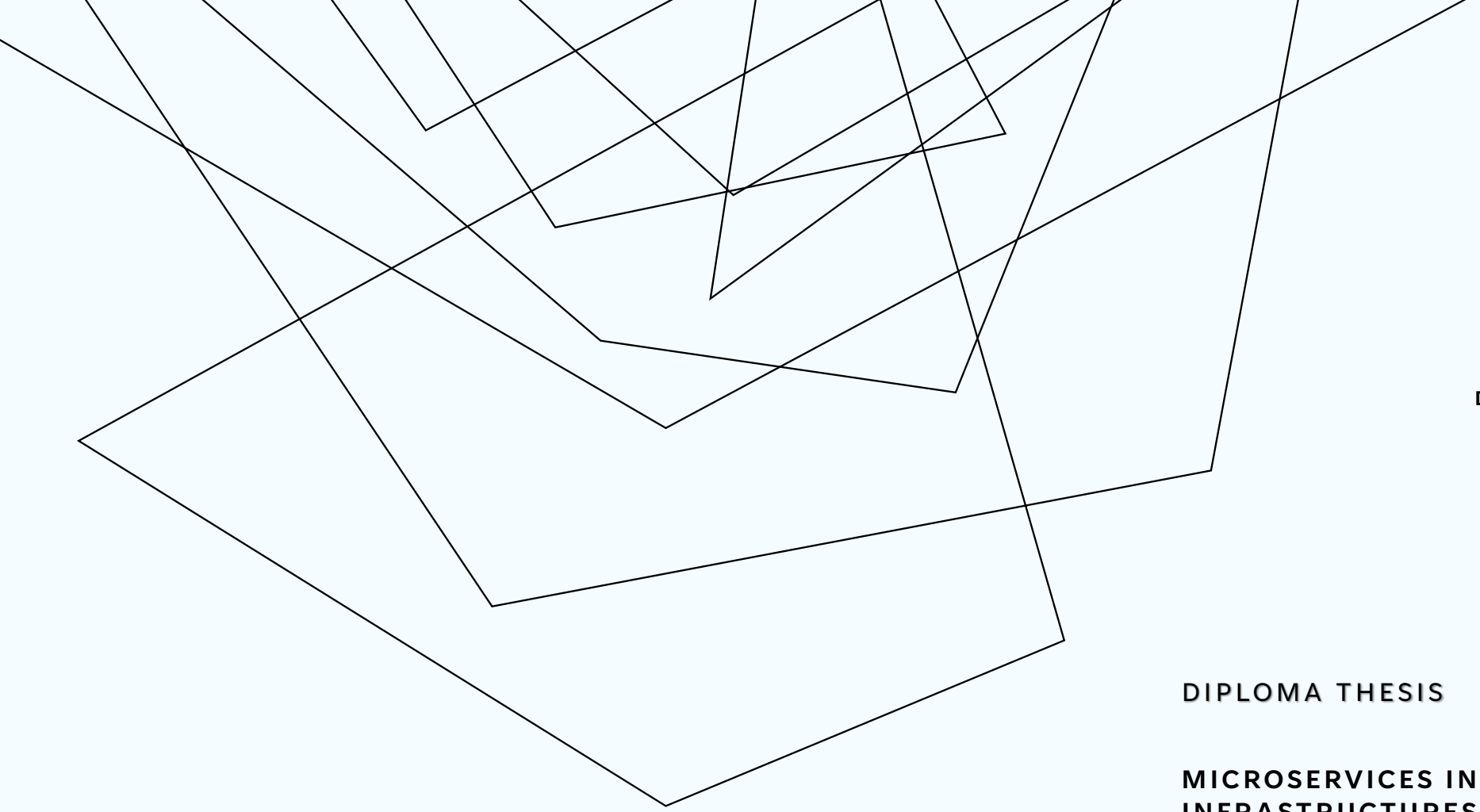


UNIVERSITY OF THESSALY

SCHOOL OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

INSTITUTE OF INFORMATICS & TELECOMMUNICATIONS

DIPLOMA THESIS

MICROSERVICES IN INTERNET OF THINGS INFRASTRUCTURES FOR SMART CITY SOLUTIONS: AN EVENT-DRIVEN AIR QUALITY MONITORING APPLICATION UTILIZING APACHE KAFKA AND CLOUD METHODOLOGIES

Author: Nikolaos Kallin. Kolovos

Supervisor: Georgios Stamoulis

INTRODUCTION

Event-driven IoT **Air Quality** monitoring application, utilizing advanced cloud methodologies.

SYNAISTHISI platform, Apache Kafka, Kafka Connect and Schema Registry integration.

