EUREKA

ITEA3

TAPCOP

Traffic AI Prediction of
Common Operational Picture

D2.1 High-Level Architecture Design Detailed Backend & Functional Component Specification Of The Reference Platform Architecture In 2nd Iteration

Work Package	WP 2: Platform architecture design
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Executive Summary

Based on the extracted requirements in WP1, this deliverable provides a high-level overview of the architecture and a detailed design of its backend and functional component specification.

Additionally, in depth descriptions of the individual company instantiations are discussed such as xyzt.ai Big Data Visual Analytics Architecture, Televic's train CCTV cybersecurity architecture, Macq Mobility Manager, and Netcheck's platform architecture.

1. Introduction

1.1. Project Objective

The challenge of congestion is a perennial issue for cities around the world, and one that is rapidly worsening. Economic expansion, increased urbanization, the rise of ride-hailing services and e-commerce, underinvestment in infrastructure and mixed results from various policies and programs are seen as the primary trends that have exacerbated urban congestion in recent years.

Congestion is the breakdown in traffic flow, increase of travel time, and increase in crowding that occurs when the capacity of public spaces is exceeded. In addition to the economic costs of congestion, there are side effects like damage caused by pollutants directly introduced by idling vehicles. Authorities continuously struggle with managing and controlling traffic and crowds to prevent safety incidents and discomfort. They lack efficient solutions to mitigate problems related to urbanization.

To influence the behaviour of visitors and traffic flows, solutions are currently mainly used in the physical space, for example by placing variable message signs with instructions, by closing or opening certain routes, and by deploying employees on site. This requires effort with regard to planning, deployment of materials and people and is only possible when it is clear in advance where many people will gather in public hotspots. There are also many situations where this is not clear in advance, or where it is unclear in which direction visitor flows will spread.

The TAPCOP project solved this problem by providing insight, predictions and control mechanisms to prevent mobility issues and overcrowding. The system comprises a chain of information processing modules to:

1. collect multi-modal traffic data of amongst others vehicles, pedestrians, bicycles, public transportation and parking occupations;
2. aggregation of data to information and prediction of the situation ahead;
3. a common operational picture of the mobility situation via a single dashboard, including suggestions for intervention;
4. communication means to influence the traveling public using influencing techniques via targeted social media.

Each of these modules introduce innovations with a market value to create a unique selling proposition:

- A system that gives an overview of all transportation modalities to create a holistic solution rather than doing crowd management and traffic management separately without considering multi-model travel journeys.
- The system gives predictions allowing the authorities to start controlling and influencing the traveling public, thereby pro-actively preventing overcrowding and traffic congestion rather than reactive damage control.
- The system allows influencing of the travellers pre-trip, on-trip and on-site giving people the opportunity to travel in different directions, at different times and with different transportation modes to improve the comfort and efficiency of traveling.
- All modules are equipped with AI technology allowing the system to learn and improve over time and to adapt to new situations and new use cases, depending on the availability of data sources.

The unique selling propositions are expected to disrupt the Smart Mobility domain. The complete value chain that is covered within the consortium provides an excellent position w.r.t the competition. The potential customers are road authorities, municipalities, police, crowd management, and also event organisations of football matches, concerts and festivals.

1.2. Purpose and Scope

The objective of Work Package 2 is to support a backend platform architecture for collecting large amounts of data including various real-time streaming sources. In addition, the WP comprises the design of data storage for large-scale data exploitation and aggregation. This will allow AI-engines to analyse multi-modal data in real-time in view of creating a Common Operation Picture of the current context and predictions of the mobility situations in the short- and long-term.

The work package starts from the Use Case Requirements & Architectural Specification defined in WP1 and translates these into a functional architecture. The functional blocks contain high level description of the role of different backend components in the platform.

D2.1 provides a high-level overview of the architecture and a detailed design of its backend and functional component specification.

2. TAPCOP COMMON FRAMEWORK

Based on D1.1, the following user and business requirements have been identified driving the TAPCOP architecture.

2.1. User Requirements

1. **Intuitive and Accessible User Interface**
   - Ease of Use: The system should have a simple and intuitive user interface, accessible from multiple devices (mobiles, tablets, and computers), that allows end users to easily interact with mobility features.
   - Personalization: The interface should offer personalized options based on user preferences and needs, such as selecting faster, less congested, or greener routes.

2. **Access to Real-Time Information**
   - Continuous Updates: Users should be able to access real-time traffic and mobility information, including congestion alerts, estimated arrival times, and alternative route recommendations.
   - Notifications and Alerts: The system should be able to send automatic notifications and personalized alerts, based on current traffic conditions and user preferences.

3. **Interoperability with Existing Systems**
   - Seamless Integration: The framework should easily integrate with existing mobility and transportation systems in cities, such as traffic management systems, public transport platforms, and shared mobility applications.
   - Compatibility with IoT Devices: It should be compatible with a variety of IoT (Internet of Things) devices, such as traffic sensors, cameras, and traffic light control systems.

4. **Data Privacy and Security**
   - Protection of Personal Data: The system should comply with data protection regulations (such as GDPR), ensuring that users' personal data is protected and used responsibly.
   - Cyber Security: It should implement robust cyber security measures to protect data integrity and prevent unauthorized access.

5. **Access to Personalized Mobility Solutions**
   - AI-Based Recommendations: The framework should use advanced AI techniques to provide personalized mobility recommendations, such as optimal routes, shared transportation options, and suggestions based on traffic patterns.
   - Flexibility and Adaptability: It should allow users to change modes of transport easily, adapting to changes in traffic conditions or their travel needs.

