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Title: *AI Mavericks Team - Report on ITU WTSA Hackathon 2024 – Traffic Optimisation and Urban Mobility*

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Abstract: This document contains the submission of a report for the AI Mavericks Team towards ITU WTSA Hackathon 2024 for use case *Traffic Optimisation and Urban Mobility.*

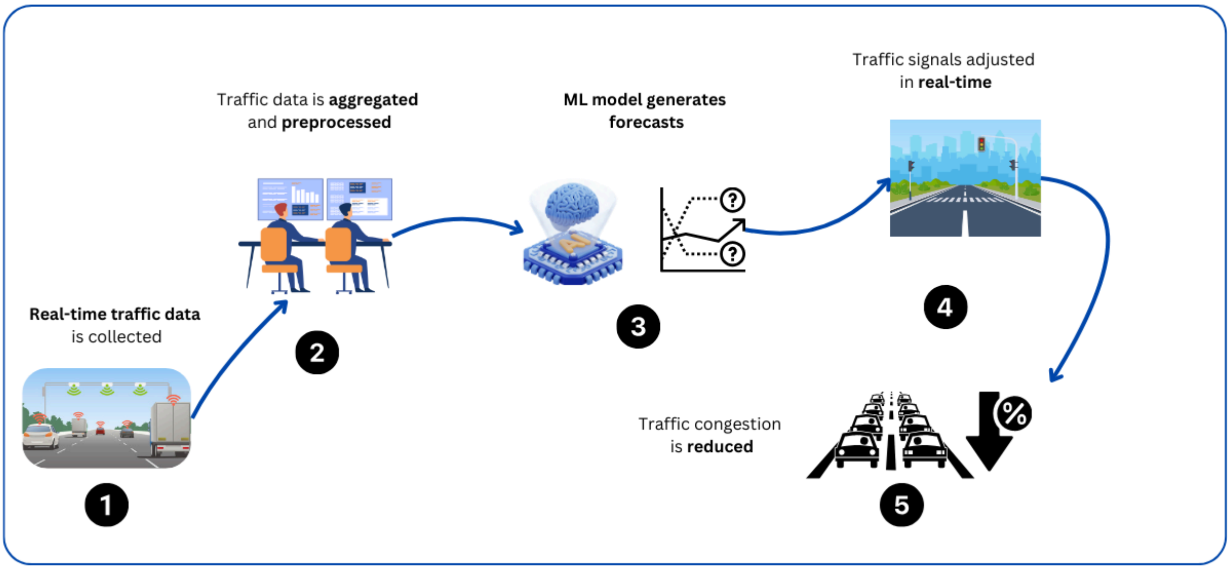
Use case introduction: "Traffic Optimisation and Urban Mobility"

A modern city is often characterised by a road network that often struggles to cope with traffic during peak-hours, resulting in bottlenecks, delays, and inefficient use of road infrastructure. These issues are exacerbated by a lack of real-time traffic management systems and data-driven decision-making. Without the ability to predict traffic patterns and optimise network resources, the city's mobility systems fail to respond dynamically to changes in traffic volume, leading to sustained congestion, especially during peak hours.

This use case focuses on building an AI/ML model to predict traffic patterns in real-time, using data from CCTV cameras or other similar sensors (loop coil induction sensors), and weather data. By leveraging 5G/6G network capabilities, the model will help manage traffic signal timings and help reduce congestion. This aligns with ***SDG 11: sustainable cities and communities.*** The following objectives will be considered:

1. *To predict traffic patterns:* by using historical and real-time data to identify areas of congestion and forecast traffic conditions.
2. *To optimise the timing of traffic lights*: By adjusting traffic lights dynamically based on the traffic flow to improve the movement of vehicles.

The scene map shown below illustrates the key components of the traffic optimisation system:



Phase 1: "*Data Collection Initiation*" - The system starts with CCTV cameras or sensors installed at key intersections collecting real-time data on traffic flow.

Phase 2: "*Data Aggregation and Processing*" - Collected data is sent to a central server for aggregation. Here, it undergoes data cleaning and feature engineering to ensure accuracy and relevancy. Relevant features include time of day, weather conditions, and historical traffic patterns.

Phase 3: "*Traffic Prediction*" - The processed data feeds into the AI traffic prediction models, which analyse current and historical patterns to predict future traffic flow. The models generate forecasts of potential congestion points based on real-time inputs.

Phase 4: "*Traffic Optimisation Implementation*" - Based on the predictions, the system dynamically adjusts traffic signal timings at intersections. This real-time optimisation helps to alleviate congestion by allowing for smoother traffic flow, effectively reducing delays.