Efficient **data validation** and **event interconnection** with Kafka Connect and Schema Registry.

High-performance, fault-tolerant, scalable **Apache Kafka** cluster.

Web application for real-time Air Quality data visualization through Web-Sockets and React.

MOTIVATION

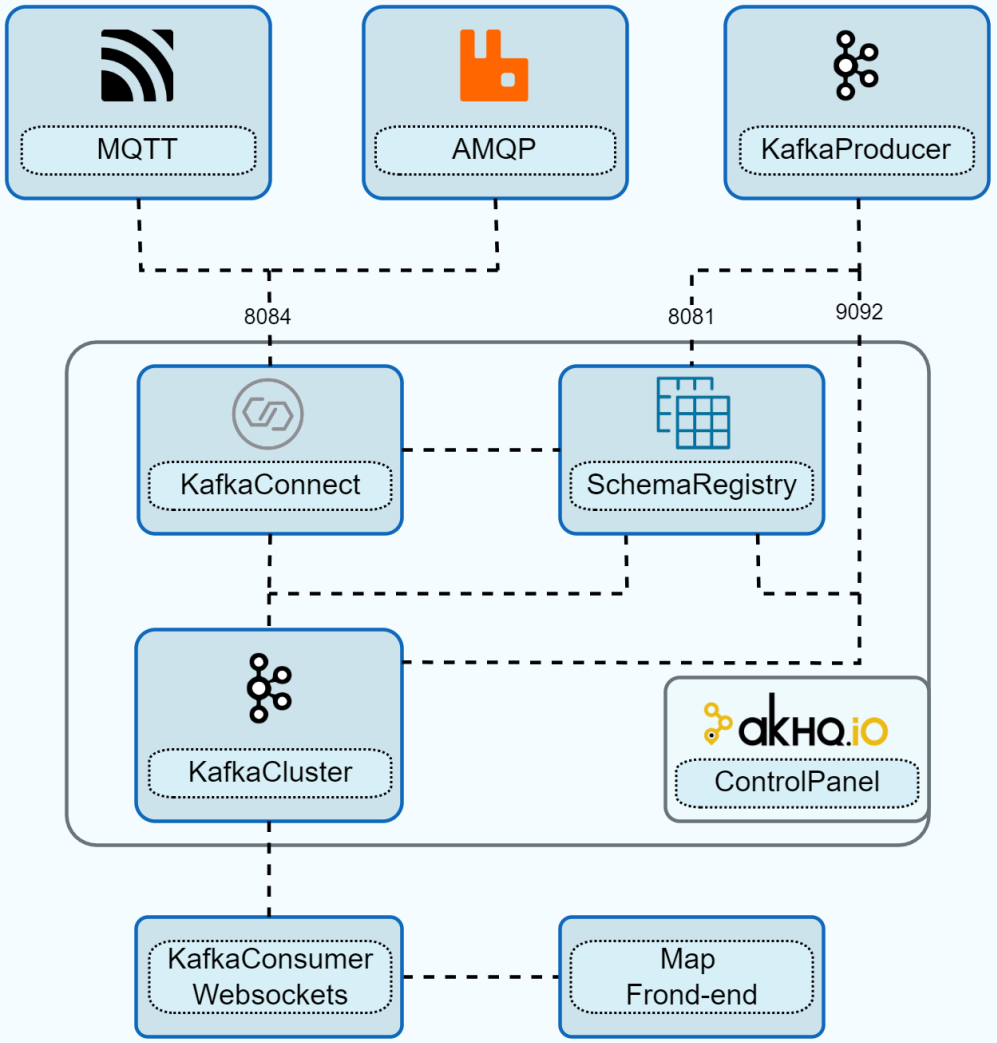
- Environmental Perspective
- Internet of Thing Perspective
- Open-source Approach
- SYNAISTHISI Platform
- Event Streaming Integration

AVAILABLE FRAMEWORKS

- Docker, Docker compose, Docker network
- Apache Kafka
- RabbitMQ, MQTT
- Kafka Connect
- Schema Registry
- Web-sockets
- React