2.2. Business Requirements

1. **Operational Efficiency and Cost Reduction**
   - Resource Optimization: The framework should improve the operational efficiency of authorities and mobility service providers by optimizing resource allocation and reducing costs associated with traffic management and urban mobility.
   - Process Automation: It should automate key processes, such as data collection and analysis, to reduce operational burden and enable faster and more accurate decisions.

2. **Sustainability and Environmental Responsibility**
   - Promotion of Green Routes: The system should prioritize routes and mobility options that reduce carbon emissions and promote environmental sustainability.
   - Incentives for Sustainable Practices: It should offer incentives to users who choose greener transportation options, such as using electric vehicles or reducing the use of fossil fuels.

3. **Regulatory Compliance and International Adaptability**
   - Adherence to Local and International Regulations: The framework should comply with all local, national and international regulations, including transportation laws, mobility regulations and safety standards.
   - Global Scalability: It must be designed to be scalable and adaptable to different urban contexts, allowing its implementation in cities of different sizes and characteristics around the world.

4. **Innovation and Competitiveness in the Market**
   - Integration of Advanced Technologies: It must incorporate the latest technologies in AI, Machine Learning and IoT to remain competitive and offer innovative solutions that outperform existing platforms in the market.
   - Continuous Improvement: It must allow for continuous improvement based on data analysis and user feedback, ensuring that the system evolves and adapts to new market needs.

5. **User-Centric and Experience Improvement**
   - User Satisfaction: The system must be designed to maximize end-user satisfaction, providing a seamless experience and tangible benefits such as reduced travel times and greater comfort.
   - Support and Customer Service: It must include efficient support and customer service mechanisms, capable of solving problems and responding to user queries in real time.

2.3. Overall structure of the TAPCOP solution

The key elements of the TAPCOP data-driven process are visualized in Figure 1 where raw data from various sources are collected, including AI-based road sensors. Afterwards, all data sources are merged to provide an optimized situational awareness picture including prediction functionality. An important Unique Selling Proposition (USP) of the TAPCOP consortium is a platform architecture for a complete value-chain solution. The expertise of the partners are complementary. We can provide a solution which covers a vertical solution for all transportation modes. This includes:

- Combining data from advanced AI-based sensors with other existing data;
- Combining data from different modalities to achieve a real common operational picture (COP);
- Real-time monitoring of the entire visitor flows (road traffic, public transport, parking, pedestrians, etc.);

- AI Prediction with different time horizons; short term (1 hour), mid term (several hours) and long term (several days) ahead. Providing the possibility to react pro-active.
- Influencing the travelling public pre-trip, on-trip and on-site as a response to predicted mobility problems and to prevent overcrowding.
- Evaluation of the effectiveness so that the added value is inherently visible.
- Operate with existing customer systems or replace them.
- Demonstration with different launching customers, boosting chances of commercial exploitation.
- Configurability and visualisation to specific customer needs.
- Scalable and suitable for local venues such as a football stadium and large scale deployment in an entire city.

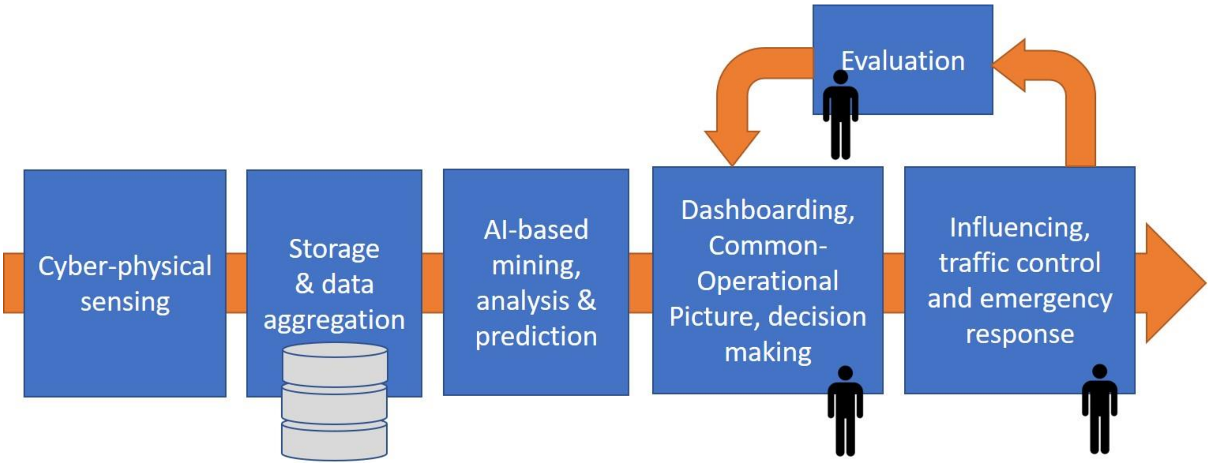


Figure 1. Data-driven process for crowd and traffic control.

3. TAPCOP architecture

3.1. General TAPCOP architecture

Based on the aforementioned requirements, general TAPCOP architecture has been designed in Figure 2.

