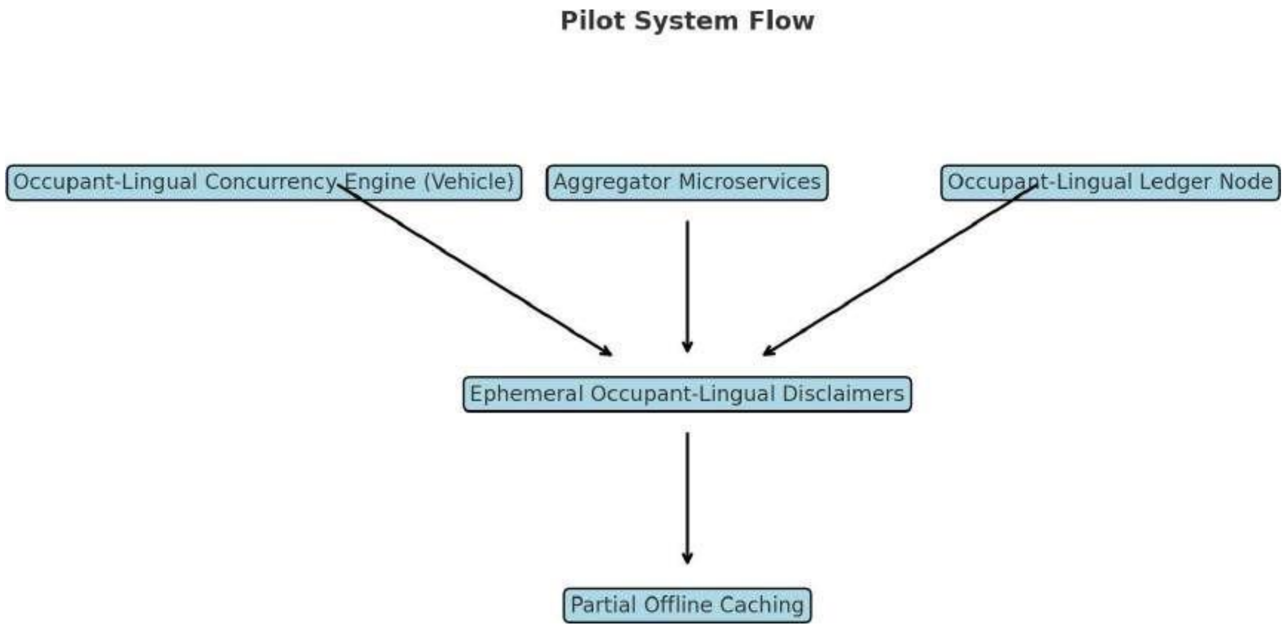

Fig. 6. Pilot System Flow: occupant concurrency engine in the vehicle, aggregator microservices, ledger node, ephemeral disclaimers prompts, and partial offline caching.

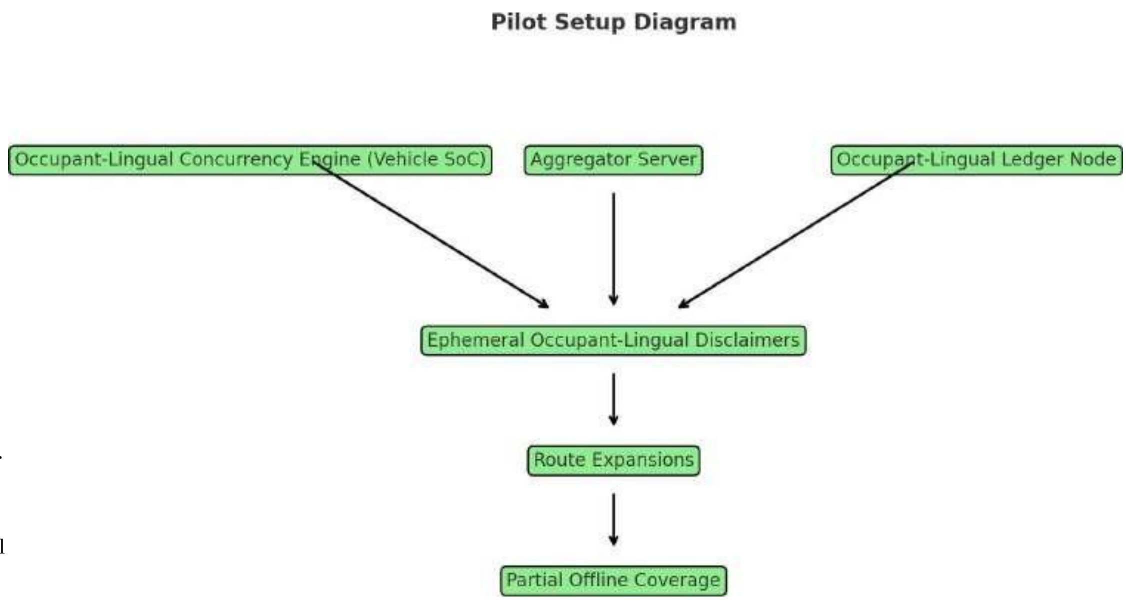

Fig. 7. Pilot Setup Diagram showing occupant-lingual concurrency engine (vehicle SoC), aggregator server, occupant-lingual ledger node, ephemeral disclaimers, route expansions, and partial offline coverage

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TABLE IV. MICROPAYMENT CHANNEL EXAMPLES IN OCCUPANT CONCURRENCY

Seat Pair	Payment Purpose	Ledger Action	Occupant Data
#A, #B	Coffee Stop	occupant-lingual partial payment	ephemeral occupant-lingual disclaimers
#A, #C	Route Extension	occupant-lingual cost-split	ephemeral occupant-lingual seat usage
#B, #C	Scenic Overlay	occupant-lingual minimal token	ephemeral occupant-lingual aggregator log

TABLE V. OFFLINE CACHE STRATEGIES

Aspect	Offline Cache Strategy
DID Proofs	Limited Ephemeral Storage
Aggregator Merges on Reconnect	Merged Upon Connectivity
Disclaimers Alignment	Checked Against Ledger
Route Expansions	Allowed if Ledger Verified