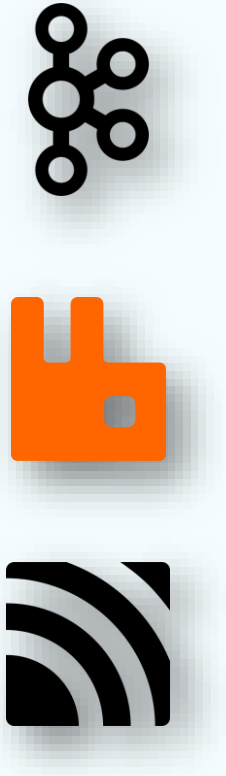
ARCHITECTURE AND IMPLEMENTATION

SYSTEM OVERVIEW

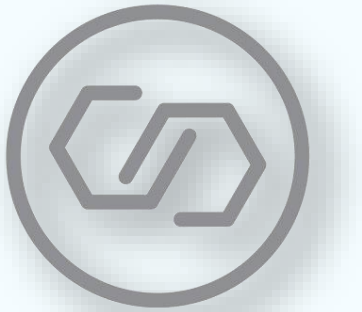


DATA INGESTION

- Producers support native Kafka, AMQP, and MQTT protocols
- Interoperability
- Data Structure
- Data validation



INTEROPERABILITY



Kafka Connect

Bidirectional interconnection between RabbitMQ broker and Kafka.

Alignment of **source connector** with the application's data flow requirements.

Fault-tolerance provided by distributed mode configuration.

Efficient integration with a wide variety of external systems.

Reduction in **development time**.

DATA STRUCTURE

```
{
  "deviceID": "sensor1",
  "latitude": 39.36103,
  "longitude": 22.94248,
  "pm25": 12.5,
  "temperature": 22.5,
  "humidity": 60.0,
  "timestamp": 164099520
}
```

Adoption of JSON file format for **broad system support**.

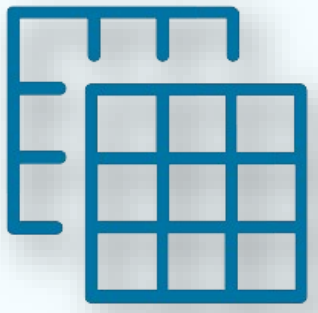
JSON messages with specific fields for **data capture**.

DeviceID and geolocation fields for **spatial data representation**.

Universal timestamps utilizing Unix epoch time.

High **scalability** and **flexibility** in data structure.

DATA VALIDATION



Schema Registry

Avro implementation for compact and efficient serialization of JSON.

Message size reduction by 40% or more.

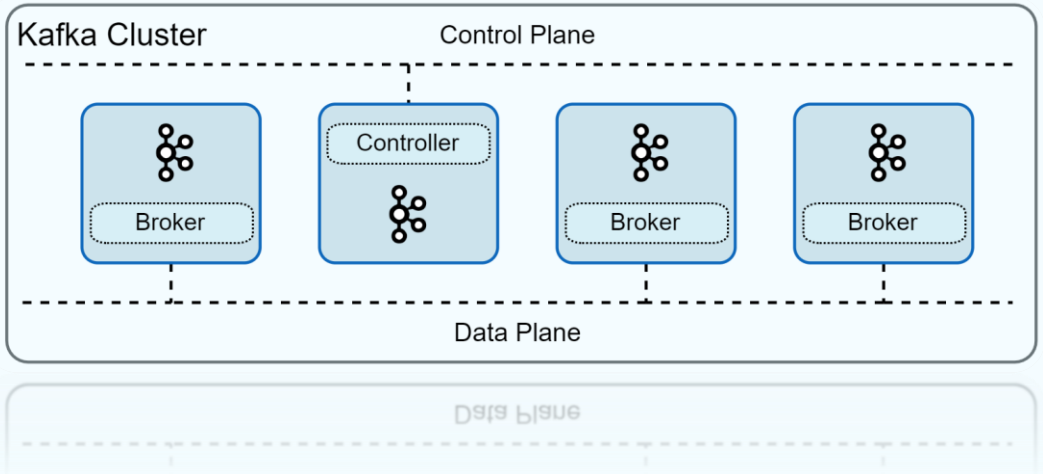
Centralized data management is provided.

Consistent event data structure is ensured.

Flexible interconnection with pre-existing sensors.

Data integrity ensured through schema versioning and evolution.

KAFKA CLUSTER PLATFORM



- Control Plane
- Data Plane
- Control Panel

KAFKA CLUSTER CONFIGURATION AND MANAGEMENT

Four-node Kafka implementation, one controller and three data brokers.

Reliability and **fault-tolerance** by three-broker data plane.