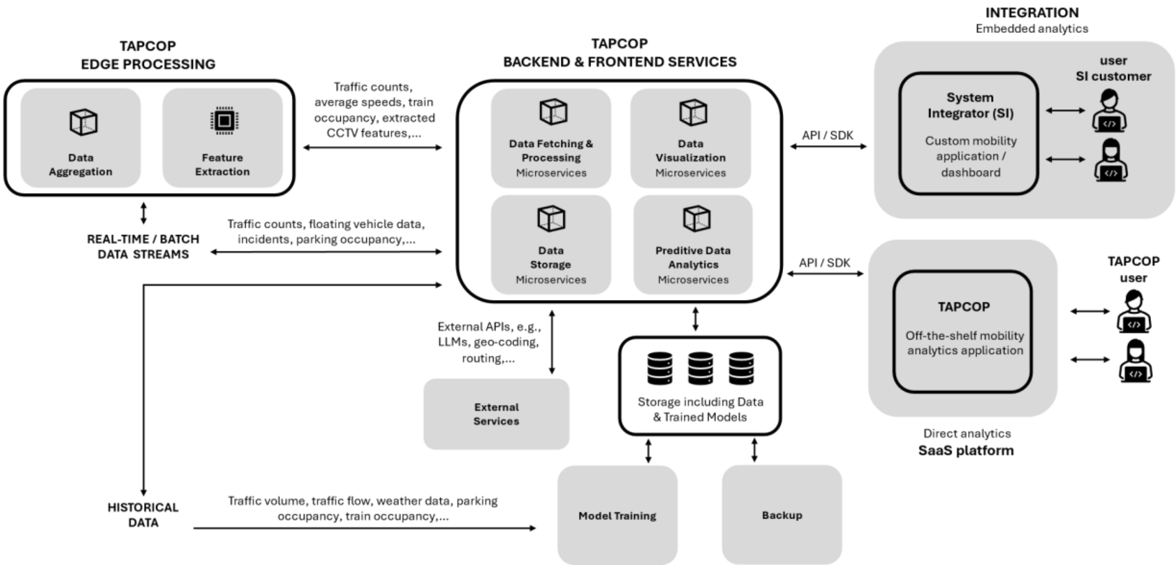


Figure 2. TAPCOP reference architecture and building blocks.

It consists of edge processing components, backend and frontend services and several external components and analytics solutions. In what follows, a more detailed description of the core components is provided:

- **Edge processing**
    - Performs tasks on acquired traffic data (traffic counts, floating vehicle, incidents, parking/train occupancy) such as data filtering, preprocessing, aggregation, and initial feature extraction and analysis locally (camera's, sensors) before transmitting insights to the backend services.
    - This enables real-time decision-making and reduces latency and bandwidth usage and additionally can avoid collection and transmission of privacy-sensitive data.
- **Backend services**
    - Set up as microservices, handle the data processing & storage, and predictive analytics based on the model training and external services providing geo-coding, routing, etc.
    - Model training utilizes real-time data streams of the current traffic information as well as historical data in order to predict its evolution in the following minutes to hours.
- **Frontend services**
    - Provide data visualizations to the end users, display insights through interactive interfaces, and allow users to interact with the predictive analytics and data sources at the backend.
- **System Integrator**
    - Covers a custom mobility application and dashboard designed to optimize the flow of traffic, visualize insights, manage congestion, and provide real-time information to the traffic authorities and municipalities.

  - We expect that thanks to the work executed within TAPCOP, such tools can be used to improve efficiency, reduce accidents, and enhance the overall transportation experience in cities during specific events.
- **SaaS platform**
  - Off-the-shelf mobility analytics application providing direct insights to users.

3.2. TAPCOP Dashboard – MVP Mockup

Main Dashboard:

- Interactive map display showing real-time data (traffic, incidents).
- Key indicators: congestion level, real-time alerts, weather forecast.
- Side panel with predictive information and recommendations on alternative routes and traffic management.
- Notifications showing important alerts.

Predictive Screen:

- Dynamic charts showing mobility predictions (10 minutes to 24 hours).
- Section for displaying events and their expected impact on urban mobility.

Configuration and settings:

- Options for filtering the types of data displayed (vehicles, events, weather).
- Selection of prediction time periods.

3.2.1. UML Component Diagram – TAPCOP

The UML component diagram provides an architectural overview of the TAPCOP system (Figure 3), focusing on key components and their interactions:

Edge Processing

- **Data Aggregation**: Collects and consolidates raw data from multiple traffic sources (e.g., cameras, sensors).
- **Feature Extraction**: Processes aggregated data locally, extracting meaningful features before transmitting results, which reduces latency and bandwidth use.

Backend Services

- **Data Fetching & Processing**: Receives data from edge components and external services, performing further refinement and processing.
- **Data Storage**: Stores processed and historical data efficiently, allowing quick access for analytics.
- **Predictive Data Analytics**: Applies machine learning models and algorithms to predict future traffic conditions using historical and real-time data.
- **Data Visualization**: Transforms analytical results into visual representations for end users.

External Components

- **External Services**: Third-party services (e.g., routing, geocoding) to enhance backend capabilities.
- **Model Training**: Develops and trains predictive models using historical datasets.
- **Backup**: Provides redundancy and ensures data integrity through regular data backups.

Frontend Services

- **Interactive Dashboard**: Presents visual analytics, real-time traffic conditions, predictions, and actionable insights through a user-friendly graphical interface.

System Integrator

- **Custom Mobility Application**: Tailored dashboard application, specifically designed for optimizing urban traffic, managing congestion, and assisting authorities with mobility strategies.

SaaS Platform

- **TAPCOP Standard Application**: Provides ready-to-use mobility analytics to customers, enabling quick adoption without custom setup.