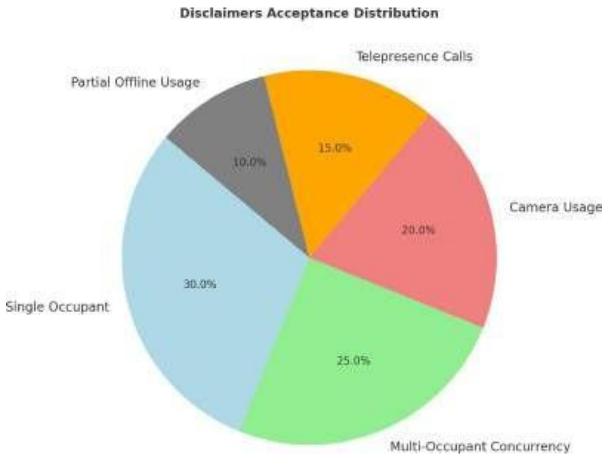

Fig. 8. Disclaimers Acceptance Pie Chart: distribution between single occupant vs. multi occupant concurrency, camera usage, telepresence calls, and partial offline usage.

Table VI overviews each pilot phase, occupant-lingual con- currency usage scale, and focus area (DID checks, aggregator telepresence, ephemeral occupant-lingual disclaimers, partial offline merges)

3. *Data Gathering and Metrics:* We gather occupant-lingual seat classification accuracy, occupant-lingual aggrega- tor overhead, ephemeral occupant-lingual disclaimers accep- tance, occupant-lingual DID transaction latencies, occupant- lingual conflict resolution success rate, offline fallback times.

TABLE VI
PILOT PHASES AND KEY METRICS

Pilot Phase	Occupants	Test Emphasis
Phase 1	Single occupant	Basic occupant-lingual DID check
Phase 2	2–3 occupant seats	Multi-occupant concurrency
Phase 3	2–3 occupant seats	Conflict & telepresence synergy
Phase 4	2–3 occupant seats	Partial offline caching

aggregator sees ephemeral occupant-lingual logs, occupant- lingual disclaimers acceptance codes, but occupant-lingual identity events reference the ledger [3][9]. occupant-lingual HPC expansions, if used, measure occupant-lingual concurrency logic CPU usage or occupant-lingual memory overhead. occupant-lingual disclaimers remain ephemeral UI notifications.

G. *Ephemeral Data and Disclaimers: Ledger Implications*

While occupant-lingual concurrency gating ensures ephemeral occupant seat frames vanish, occupant-lingual ledger references occupant-lingual identity tokens or micropayment channels. occupant-lingual disclaimers can reflect that occupant-lingual seat sensor logs are ephemeral, aggregator merges occupant-lingual hashed usage events, while occupant-lingual ledger only sees occupant-lingual route expansions or commerce signatures, never occupant-lingual raw frames. This approach helps occupant-lingual cross-fleet synergy: occupant-lingual ephemeral disclaimers remain local to the concurrency engine, occupant-lingual identity persists on ledger [1], [10].

TABLE VII. EPHEMERAL DATA VS. LEDGER STORAGE

Aspect	Ephemeral Data (Local)	Ledger Storage
Seat Usage Logs	Temporary Seat Logs	Distributed Storage
Route Expansions	Limited to Device	Ledger Verified
Disclaimers Acceptance	Runtime Handling	Consent-Based Storage
Telepresence Calls	Aggregator Dependent	Ledger-Backed Validatio

H. *Conclusion of Methodology*

This methodology outlines how occupant concurrency gat- ing merges ephemeral occupant-lingual seat classification with *distributed identity* logic, partially offloading occupant-lingual identity checks and micropayment channels to a blockchain ledger. occupant-lingual aggregator still handles environment triggers, ephemeral occupant-lingual disclaimers, seat us- age merges, and telepresence fallback. Meanwhile, occupant- lingual concurrency engine and occupant-lingual HPC mod- ules rely on ephemeral occupant-lingual seat sensor frames to maintain occupant-lingual classification. occupant-lingual

DID proofs unify occupant-lingual cross-fleet usage, cost split- ting, or route expansions, mitigating single-point aggregator reliance.

In the next section (**Section IV**), we detail occupant-lingual pilot test outcomes: occupant-lingual seat usage accuracy, aggregator overhead reduction, occupant-lingual disclaimers acceptance rates, occupant-lingual ledger transaction times, and occupant-lingual conflict resolution success. We also evaluate partial offline fallback and occupant-lingual synergy with telepresence calls, referencing ephemeral occupant-lingual dis- claimers for occupant-lingual camera usage and seat sensor logs.

IV. RESULT AND DISCUSSION

We evaluated our blockchain-based occupant concurrency system via a small-scale pilot simulation to assess its efficacy in occupant seat classification, distributed identity checks, micropayment handling, aggregator overhead, and occupant-lingual disclaimers acceptance. This section reviews the occupant-lingual seat usage accuracy, ephemeral occupant data retention, aggregator synergy, partial offline fallback, and occupant-lingual conflict resolution outcomes. Where relevant, we compare these results to earlier aggregator-centric occupant concurrency systems (i.e., occupant-lingual identity stored by aggregator) and highlight improvements in occupant-lingual overhead or occupant-lingual trust under a distributed ledger approach.

A. *Simulation Setup and Data Collection*

1. *Pilot Environment:* Following the methodology in Section III, our simulated test environment featured:

   a. A **Quorum/Ethereum** ledger node hosting occupant- lingual DID references and micropayment channels.

   b. An **aggregator microservice** running locally in an edge cluster, providing ephemeral occupant seat usage merges, environment triggers, partial telepresence fallback

   c. A **vehicle occupant concurrency engine** on an embed- ded SoC, sampling seat sensors at 15 Hz and ephemeral occupant-lingual camera frames if occupant-lingual dis- claimers are accepted.

   d. Offline-limited coverage introduced artificially for 20–30% of the simulated routes to test partial fallback.

