



TRACE

inTegration
& haRmonizAtion
of logistiCs
opErations

TRACE Reference Architecture A Technical Overview

Technical Brochure

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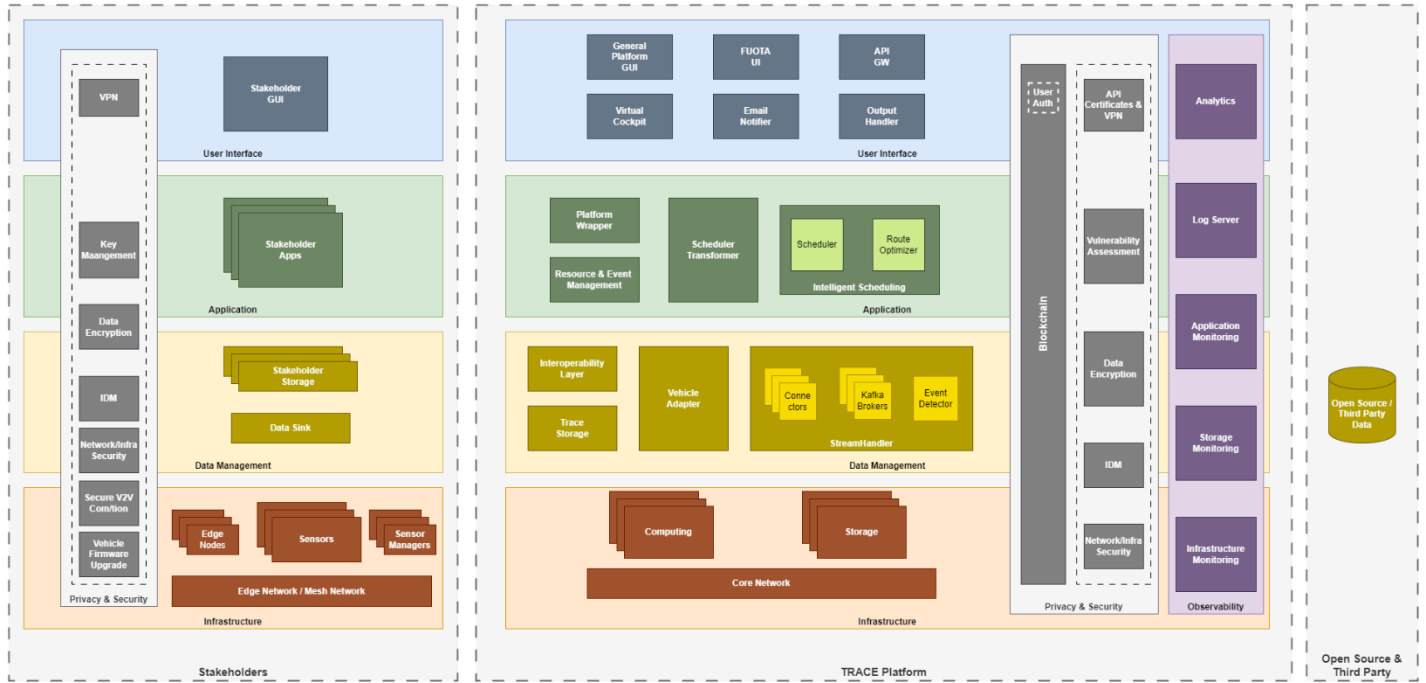