Phase 5: "*Optimised Traffic Flow Achieved*" - The culmination of these phases results in optimised traffic flow across the city. Traffic congestion is reduced, travel times are improved, and overall urban mobility is enhanced, contributing to a more sustainable city.

use case requirements

Requirement-1: It is essential that real-time traffic data on traffic flow or volume be collected from CCTV cameras or other alternative sensors installed at key intersections.

Requirement-2: It is critical that weather data be integrated to enhance the analysis of traffic flow and congestion.

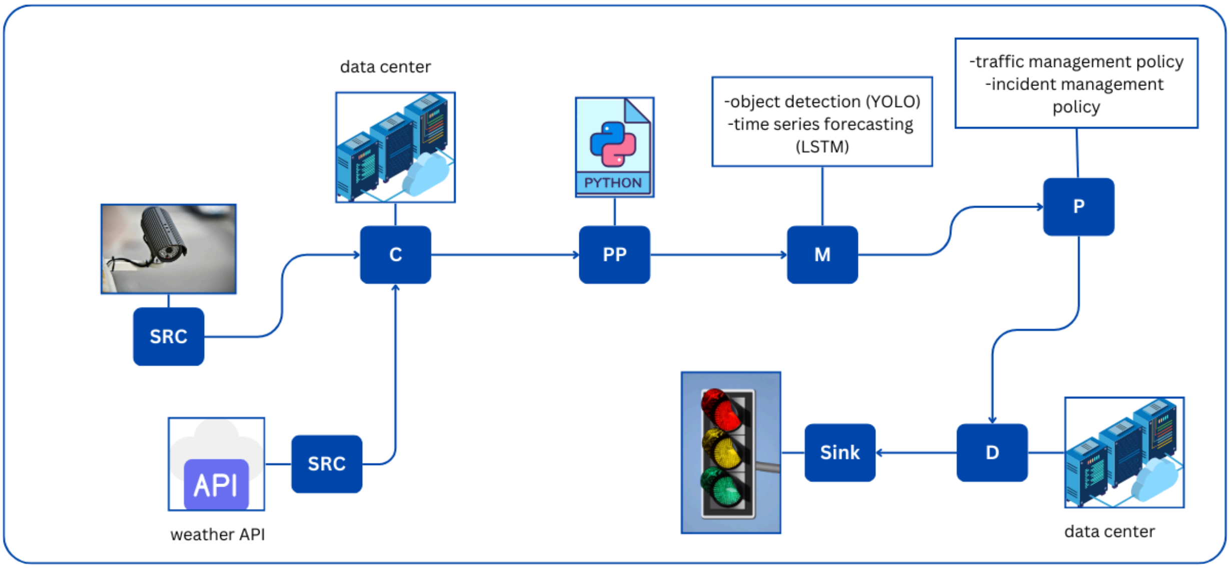
Requirement-3: It is important that an AI traffic prediction model(s) be developed to analyse historical and real-time data to predict future traffic conditions and identify congestion points.

Requirement-4: It is necessary that the system dynamically adjust traffic signal timings based on AI predictions to optimise traffic flow effectively.

Requirement-5: It is essential to ensure low-latency data transmission between sensors and server, and between server and traffic controllers that control the operate the traffic lights.

AI/ML Pipeline design

The AI/ML concepts used in this pipeline are traffic prediction and dynamic signal optimization. The design aligns with ITU standards (ITU Y.3172) for integrating AI/ML into network operations, ensuring compatibility and interoperability. The pipeline consists of several key components that work together to predict traffic conditions and optimise traffic flow in real-time.



1. *SRC (Source):* The sources of data will include CCTV cameras installed at key intersections, which will provide real-time data on vehicle counts, speeds, and traffic incidents. Real-time weather data through an API (e.g. Open Weather Map) will enhance traffic flow analysis.
2. *C (Collector):* A centralised Traffic Management Center will serve as the collector, aggregating data from traffic sensors and other sources. It will configure these sources to ensure accurate and timely data collection.
3. *PP (Preprocessor)*: Data preprocessing will involve using Python libraries such as Pandas and NumPy to clean and aggregate the collected data. This step ensures that the data is ready for analysis by removing duplicates, handling missing values, and extracting relevant features like time of day and weather conditions.
4. *M (Model):* Object detection algorithms will be utilised to get the vehicle count. A traffic prediction model will utilise algorithms such as Google's Temporal Fusion Transformer (TFT) networks for multivariate time-series forecasting. This model will analyse the processed data to predict future traffic conditions and identify potential congestion points.
5. *P (Policy):* Policies for adjusting traffic signals will be applied based on the model's predictions. For instance, if congestion is predicted, traffic signals will be adjusted according to predefined rules to minimise delays.
6. *Distributors*: A server at the data centre will act as the distributor, sending optimised traffic signal timings to intersections. It will configure the traffic signal systems to ensure they respond correctly to the received instructions.
7. *SINK*: Traffic lights at road intersections will serve as the SINK, taking actions based on the outputs from the machine learning model. These signals will adjust their timings dynamically to improve traffic flow based on real-time predictions.