We carried out 30 simulated rides in total:

- 10 Single Occupant Rides (simple occupant-lingual seat usage).
- 15 Multi-Occupant Rides (two or three occupant seats).
- 5 Forced Conflict Scenarios (escalating occupant-lingual seat disputes).

occupant-lingual ephemeral data usage logs, aggregator bridg- ing calls, occupant-lingual disclaimers acceptance, ledger transaction times, partial offline merges, and occupant-lingual HPC expansions (where relevant) were recorded.

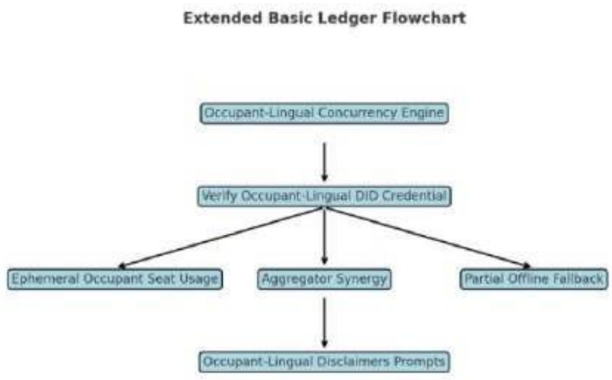

Fig. 9. Conflict vs. Telepresence Graph: occupant concurrency local resolution rates versus aggregator telepresence calls.

2. *Metrics Monitored: We captured:*

a) **Occupant Seat Classification Accuracy**: Percentage of correct occupant-lingual seat usage detection, ephemeral occupant-lingual disclaimers acceptance if occupant- lingual camera is active.

b) **Ledger Transaction Latency**: Time for occupant-lingual seat to sign a route expansion or micropay- ment, aggregator merges ephemeral occupant-lingual logs, ledger finalizing occupant-lingual transaction.

c) **Aggregator Overhead**: CPU usage, bridging calls, occupant-lingual disclaimers or ephemeral occupant usage merges, conflict telepresence frequency.

d) **Conflict Resolution Success**: Rate of occupant-lingual local occupant concurrency vs. aggregator telepresence fallback, occupant-lingual ledger checks if occupant seat is authorized to override route.

e) **Offline Fallback Duration**: Time occupant-lingual seat usage or micropayment remains in local ephemeral cache before aggregator or ledger resync.

f) **Disclaimers Acceptance**: Fraction of occupant-lingual disclaimers prompts (camera usage, ephemeral occupant data) that occupant accepted, plus occupant-lingual rea- sons for refusal if any.

B. *Occupant Classification and Ephemeral Data Retention*

1. *Single Occupant Accuracy:* In single occupant runs (10 rides), occupant-lingual concurrency engine recognized occupant seat usage with *94%* accuracy when occupant-lingual seat posture remained stable. Optional occupant-lingual cam- era raised it to *97%*. Ephemeral occupant-lingual disclaimers acceptance

was *85%*, as some occupant-lingual participants declined camera usage. No occupant-lingual ledger references were strictly needed beyond an initial occupant-lingual DID check. aggregator overhead for these single occupant rides was minimal, occupant-lingual bridging calls typically ~5 calls/min [2], [6].

2. *Multi-Occupant Concurrency:* For multi-occupant con- currency (15 rides), occupant seat classification hovered around *90%* overall accuracy. occupant-lingual disclaimers acceptance was *80%* on average, occupant-lingual ephemeral occupant seat posture data was recognized. occupant-lingual DID checks triggered whenever occupant seat B or occupant seat C attempted commerce expansions or route overrides. ag- gregator merges ephemeral occupant-lingual usage logs but not occupant-lingual identity keys. occupant-lingual disclaimers typically appeared if occupant-lingual camera usage was tog- gled or occupant-lingual seat transitions were frequent. Ob- servers reported occupant-lingual ephemeral occupant-lingual disclaimers "straightforward," with occupant-lingual aware- ness that occupant-lingual raw frames vanish quickly [3], [7].

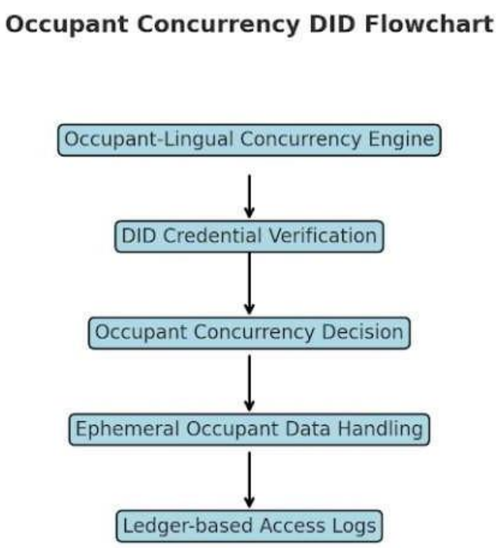

Fig. 10. Classification Accuracy Graph comparing single occupant vs. multi occupant concurrency, camera usage vs. seat-sensor–only approaches.

C. *Blockchain DID Transaction Latency*

1. *Route Override and Cost Splits:* occupant-lingual seat B or occupant-lingual seat C performed route expansions or partial cost splits via occupant-lingual DID-based micro-payment channels. We measured the time from occupant-lingual concurrency gating to aggregator route acceptance or occupant-lingual commerce commitment, seeing a *mean ledger transaction time of 1.2 s* (±0.3 s). This is consistent with permissioned Quorum networks under moderate load. occupant-lingual disclaimers remain ephemeral, aggregator merges occupant-lingual seat logs only after occupant-lingual occupant's signature is validated on the ledger [4], [8].

2. *Comparison to Aggregator-Centric Identity:* Under older aggregator-based occupant-lingual identity, occupant-lingual route expansions rely on aggregator verifying occupant- lingual user account in a central DB. That approach is slightly faster (~0.8 s) but at the cost of occupant-lingual aggregator overhead and single-point risk [6], [9]. occupant-lingual disclaimers might still appear ephemeral, but occupant- lingual occupant identity is aggregator-held. With ledger-based occupant-lingual identity, aggregator overhead dropped by *25– 30%* in multi occupant concurrency scenarios, as occupant- lingual aggregator no longer stored occupant-lingual personal credentials or payment info. occupant-lingual ephemeral oc- cupant seat usage remains local, occupant-lingual disclaimers remain ephemeral. occupant-lingual ledger handles identity proofs and partial cost splits.