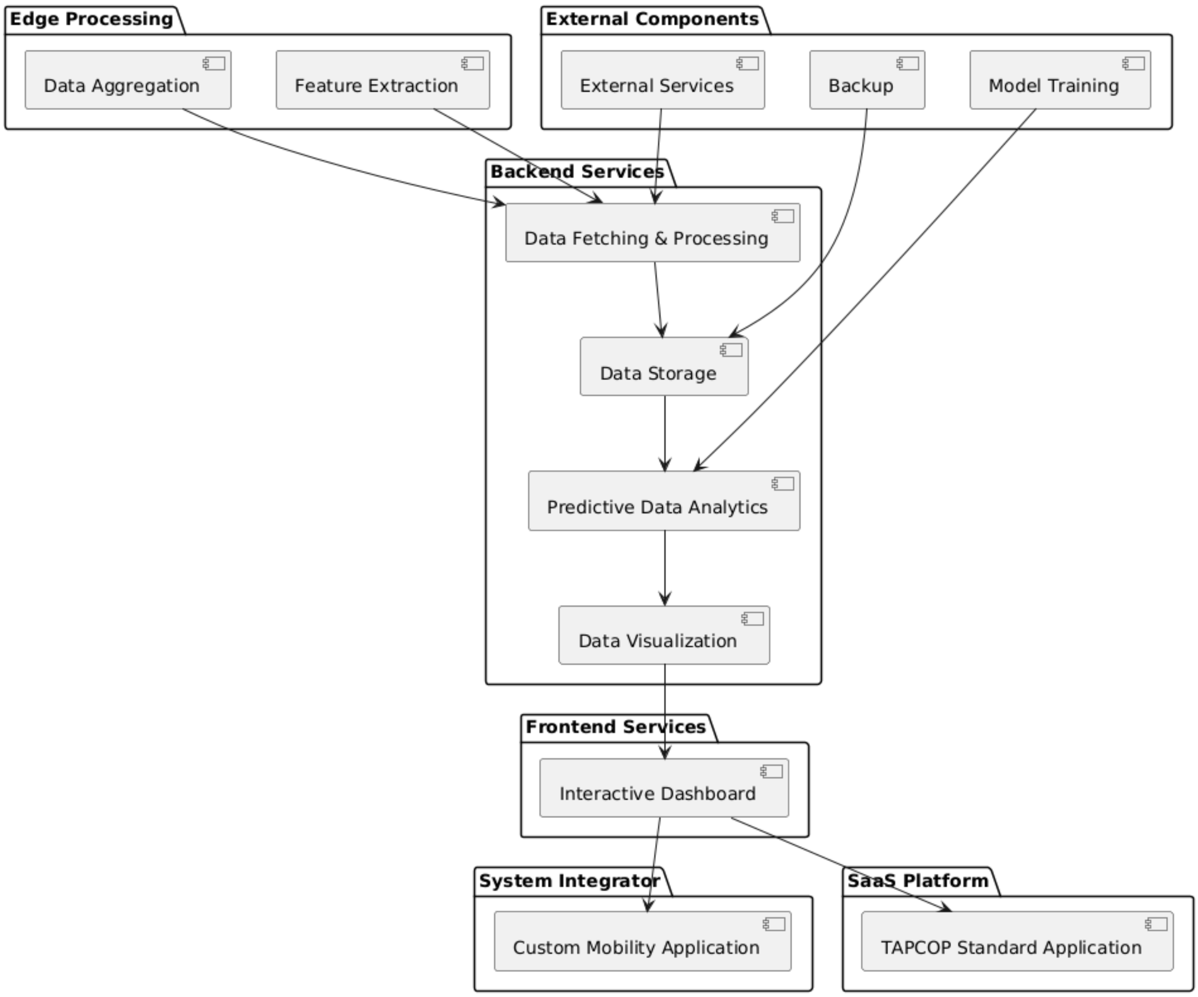


Figure 3. Architectural overview of the TAPCOP system.

Component Interactions

- **Edge Components → Backend Services**: Edge processing feeds backend components with pre-processed and structured data.
- **Backend Services ↔ External Components**: The backend interacts with external components for enriched data and model training.
- **Backend Services → Frontend Services**: Processed and predictive analytics data are visualized through interactive dashboards.

- **Frontend Services → System Integrator & SaaS Platform**: End-users interact through either customized or standard TAPCOP interfaces, utilizing the analytics provided by frontend services.

This modular and interoperable structure facilitates real-time analytics, predictive traffic management, and enhanced user interaction, aiming at optimizing urban mobility and responsiveness to traffic conditions.

3.3. xyzt.ai Big Data Visual Analytics Architecture

The xyzt.ai platform implementation for TAPCOP follows closely the general architecture. The implementation is cloud-agnostic, but a SaaS environment is deployed on Amazon AWS as presented in Figure 4.