Relation to Standards

The design and implementation of the Traffic Optimisation and Urban Mobility system is aligned with the relevant standards established by the International Telecommunication Union (ITU) to ensure interoperability, reliability, and efficiency. The system leverages AI/ML capabilities in a networked environment, conforming to the following key standards:

1. ITU-T Y.3172 – Architectural Framework for Machine Learning in Future Networks: The AI/ML pipeline design of the system is structured based on the framework outlined in ITU-T Y.3172, which specifies how machine learning can be integrated into future networks.
2. ITU-T Y.3181 – Machine Learning-Based Data Handling Framework: This standard provides guidelines for handling large volumes of data in AI/ML systems, which is essential for processing the real-time traffic data in the proposed system.
3. ITU-T Y.3061 – Framework for Autonomous Networks - The system also adheres to the principles of ITU-T Y.3061, which provides a framework for building autonomous networks. The traffic management system aims to function autonomously by dynamically adjusting traffic signal timings based on real-time conditions, without the need for manual intervention.
4. ITU-T Y.3112 – Framework for Data-Driven Networking: This standard supports the system's approach to managing and utilising data-driven insights for network optimization. The system should ensure the optimal use of network resources, such as bandwidth and processing power, for real-time traffic management.

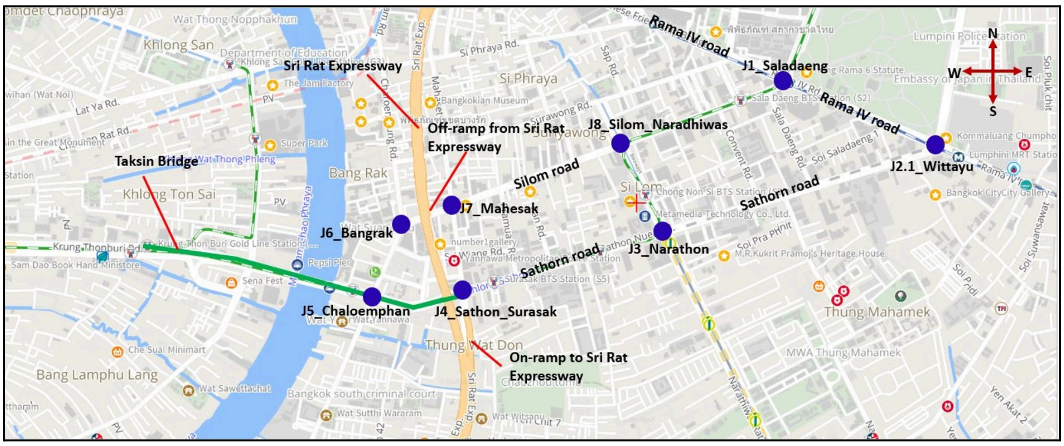
Code submission details

The code can be accessed via github. Instructions on how to retrieve and process data, as well as developing models is detailed in the README.md.

Overview of Datasets and Self-Testing Results

Datasets

1. ***Traffic flow data:*** Data was collected by Mon, et. al (2022) from sensors (CCTV cameras, thermal cameras and induction loop sensors) installed on the approaching lanes of the Sathorn-Surasak intersection in the Sathorn area of Bangkok. Traffic volume data was collected every 5 s for 37 months from September 2016 to September 2019. The dataset has temporal and spatial coverage of Sathorn road's main urban areas, including weekdays, weekends, and public and national holidays. The data can be accessed here.



2. ***Weather data***: To get access to historical weather data we used Open-Meteo Historical Weather API. via the Python API client. The dataset has a resolution of 1 hour.

References

Mon, E.E., Ochiai, H., Komolkiti, P. *et al*. Real-world sensor dataset for city inbound-outbound critical intersection analysis. *Sci Data* 9, 357 (2022). https://doi.org/10.1038/s41597-022-01448-6