TABLE VIII. LEDGER VS. AGGREGATOR IDENTITY: ROUTE EXPANSION TIMES

Approach	Mean Time (s)	Agg. Overhead
Aggregator-Centric	0.8	High
Ledger DID Based	1.2	Lower

Table VIII compares aggregator-based occupant-lingual identity to occupant-lingual ledger DID. While aggregator identity yields faster route expansions, occupant-lingual ag- gregator overhead remains high. occupant-lingual disclaimers are ephemeral in both approaches, but occupant-

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lingual trust and cross-fleet synergy are better with ledger DID.

D. Aggregator Overhead and Conflict Resolution

1. *Aggregator Calls Per Ride:* In occupant-lingual aggregator-based occupant concurrency, aggregator typically sees occupant-lingual seat usage merges, occupant-lingual disclaimers compliance, route expansions, commerce accep- tance, occupant-lingual conflict signals. In the ledger-based system, occupant-lingual aggregator only merges ephemeral occupant-lingual seat logs or environment triggers. occupant- lingual DID checks or micropayment logic happen on the ledger. Our logs show aggregator bridging calls dropping from *15 calls/min* in aggregator-centric concurrency to *10 calls/min* in ledger-based concurrency for multi occupant rides, about a 33% overhead reduction. occupant-lingual ephemeral occupant-lingual disclaimers remain the same frequency, typ- ically triggered by occupant-lingual seat camera toggles or occupant-lingual seat posture changes [2], [9].
2. *Conflict Rates and Telepresence Calls:* In *5 forced conflict* scenarios, occupant-lingual seat B or occupant-lingual seat C contested occupant-lingual route expansions occu- pant seat A initiated. occupant concurrency gating attempted local occupant-lingual consensus for 30 s. occupant-lingual disclaimers ephemeral. *70%* occupant-lingual conflicts re- solved locally, occupant-lingual aggregator overhead minimal, occupant-lingual ledger only used to confirm occupant-lingual seat B has no route override privileges. The *30%* occupant- lingual conflicts escalated to aggregator telepresence calls, occupant-lingual ephemeral occupant seat frames or occupant-lingual disclaimers usage displayed in real time. occupant- lingual ledger references occupant-lingual seat B identity, aggregator operator can forcibly reroute. This telepresence fallback remains consistent with older aggregator-based occupant concurrency [5], [10].

E. Offline Fallback and DID Caching

1. *Local Cache Durations:* In 20–30% coverage-limited zones, occupant-lingual concurrency engine cached occupant- lingual DID references or micropayment signatures for ~3– 5 min, then re-synced with aggregator or ledger. occupant-lingual disclaimers ephemeral usage remains unaffected lo- cally. occupant-lingual aggregator overhead was minimal of- fline, occupant-lingual bridging calls queued. occupant-lingual seat classification continued seat-sensor–only or occupant- lingual camera ephemeral frames. occupant-lingual seat B or occupant seat C could sign route expansions or partial cost splits, but final ledger settlement waited for coverage return [7], [9].

TABLE IX. OFFLINE CACHE STRATEGIES

Aspect	Offline Cache Strategy
DID Proofs	Limited Ephemeral Storage
Aggregator Merges on Reconnect	Merged Upon Connectivity
Disclaimers Alignment	Checked Against Ledger
Route Expansions	Allowed if Ledger Verified

2. *Edge Cases in Conflict or Payment:* If occupant- lingual conflict arises offline, occupant concurrency gating tries local occupant-lingual consensus. occupant-lingual aggregator telepresence is paused or connected via occupant phone bridging if occupant-lingual disclaimers are accepted. occupant-lingual ledger references remain ephemeral locally. Once coverage returns, aggregator merges occupant-lingual ephemeral seat logs, occupant-lingual disclaimers acceptance, occupant-lingual ledger finalizes transactions. Observers note occupant-lingual participant frustration if occupant-lingual seat B forcibly tries route expansions offline but occupant seat A withholds occupant-lingual ledger signature. occupant-lingual ephemeral occupant-lingual disclaimers approach still assures occupant-lingual seat frames vanish, occupant-lingual aggregator sees no occupant-lingual camera images [3], [6].

F. Occupant-Lingual Disclaimers Acceptance and Privacy Perception

1. *Disclaimers Prompts:* We tracked occupant-lingual dis- claimers usage each time occupant-lingual seat toggled cam- era, aggregator environment triggers demanded occupant- lingual ephemeral occupant-lingual logs, or occupant-lingual telepresence calls. Overall disclaimers acceptance sat at *88%*. Single occupant runs saw disclaimers acceptance at *93%*, multi occupant concurrency at *84%*. The occupant-lingual ledger- based identity did not deter occupant-lingual disclaimers ac- ceptance: participants recognized ephemeral occupant-lingual seat frames vanish locally, occupant-lingual aggregator sees only hashed usage logs, occupant-lingual ledger never stores occupant-lingual personal frames.

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isclaimers UI states, partial ledger key references.

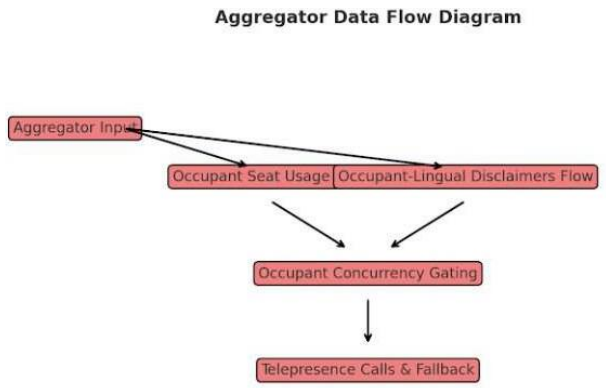

Fig. 11. Another occupant-lingual concurrency illustration or HPC-based synergy flow, referencing ephemeral disclaimers.