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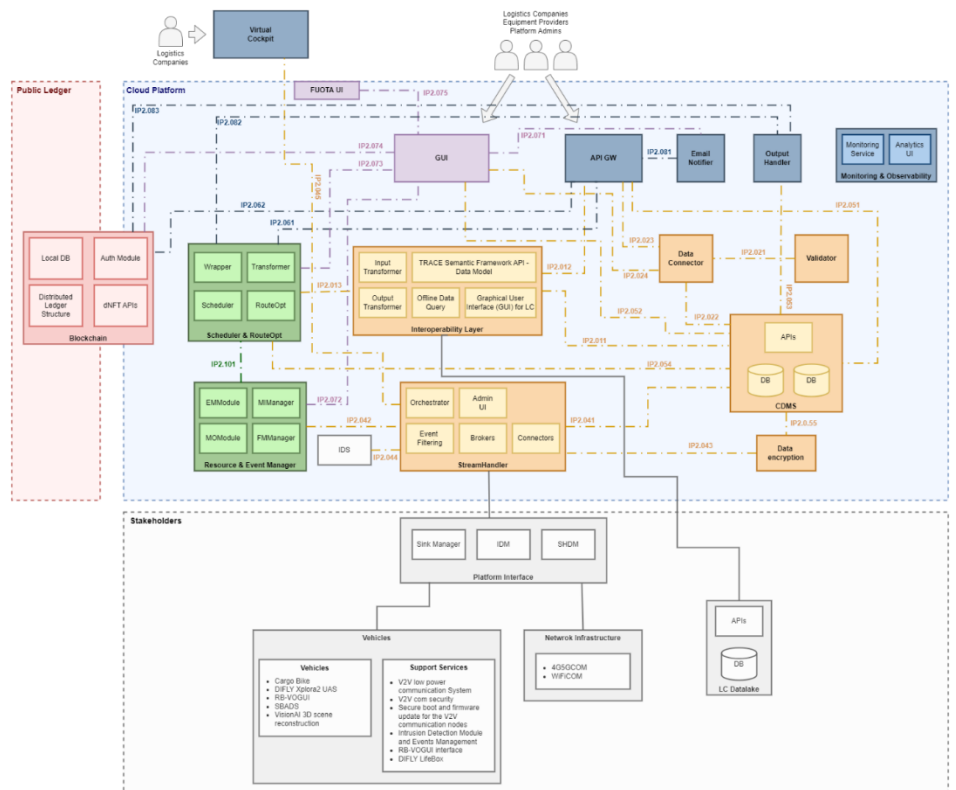
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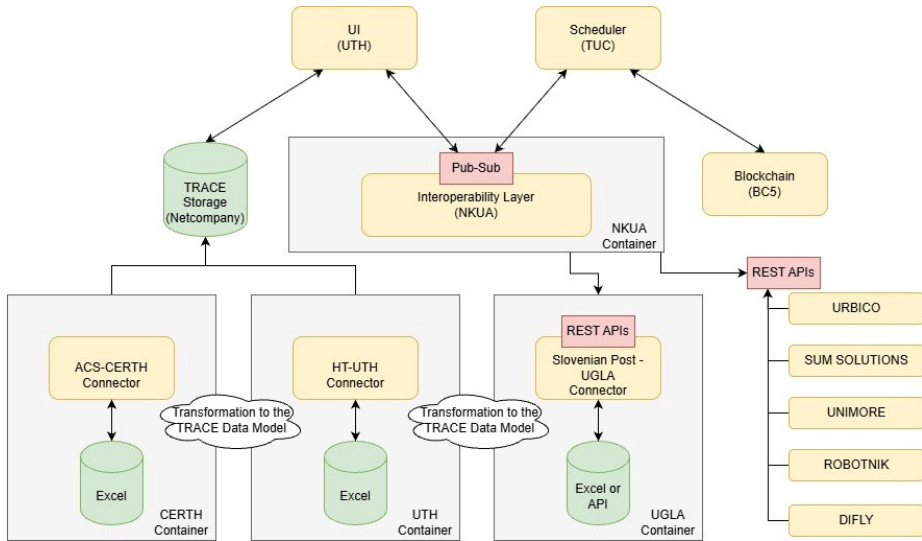
Platform Architecture. TRACE implements a four-layer architecture designed for scalable multi-modal logistics integration. The Infrastructure Layer provides 4G/5G NSA network connectivity with complementary WiFi and V2V communication options. The Data Management Layer comprises the StreamHandler (Apache Kafka-based real-time data processing) and Cloud-based Data Management System (MongoDB document storage and S3 object storage). The Application Layer contains optimization modules including Scheduler, Route Optimizer, and Resource & Event Manager. The User Interface Layer exposes functionality through REST APIs, graphical dashboards, and specialized interfaces including FUOTA UI for firmware updates.



Integration Architecture. The platform defines 17 validated integration points connecting all components. Integration occurs through three primary mechanisms: REST APIs for synchronous request-response patterns, Pub/Sub messaging via Kafka topics for asynchronous event-driven communication, and programmatic interfaces for security operations. The Integration Matrix documents all component interactions with specific identifiers, responsible partners, and implementation details.