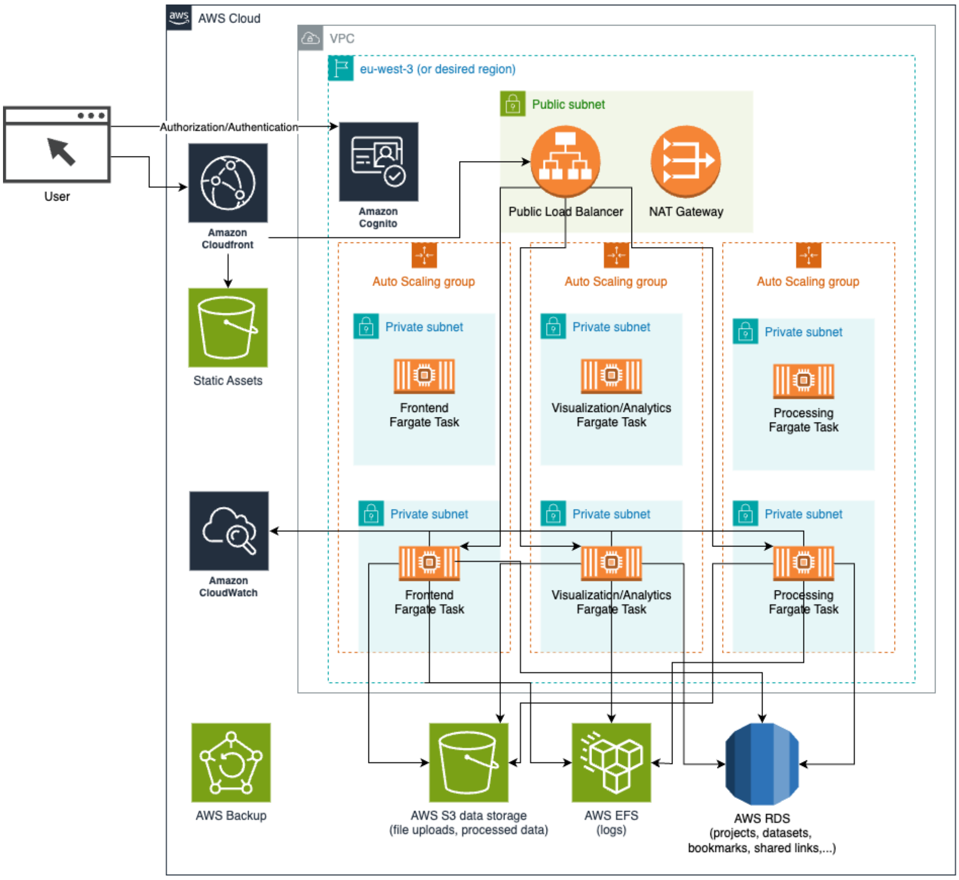


Figure 4. xyzt.ai TAPCOP architecture realization on Amazon Web Services.

xyzt.ai leverages various AWS services, such as AWS S3 and EFS for big data storage, AWS RDS for relational data storage, AWS Fargate (ECS) for scalable compute micro-services, AWS CloudWatch for monitoring and log reporting, and AWS Backup for backups. A load balancer and scaling groups make sure that the different micro-services for backend and frontend can scale automatically. The Visualization/Analytics and the Frontend micro-services expose public REST APIs for data upload, data processing, data querying, and dashboard creation. The REST APIs follow the OpenAPI conventions.

Figure 5 provides a screenshot of the frontend of xyzt.ai.

Figure 5. Frontend of the xyzt.ai platform.

3.4. Train CCTV cybersecurity architecture

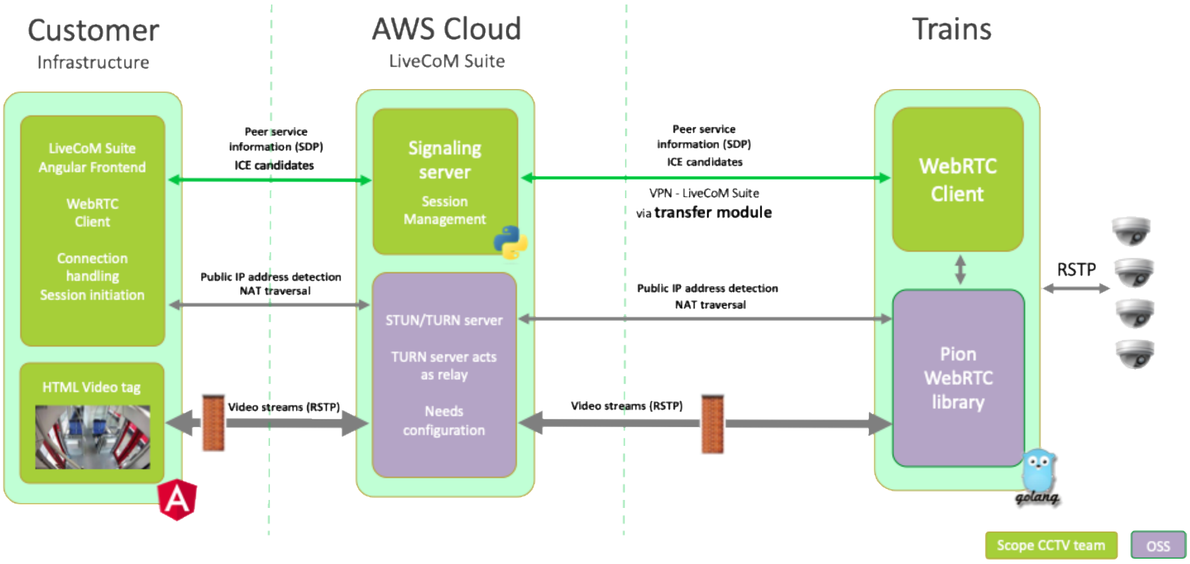


Figure 6. Train CCTV system.

The increasing deployment of CCTV systems in trains introduces significant security and privacy risks. Multiple stakeholders, including train conductors, control center personnel, and law enforcement agencies, require access to footage for various operational and investigative purposes. However, ensuring passenger privacy and preventing unauthorized access to video footage are critical concerns.

This research project presents a robust software architecture (Figure 6) designed to authenticate authorized personnel and enforce access control based on predefined authorization levels. Additionally, the architecture ensures secure transmission of video data from onboard cameras to a cloud-based storage system while preventing unauthorized access or data breaches.