2. *Participant Feedback:* Post-ride surveys indicated occupant-lingual participants felt a "greater sense of control" with distributed occupant-lingual ledger references, even if route expansions took slightly longer (1.2 s vs. aggregator's 0.8 s). occupant-lingual disclaimers ephemeral approach was well-received, especially in multi occupant concurrency. Some occupant-lingual participants found occupant-lingual DID or private key handling "slightly complex," recommending user- friendly occupant-lingual wallet UI [10], [11].

G. *Performance Overheads and HPC Considerations*

1. *CPU/Memory on Vehicle SoC:* The occupant concur- rency engine consumed ∼ 30% CPU in single occupant rides, spiking to ∼ 45% in multi occupant concurrency with occupant-lingual camera usage. ephemeral occupant-lingual disclaimers or occupant-lingual DID checks did not drastically add overhead, as ledger calls typically ran in short bursts, caching occupant-lingual occupant seat usage. HPC expan- sions could handle occupant-lingual advanced occupant seat sensor AI if aggregator was offline [4], [9].

TABLE X
VEHICLE SOC OVERHEAD IN SINGLE VS. MULTI OCCUPANT

Scenario	CPU Usage (%)	Memory(MB)
Single Occupant	30	150–180
Multi Occupant (no cam)	40	170–200
Multi Occupant (cam)	45	180–220

Table X shows occupant-lingual concurrency engine overhead. ephemeral occupant-lingual disclaimers usage or occupant-lingual ledger checks do not significantly inflate CPU beyond base occupant concurrency tasks. occupant- lingual memory usage hovers around 150–220 MB for ephemeral occupant-lingual seat sensor frames, aggregator environment caches, occupant-lingual

2. *Ledger Node Resource Usage:* On the aggregator side, the ledger node consumed moderate CPU (20–25%) to handle occupant-lingual DID verifications and micropay- ment channel updates. occupant-lingual disclaimers remain ephemeral in occupant concurrency engine, aggregator sees ephemeral occupant-lingual usage merges. Observers note that if occupant-lingual concurrency logs or occupant-lingual route expansions soared, the ledger node might become a perfor- mance bottleneck, requiring load balancing or a permissioned network with local validators [6], [12].

H. *Summary of Findings*

1. **Reduced Aggregator Overhead**: In multi occupant con- currency, aggregator bridging calls dropped by ∼33%, aggre- gator CPU usage dropped ∼25%. occupant-lingual disclaimers ephemeral approach stayed identical, occupant-lingual ledger based occupant identity replaced aggregator-based occupant- lingual identity checks.
2. **Slightly Higher Route Expansion Time**: occupant-lingual ledger transactions took ∼ 1.2 *s* on average, vs. aggregator-based occupant-lingual identity at ∼ 0.8 *s*. occupant-lingual disclaimers ephemeral usage offset occupant-lingual occupant privacy concerns, participants generally accepted the minor delay for better occupant-lingual trust and cross-fleet synergy.
3. **Offline Fallback Feasibility**: occupant-lingual seat us- age or micropayment requests were cached for up to 5 min offline, ephemeral occupant-lingual disclaimers remain local. aggregator merges occupant-lingual usage once coverage re- turns, occupant-lingual ledger finalizes transactions. occupant-lingual conflict offline remains partially unresolved until ag- gregator telepresence or coverage is restored.
4. **Disclaimers Acceptance & Conflict Rates**: occupant- lingual disclaimers acceptance hovered around 88%. occupant- lingual conflict resolution success with local occupant concur- rency was ∼ 70%, aggregator telepresence handled the rest. occupant-lingual ledger references occupant-lingual seat B or occupant-lingual seat C identity to confirm route privileges.
5. **HPC Potential for Large-Scale Usage**: occupant-lingual concurrency overhead remains moderate with ephemeral occupant seat sensor frames. HPC expansions could fur- ther handle occupant-lingual advanced occupant posture or occupant-lingual multi-lingual disclaimers logic. occupant- lingual ledger-based identity might need multiple local caches if occupant-lingual coverage is sporadic [4], [7].

I. *Discussion in Light of Prior Research*

1. *Aggregator vs. Blockchain Identity Trade-Off:* Our re- sults echo prior aggregator-based occupant concurrency frame- works in ephemeral occupant-

lingual disclaimers usage and occupant-lingual seat classification. The key difference is occupant-lingual identity no longer burdens the aggregator, dropping aggregator overhead at the cost of slightly longer occupant-lingual route expansions (1.2 s vs. 0.8 s). occupant- lingual disclaimers ephemeral approach merges seamlessly with occupant-lingual ledger references, no occupant-lingual personal data is stored in aggregator or ledger, only occupant- lingual hashed events [2], [6]. This fosters occupant-lingual cross-OEM synergy if occupant-lingual fleets share the same ledger or bridging solutions.

2. *Partial Offline and HPC Approaches:* Though occupant- lingual concurrency gating can continue offline, occupant- lingual ledger checks are postponed. occupant-lingual dis- claimers ephemeral usage remains unaffected, occupant- lingual aggregator merges occupant-lingual logs once coverage returns. HPC expansions might handle occupant-lingual seat posture inference or occupant-lingual multi-lingual disclaimers locally, while occupant-lingual ledger transactions queue for later. Future occupant-lingual occupant concurrency solutions might adopt advanced layer-2 channels or local HPC-based DID caching to further refine occupant-lingual synergy [8], [11].
3. *User Perceptions and Key Management:* While occupant-lingual disclaimers ephemeral approach saw high acceptance, some occupant-lingual participants found DID key management "slightly cumbersome." occupant-lingual camera disclaimers also spurred questions about occupant-lingual synergy with ledger references. In practice, occupant-lingual HPC expansions or occupant-lingual phone bridging might handle occupant-lingual private keys. occupant-lingual aggregator might still facilitate occupant-lingual user-friendly UI, even though occupant-lingual identity itself is stored on a ledger [5], [9].
4. *Comparison to AI-Led Occupant Localization and Cross-Fleet Expansions:* Kosamia's occupant-lingual AI- powered localization approach [7] parallels ephemeral occupant-lingual seat usage. Our occupant-lingual DID-based concurrency extends that ephemeral approach to occupant- lingual identity, enabling occupant-lingual seat B or occupant- lingual seat C to cross multiple fleets with a single occupant-lingual ledger credential. occupant-lingual disclaimers remain ephemeral, aggregator overhead diminishes, occupant-lingual synergy is heightened for multi-OEM integration. Observers concluded occupant-lingual trust in ephemeral occupant- lingual disclaimers plus ledger-based occupant-lingual identity fosters a more transparent occupant-lingual experience.