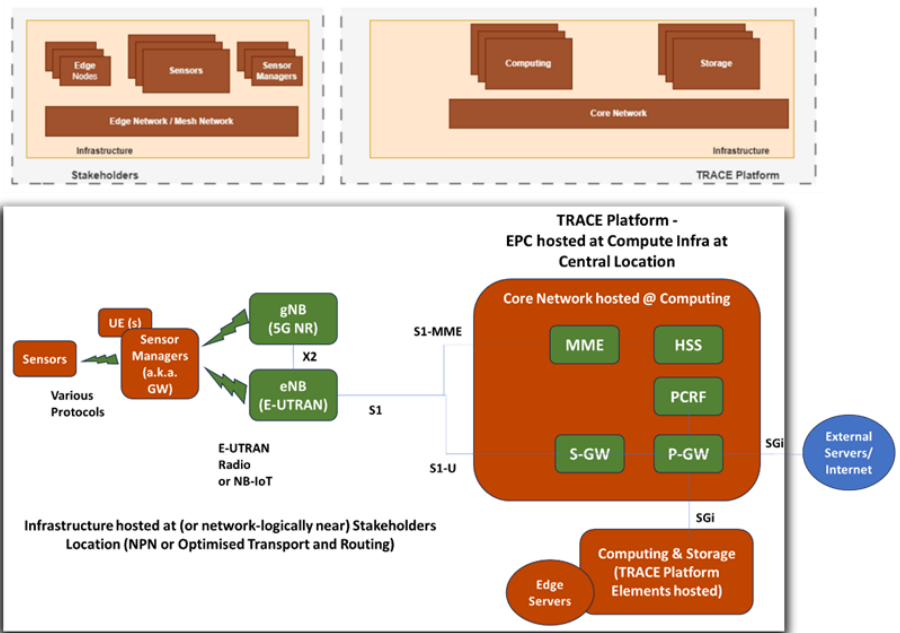
Data Management. The StreamHandler manages three data stream categories: inbound streams from logistics systems and vehicles, outbound streams delivering optimization results to operators, and internal asynchronous communication between platform components. Ten dedicated Kafka topics organize data flows by domain. The CDMS provides persistent storage through a MongoDB cluster with 19 collections and S3 object storage with two buckets (sh-large-files: 50.39 GB and trace: 447.91 MB). The FastAPI layer exposes 45+ endpoints with Pydantic validation and OpenAPI/Swagger documentation.



Interoperability Layer. The TRACE Data Model standardizes 16 core entity classes (Company, Vehicle, Shipment, Journey, Load, Sensor, Event, Area, Point, Waypoint, Depot, Battery, Transportation Mode, Pricing Table, Status Update, Box Status, Intrusion Alert) with defined attributes, relationships, and cardinality. Data connectors transform heterogeneous source formats into the standardized model. REST endpoints and Pub/Sub topics expose the Interoperability Layer to downstream components including Scheduler, API Gateway, and CDMS.

Communication Infrastructure.

The primary deployment architecture combines 4G/LTE E-UTRAN and 5G NR radio access networks with core network functions (MME, HSS, PCRF, S-GW, P-GW) hosted at centralized compute infrastructure. Edge computing resources enable low-latency processing near demonstration sites. Alternative 5G Standalone architecture with Non-Public Network deployment minimizes transport hops. WiFi provides fallback connectivity for devices lacking mobile coverage. V2V communication supports platooning and direct vehicle-to-vehicle coordination.



Security and Encryption. Data encryption operates at two levels: in-transit encryption through StreamHandler using user-provided encryption keys, and at-rest encryption in CDMS MongoDB using per-user encryption keys. The Intrusion Detection System (IDS) analyzes vehicle sensor data via dedicated Kafka topics to detect anomalies and behavioral deviations. User authentication and authorization leverage blockchain-based mechanisms with RESTful API exposure.

Blockchain Integration. The platform records all transportation operations as dynamic Non-Fungible Tokens (dNFTs) on a distributed ledger, ensuring immutability and transparent auditability. The dNFT API layer (IP2.083) enables Output Handler modules to create schedule records. A local MongoDB instance stores metadata supporting authentication (Auth Module), distributed ledger operations, and dNFT management.

Weather and Traffic Integration. The Weather Management System integration implements a Route Sector Wind and Temperature (RSWT) scale rating vehicles 1-5 across four parameters: rain (0-50 mm/h to 0-2 mm/h), snow (0-5 cm/h to 0), wind (0-80 km/h to 0-10 km/h), and temperature (-40 to +60°C to +5 to +20°C). Vehicle filtering operates automatically before optimization. Traffic Management System integration enables real-time and historical traffic data ingestion through REST APIs, with planned transition to EO4EU (Earth Observation for EU) services for standardized weather data access.

Deployment Validation. The architecture has been validated across three European demonstration sites (Greece, Slovenia, Italy) supporting diverse transportation modes: traditional logistics vehicles, cargo bikes, and unmanned aerial vehicles. Integration testing confirmed successful data exchange across all 17 integration points. Network architecture achieves 99.99% availability through co-located or strategically deployed radio access nodes with optimized routing from public network gateways to edge resources. The platform supports real-world synchromodal operations coordinating first-mile, middle-mile, and last-mile delivery stages.

Technical Specifications

Streaming Platform	Apache Kafka with 10 dedicated topics
Document Storage	MongoDB cluster with 19 collections
Object Storage	S3 with two buckets (50.86 GB total)
API Framework	Python FastAPI with 45+ endpoints
Data Validation	Pydantic models with JSON schema
Geospatial Standard	WGS84 (World Geodetic System 1984)
Integration Points	17 validated connections across components
Network Options	4G/5G NSA, 5G SA, WiFi, V2V
Entity Classes	16 standardized data model classes
Security	Dual-layer encryption (transit and rest), IDS, blockchain



<https://trace-horizon.eu/>