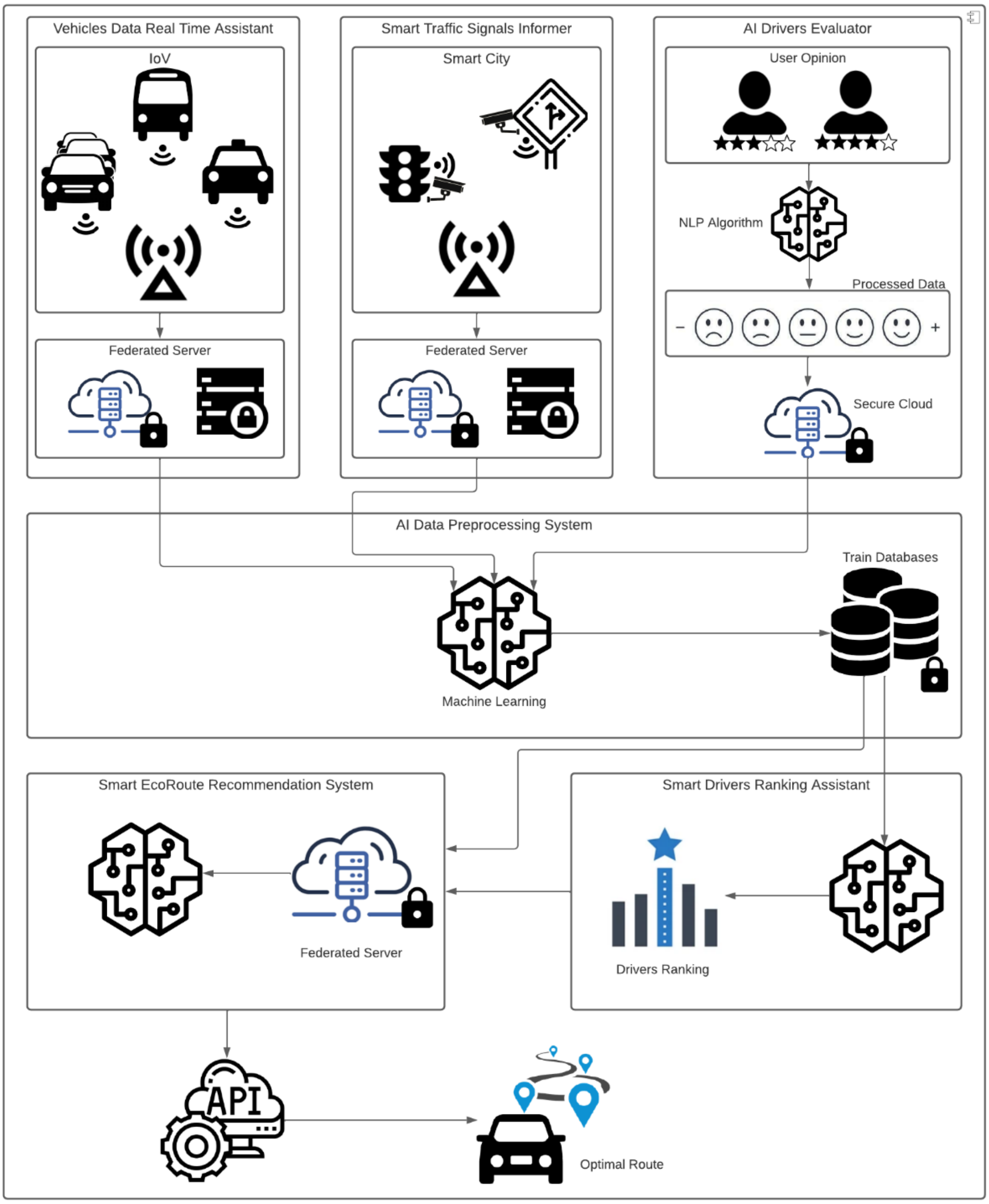
System Overview

To meet the stringent security and accessibility requirements, the TAPCOP project researched a distributed CCTV architecture for trains. The system integrates multiple components to ensure controlled and secure access to video footage while preserving privacy.

Key Features

1. **Secure Video Streaming and Storage**
   - CCTV cameras installed throughout the train stream video via encrypted RTSP (Real-Time Streaming Protocol) to a WebRTC client.
   - The footage is locally buffered and stored for onboard review.
2. **Onboard Access Control**
   - Train drivers and conductors can review footage through an HMI (Human-Machine Interface) after successful authentication.
   - The authentication mechanism ensures that only authorized personnel can access the footage based on predefined permission levels.
3. **Remote Access and Cloud-Based Session Management**
   - For remote access from control centers or law enforcement agencies, a cloud-based session management system is implemented.
   - The session is established through Peer Service Information packages (SDP) from the requesting entity to the cloud and then relayed over a VPN to the train.
   - A secure video stream pipeline is configured with appropriate access settings, ensuring controlled and encrypted RTSP transmission.
4. **Privacy Protection and Data Security**
   - Privacy-sensitive information is selectively redacted either at the camera level or within the onboard video recorder.
   - All data transfers between cameras, onboard recorders, and the cloud are encrypted to prevent unauthorized access or tampering.

3.5. Netcheck Platform architecture



Interoperability is achieved through extraction, transformation and loading (ETL) tools, which synchronize data between both databases. In addition, integrated APIs allow system modules to perform queries directly in both tools depending on the type of data they need.

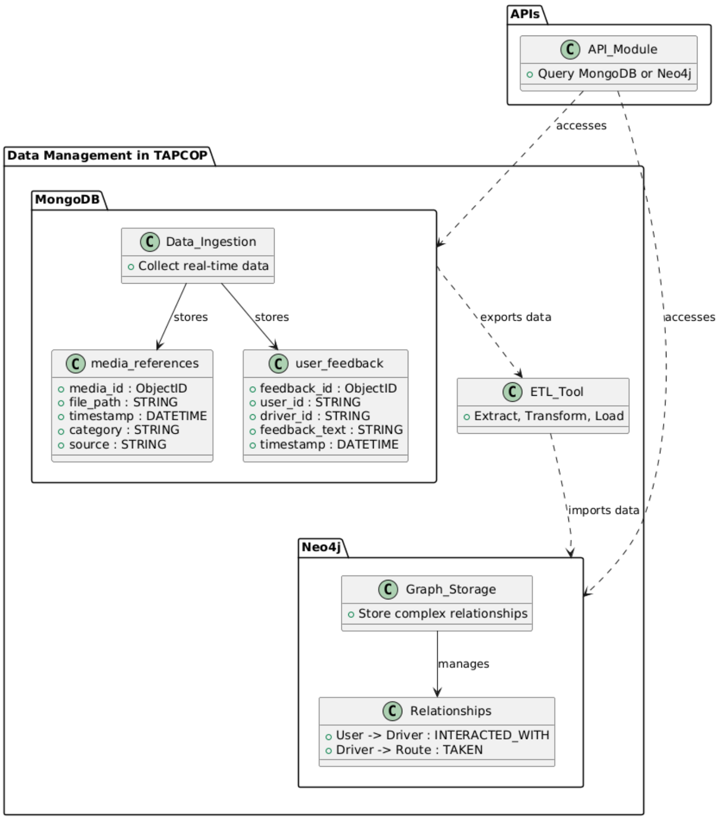


Figure 7. UML Interoperability diagram.