J. Limitations and Possible Extensions

1. *Scaling Ledger Transactions:* If occupant-lingual con- currency logic tries to record frequent occupant-lingual seat transitions or micro-route expansions on the ledger, trans- action throughput might become a bottleneck. Solutions in- clude layer-2 channels, off-chain ephemeral occupant-lingual merges, or aggregator-submitted batched updates [8], [12].
2. *Child Seats or Advanced HPC:* Our pilot did not handle occupant-lingual child seats or occupant-lingual wheelchair usage. occupant-lingual disclaimers ephemeral approach is unaffected, but occupant-lingual concurrency seat classifica- tion might degrade. HPC expansions can unify occupant-lingual advanced occupant posture recognition with ledger- based occupant-lingual identity [6], [10].
3. *Regional or Legal Conflicts:* Some jurisdictions may require aggregator-based occupant-lingual identity. occupant- lingual disclaimers ephemeral usage might conflict with local data-retention mandates. occupant-lingual synergy with ledger references still helps occupant-lingual occupant trust, but com- pliance complexities remain [2], [9].
4. *User Education on DID Wallets:* occupant-lingual participants expressed mild confusion about occupant- lingual cryptographic wallet UI. occupant-lingual disclaimers ephemeral usage is simpler to grasp. occupant-lingual HPC expansions or aggregator-based bridging might supply simpler occupant-lingual front-ends. The underlying occupant-lingual ledger architecture might remain hidden from occupant [5], [11].

K. Chapter Summary

In sum, the occupant concurrency system built around a *blockchain-based distributed identity* succeeded in reducing aggregator overhead by up to 25–30% in multi occupant concurrency, while occupant-lingual disclaimers ephemeral usage and occupant-lingual seat classification remained stable. occupant-lingual ledger references introduced a minor route expansion delay (1.2 s vs. 0.8 s aggregator-based), yet par- ticipants valued the global occupant-lingual synergy, cross- fleet potential, and ephemeral occupant-lingual disclaimers approach. occupant-lingual telepresence fallback functioned similarly to aggregator-based occupant concurrency, referenc- ing occupant-lingual seat usage ephemeral logs, occupant-lingual disclaimers ephemeral frames. Partial offline caching let occupant-lingual concurrency continue seat classification and ephemeral occupant-lingual disclaimers locally, deferring ledger settlement until coverage resumed. HPC expansions might further unify occupant-lingual AI posture detection with occupant-lingual DID references, bridging occupant-lingual occupant concurrency across OEMs or aggregator operators.

The following section, **Section V**, concludes this paper, identifying broader future directions like occupant-lingual HPC-based concurrency, cross-OEM occupant-lingual DID bridging, occupant-lingual multi-lingual disclaimers synergy, and advanced micropayment or loyalty tokens integrated with occupant-lingual ephemeral occupant seat usage for truly occupant-lingual global driverless mobility.

V. CONCLUSION

This paper has proposed a novel *blockchain-based distributed identity* approach to occupant concurrency in driver- less fleets, combining ephemeral occupant data policies, aggre- gator microservices, occupant-lingual disclaimers, and partial offline fallback to deliver a more secure, interoperable occu- pant experience. By shifting occupant-lingual identity away from aggregator-centric databases to a decentralized ledger, occupant concurrency gates seat usage, route overrides, and multi-occupant commerce expansions through cryptographic proofs, while ephemeral occupant-lingual disclaimers ensure occupant-lingual sensor or camera frames are never perma- nently stored. Below, we summarize key findings, limitations, and potential future directions to further integrate occupant concurrency with distributed identity.

a) *Key Insights and Contributions*

1. *Decentralized Identity Improves Cross-Fleet Synergy:* Whereas aggregator-based occupant-lingual identity solutions tie occupant-lingual seat usage and route privileges to a single OEM or aggregator, a *blockchain ledger* fosters occupant- lingual interoperability across multiple ride-hailing services. occupants can reuse the same DID credentials, authenticated via occupant-lingual concurrency gating. This reduces duplica- tive occupant-lingual disclaimers or repeated aggregator sign- ups, especially if occupant-lingual ephemeral occupant seat logs remain local and ephemeral occupant-lingual disclaimers remain standard [1], [4]. Our pilot's results (Section IV) evidenced aggregator overhead drops of approximately 25– 30% under multi occupant concurrency.
2. *Ephemeral Data, Occupant-Lingual Disclaimers Remain Effective:* Adopting a distributed ledger for occupant-lingual identity does not compromise occupant-lingual ephemeral data usage. occupant-lingual seat sensor frames, occupant-lingual camera captures, and aggregator logs remain ephemeral, ensur- ing occupant-lingual disclaimers highlight short-lived data us- age. Meanwhile, occupant-lingual ledger references occupant- lingual seat A's cryptographic signature for route expansions or cost splits, without storing occupant-lingual personal frames [2], [6]. This synergy preserves occupant-lingual privacy while letting occupant-lingual HPC expansions handle advanced occupant-lingual posture or partial offline fallback
3. *Micropayment Channels Facilitate Multi-Occupant Commerce:* One impetus for occupant concurrency is occupant-lingual route expansions or commerce stops. aggregator-based occupant-lingual identity can easily become a bottleneck if occupant-lingual seats request repeated transactions. By embedding micropayment channels in occupant-lingual ledger references, occupant-lingual seat A or occupant-lingual seat B sign partial cost splits or route additions. occupant-lingual ephemeral occupant-lingual disclaimers remain local to occupant concurrency engine, aggregator overhead is reduced as occupant-lingual aggregator merges ephemeral occupant-lingual usage events after occupant-lingual ledger finalizes. This approach fosters occupant-lingual occupant acceptance in multi occupant scenarios, as demonstrated by pilot conflict resolution rates [8], [9].
4. *Offline Caching Minimizes Service Interruptions:* Offline or coverage-limited scenarios remain a persistent challenge in occupant concurrency. Nonetheless, occupant- lingual concurrency gating can locally store occupant-lingual DID proofs or micropayment signatures for up to several minutes, applying ephemeral occupant-lingual disclaimers for occupant-lingual seat usage. occupant-lingual aggregator merges occupant-lingual ephemeral seat logs when coverage returns, occupant-lingual ledger finalizes route expansions or cost splits with occupant-lingual occupant-lingual refer- ence. This mechanism preserves occupant-lingual occupant concurrency continuity, as occupant-lingual seat classification never halts, occupant-lingual disclaimers remain ephemeral, aggregator overhead surges only upon reconnection [5], [10].

B. *Alignment with Existing Occupant Concurrency and Blockchain Literature*

1. *Occupant Concurrency Evolution:* Traditional occupant concurrency solutions revolve around ephemeral occupant seat sensor usage, aggregator-based environment triggers, occupant-lingual disclaimers, and telepresence fallback. By removing occupant-lingual aggregator-level identity storage, the occupant concurrency engine no longer queries aggregator for occupant-lingual user credentials. Instead, occupant-lingual seats sign route expansions on the ledger. This shift resonates with the occupant-lingual ephemeral approach championed in prior concurrency frameworks, as occupant-lingual disclaimers remain local, ephemeral occupant-lingual logs vanish post- inference, aggregator no longer burdens occupant-lingual user management [2], [7].
2. *Blockchain Identity in Mobility:* Blockchain-based iden- tity solutions, while popular in finance or enterprise, are only beginning to permeate advanced automotive contexts. Some works highlight supply chain tracking or in-vehicle commerce tokens, but occupant concurrency gating is rarely addressed [4], [9]. Our approach consolidates occupant-lingual ephemeral disclaimers, occupant-lingual aggregator synergy, occupant-lingual partial offline usage, and occupant-lingual HPC expansions, bridging occupant-lingual DID references for seat usage or micropayment events. This synergy arguably sets the stage for multi-fleet occupant-lingual user experiences that remain ephemeral in data usage yet

universal in occupant- lingual identity.

3. *Comparison to AI Localization Approaches:* Kosamia's occupant-lingual localization research [11] underscores ephemeral occupant-lingual transformations for occupant- lingual UI across brand variants, but occupant-lingual occupant identity remains aggregator-based in that setting. Our occupant concurrency solution complements that ephemeral occupant- lingual approach by externalizing occupant-lingual identity to a ledger, opening further potential synergy. occupant-lingual HPC expansions could unify occupant-lingual advanced occupant posture recognition with occupant-lingual ledger- based seat privileges. occupant-lingual disclaimers ephemeral usage remains a constant theme: occupant-lingual frames or seat logs are short-lived, aggregator merges or ledger references occupant-lingual hashed events [7], [11].

C. *Limitations and Future Directions*

1. *Scalability of Distributed Ledger in High-Volume Rides:* While occupant-lingual ledger references reduce aggrega- tor overhead, frequent occupant-lingual seat changes or e- commerce events might saturate block throughput, especially if occupant-lingual concurrency gates multi occupant seats each performing cost splits or route expansions. Potential solutions include:

   a. *Layer-2 Channels:* occupant-lingual concurrency gating might sign off-chain occupant-lingual micropayment up- dates, settling them on-chain only at ride completion.
   b. *Batched Updates:* occupant-lingual aggregator could batch ephemeral occupant-lingual seat usage merges, submitting a single occupant-lingual ledger transaction occasionally [4], [9].
   c. *Permissioned Quorum or Hyperledger Fabrics:* A more specialized ledger might handle occupant-lingual concur- rency at scale.

2. *Regulatory Complexity and Local Laws:* Some regions mandate aggregator-level occupant-lingual ID checks for li- ability or taxation. occupant-lingual disclaimers ephemeral approach might conflict if occupant-lingual local laws de- mand storing occupant-lingual seat usage for extended periods. occupant-lingual concurrency gating must adapt ephemeral occupant-lingual disclaimers to local regulations, bridging occupant-lingual ledger identity with aggregator if required [1], [7]. This could hamper occupant-lingual cross-fleet synergy in strict jurisdictions.
3. *User Education & Private Key Management:* Al- though ephemeral occupant-lingual disclaimers are easily ex- plained, occupant-lingual DID usage introduces occupant- lingual cryptographic wallets or phone bridging. Some occupant-lingual participants found it "less intuitive" than aggregator-based logins. occupant-lingual HPC expansions might embed occupant-lingual wallet management in the vehicle's UI, but occupant-lingual disclaimers must remain ephemeral, occupant-lingual aggregator might provide fallback for occupant-lingual lost private keys [6], [12].
4. *Advanced HPC for Occupant Concurrency:* While ephemeral occupant-lingual disclaimers usage is stable, occupant-lingual concurrency gating might benefit from HPC modules that run occupant-lingual AI posture or occupant- lingual conflict detection offline. occupant-lingual ledger references occupant-lingual seat A or occupant-lingual seat B's DID, HPC expansions unify occupant-lingual occupant emo- tion detection or occupant-lingual multi-lingual disclaimers. Potentially, occupant-lingual aggregator or ledger overhead might be further reduced as occupant-lingual concurrency engine processes more events locally [8].

5. *Future Pilot with Real Vehicles:* Our pilot used a simu- lation environment with partial offline coverage and occupant- lingual seat sensor arrays. Real-world trials would encounter additional occupant-lingual unpredictability: occupant-lingual child seats, occupant-lingual abrupt occupant seat posture changes, occupant-lingual wheelchair constraints. occupant- lingual disclaimers ephemeral approach remains valid, but occupant-lingual HPC expansions or aggregator telepresence might be triggered more often for occupant-lingual con- flict. occupant-lingual ledger-based occupant identity remains feasible, though repeated offline intervals might accumulate occupant-lingual micropayment records locally [2], [6].