The Data framework in Figure 8 has three main functions:

Data Collection: Captures real-time information from IoT sensors and connected devices, as well as historical or batch data from external sources. This process ensures that the data is relevant, up-to-date, and representative.

Data Aggregation: Combines, validates, and organizes data from multiple sources. This includes eliminating redundancies, harmonizing formats, and ensuring consistency across all processed information.

Data Publishing: Distributes processed data through standardized APIs and access control systems, ensuring that only authorized users can access specific information based on their permissions.

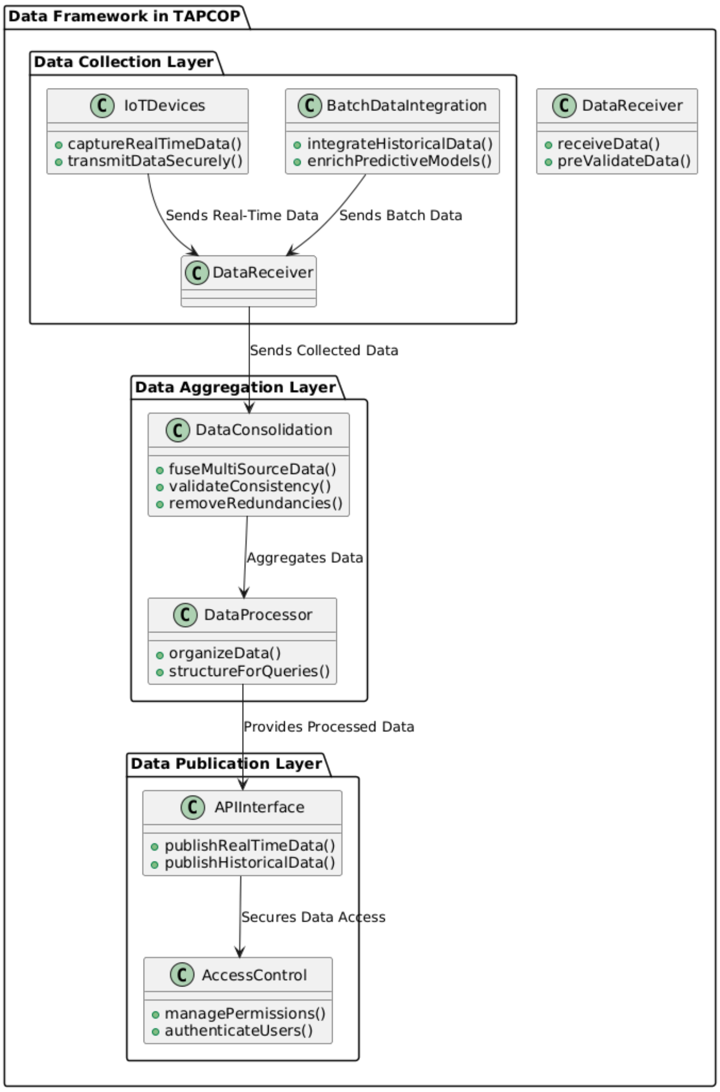


Figure 8. Data framework in TAPCOP.

3.6. Macq Mobility Manager

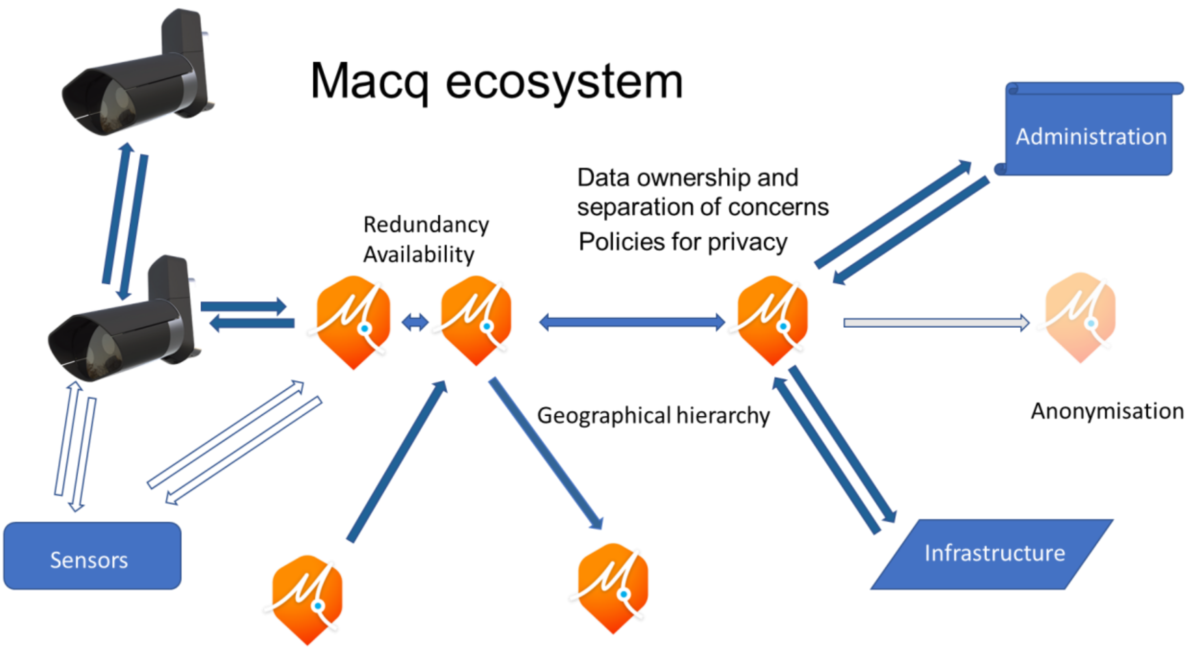


Figure 9 Macq ecosystem showing interconnections

The Macq ecosystem consists of backend servers and on the edge sensors with embedded computation capabilities.