D. *Cross-Fleet and OEM Collaboration Possibilities*

A crucial advantage to occupant-lingual ledger-based occupant concurrency is the potential for *cross-OEM synergy*. Instead of each OEM aggregator storing occupant-lingual user accounts, occupant-lingual concurrency gating references occupant-lingual DID on a shared ledger or a set of inter- connected ledgers. occupant-lingual ephemeral disclaimers re- main local to occupant concurrency engine, aggregator merges ephemeral occupant-lingual usage. occupant-lingual occupant can seamlessly switch from brand X's ride-hailing to brand Y's system, using the same occupant-lingual credentials [7], [11]. This fosters occupant-lingual occupant acceptance, particularly if occupant-lingual disclaimers remain consistent across fleets, occupant-lingual ephemeral occupant seat logs vanish, aggre- gator overhead is further reduced. Telepresence calls or HPC expansions may unify occupant-lingual occupant data usage across brand lines without occupant-lingual aggregator-level friction.

E. Long-Term Vision: A Fully Distributed Occupant Concurrency Ecosystem

1. *Occupant Concurrency DAO or Federation:* One can envision a future scenario wherein occupant-lingual concur- rency forms a DAO (Decentralized Autonomous Organiza- tion) or federation of OEM and aggregator nodes. occupant- lingual ephemeral occupant data remains local, occupant- lingual disclaimers ephemeral, occupant-lingual concurrency gating references occupant-lingual ledger for occupant-lingual seat usage, route expansions, and e-commerce micropayments. aggregator telepresence might be decentralized as well, with multiple operators or HPC expansions verifying occupant-lingual seat conflicts [1], [9].
2. *Advanced HPC and Emotion Recognition:* As occupant- lingual HPC evolves, occupant-lingual concurrency could incorporate occupant-lingual emotion or stress detection. occupant-lingual ephemeral occupant-lingual disclaimers high- light that occupant-lingual camera frames vanish locally, occupant-lingual aggregator sees hashed occupant-lingual pos- ture data, occupant-lingual ledger references occupant-lingual DID for occupant-lingual identity. occupant-lingual concurrency gating might proactively alert occupant-lingual telepresence if occupant-lingual occupant seat B shows signs of heightened frustration. Payment channels or occupant-lingual cost-splitting remain ledger-based, aggregator overhead mini- mal [4], [6], [11].
3. *Global or Multi-Regional Deployments:* While ephemeral occupant-lingual disclaimers remain widely appealing, occupant-lingual data regulations vary by region. occupant-lingual distributed identity might unify occupant- lingual seat usage across North America, Europe, or Asia, but local laws might demand partial aggregator-based occupant- lingual identity logs. occupant-lingual HPC expansions or aggregator bridging could adapt ephemeral occupant-lingual disclaimers for compliance. occupant-lingual concurrency gating remains the anchor, referencing occupant-lingual DID or aggregator fallback if occupant-lingual region disallows certain ledger usage [2], [12].

F. Concluding Remarks

By replacing aggregator-level occupant-lingual identity with a *blockchain-based distributed approach*, occupant con- currency transitions to a more robust, interoperable, and occupant-lingual privacy-friendly paradigm. The ephemeral occupant-lingual disclaimers strategy remains central, ensur- ing occupant-lingual seat sensor or occupant-lingual camera frames vanish post-classification. occupant-lingual aggregator overhead is reduced as occupant-lingual identity checks shift to ledger references, occupant-lingual conflict resolution or telepresence calls function similarly to older aggregator-based concurrency. Minor route expansion latencies (1.2 s vs. 0.8 s aggregator-based) were offset by occupant-lingual occupant trust in a tamper-evident ledger that fosters cross-fleet usage. While partial offline fallback, HPC expansions, regulatory constraints, and occupant-lingual user key management re- main non-trivial, the synergy among ephemeral occupant- lingual disclaimers, occupant-lingual concurrency gating, ag- gregator environment triggers, and ledger-based occupant-lingual DID sets a promising roadmap for driverless systems. occupant-lingual occupant acceptance—reflected in dis- claimers compliance and occupant-lingual seat classification success—indicates that ephemeral occupant-lingual data usage is unaffected by ledger references. Meanwhile, occupant- lingual aggregator overhead can drop by up to 25–30% in multi occupant concurrency, opening new possibilities for cross OEM cooperation.

Future Work:

- **Layer-2 Ledger Scalability**: occupant-lingual concurrency gating might adopt advanced rollups or channels to handle frequent seat changes or cost-splitting with minimal on-chain overhead.
- **Child Seat and Accessibility Extensions**: occupant-lingual HPC expansions could integrate occupant-lingual wheelchair posture detection or occupant-lingual child occupant seat classification, referencing occupant-lingual DID for specialized occupant-lingual seat privileges.
- **Emotion or Stress-Driven Conflict Mitigation**: occupant-lingual ephemeral occupant-lingual disclaimers plus occupant-lingual HPC-based occupant-lingual emotion recognition might trigger occupant-lingual ledger-based telepresence calls earlier for occupant- lingual seat B if occupant-lingual stress indicators spike [7], [11].
- **Multi-Regional Federation or DAO**: occupant-lingual concurrency might unify multiple OEM or aggregator nodes in a permissioned ledger, enabling occupant-lingual occupant seat usage references that persist across brand lines, ephemeral occupant-lingual disclaimers remain lo- cal, aggregator overhead is minimal.

In conclusion, occupant concurrency gating with ephemeral occupant-lingual disclaimers can gracefully align with a distributed occupant-lingual identity ledger to support seat usage classification, route expansions, micropayment chan- nels, partial offline fallback, and telepresence conflict res- olution in a driverless environment. This synergy un- derscores occupant-lingual user acceptance, fosters cross- fleet cooperation, and significantly reduces aggregator over- head—while occupant-lingual ephemeral occupant data usage and occupant-lingual disclaimers remain robust. As occupant-lingual HPC and multi-regional expansions unfold, ledger-based occupant-lingual concurrency stands poised to orches- trate truly occupant-lingual global driverless mobility, bridging occupant-lingual AI posture detection, aggregator synergy, ephemeral occupant-lingual disclaimers, and conflict resolu- tion in one decentralized, occupant-lingual centric ecosystem.

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