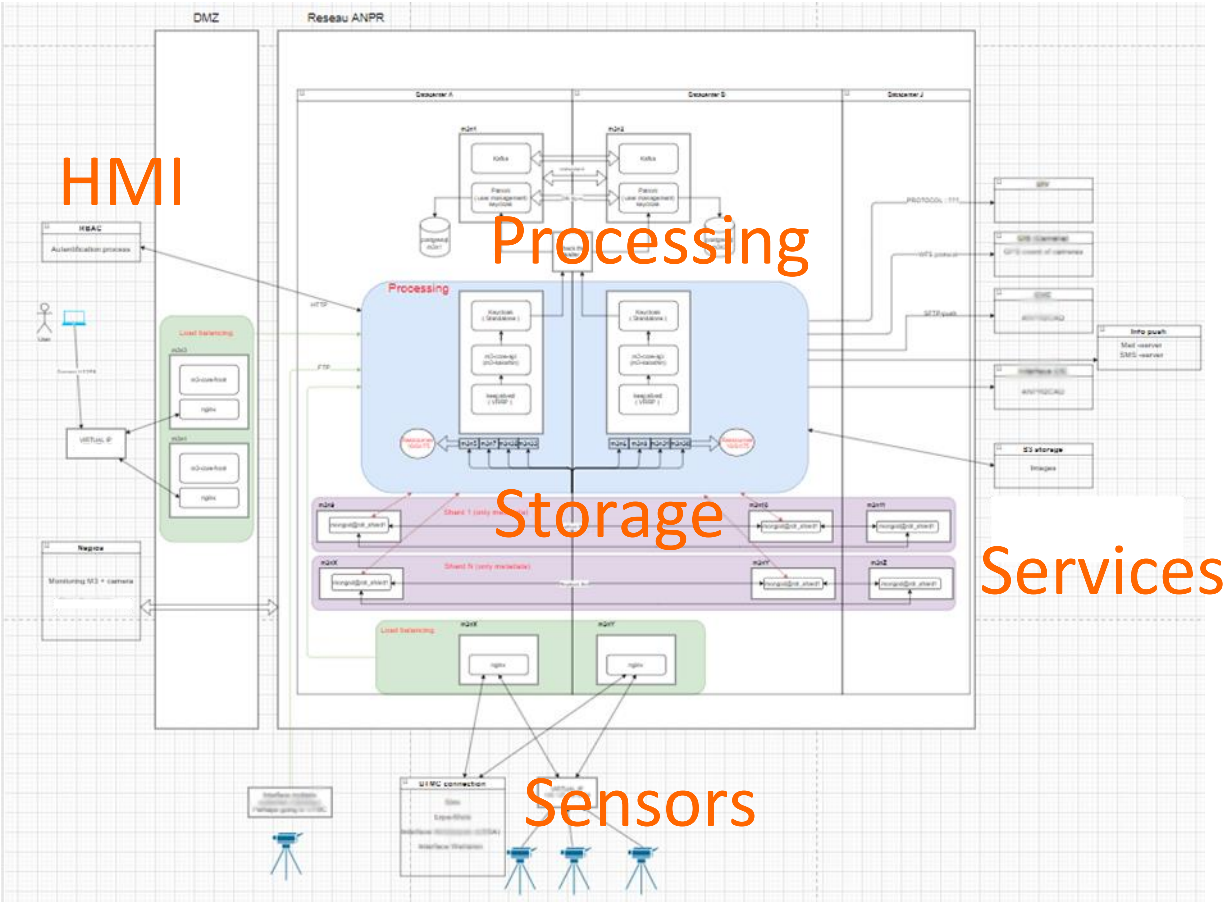


Figure 10 Internal architecture of a Macq M3 system

Depending on the client needs the Macq Mobility Manager (M3) can be made redundant by distributing it across two data centra and scalable/redundant inside a data centrum using sharding.

The Macq TAPCOP implementation follows the TAPCOP architecture. The QCAM cameras do all the processing on the edge using their embedded NVIDIA processors. Other sensors can connect to the camera via protocols or the IO interface. For passive sensors Macq has an AI box in its product gamma that is similar to the camera but without the video capture sensors and more connectivity.

The Macq Mobility Manager M3 connects to the QCAM series of camera or third-party cameras and other OEM sensors. Other already processed batch data streams like Floating Car Data, Bike parking data, Weather data, etc can in real time be collected by M3.

AI models can run on the edge (real time) and on the M3 (post processing of image data and large data analytics and fusion).

On the right-hand side of the TAPCOP architecture we find the operational human interfaces and dashboards. Connections to other data analytic systems like xytz.ai are possible.

4. Conclusion

D2.1 provides a high-level overview of the TAPCOP architecture and functional component specification. Additionally, in depth descriptions of the individual company instantiations are discussed focusing specifically on xyzt.ai's Big Data Visual Analytics Architecture, Televic's train CCTV cybersecurity architecture, Macq Mobility Manager and Netcheck's platform architecture.