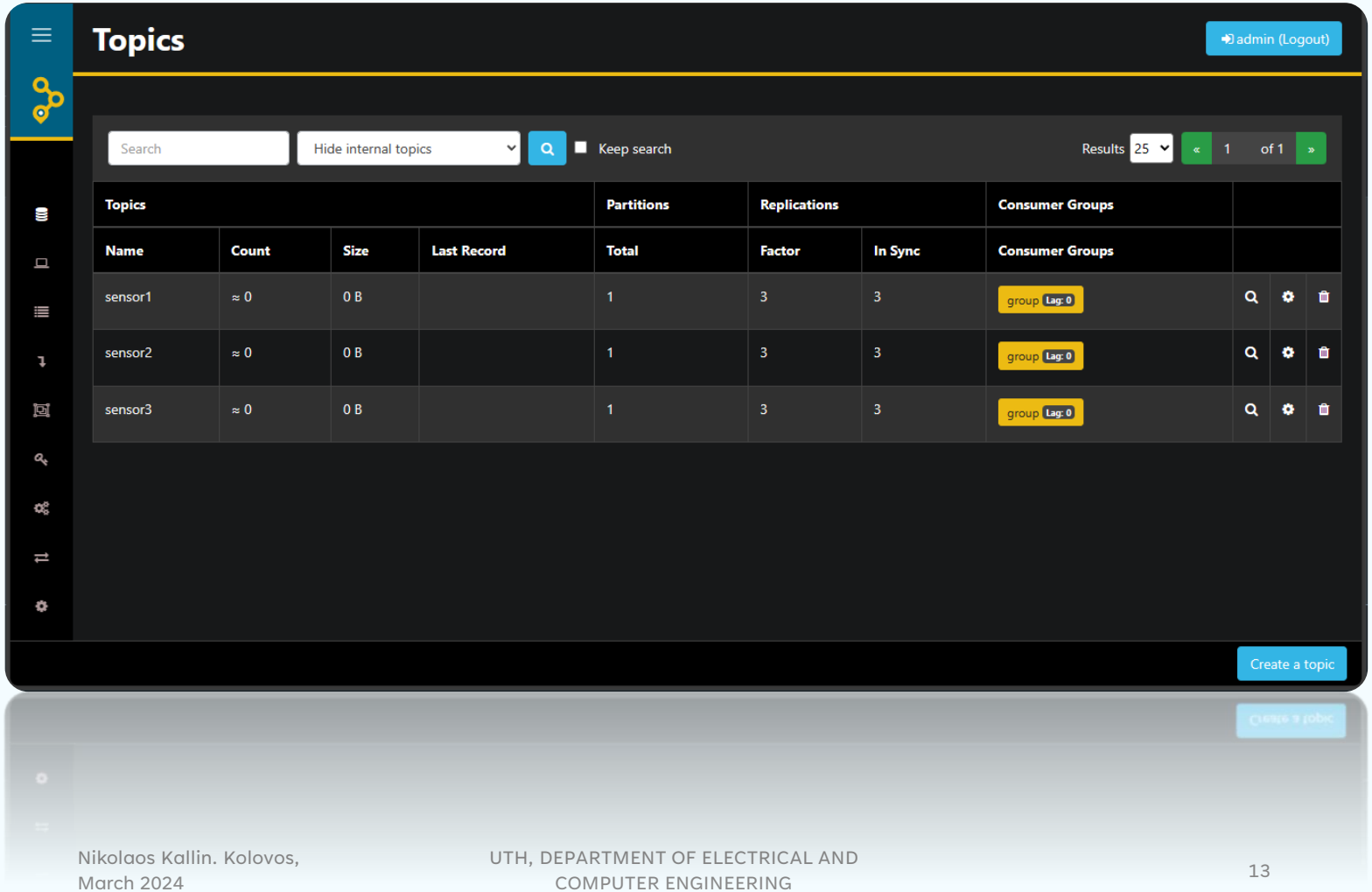
Single controller node for simplicity and robustness.

KRaft protocol, enhanced data recovery and metadata management.

Horizontal scalability, brokers addition based on demand.

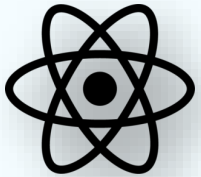
Vertical scalability managed utilizing partitions.

PLATFORM CONTROL PANEL



WEB APPLICATION

- Kafka Consumer Client
- Monolithic back-end service
- Web-sockets
- React Front-end Map



BACK-END SERVICE

Monolithic design back-end infrastructure.

Automatic topics and devices **detection** on the map.

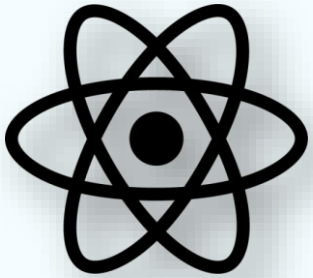
Live event handling with **Kafka consumers**.

Adjustable data consumption rate.

Front-end and back-end communication via **Web-Sockets**.

Enhanced responsiveness and **real-time data** transmission.

FRONT-END MAP



Visually appealing and highly functional React webpage.

Leaflet OpenStreetMap, a widespread open-source map solution.

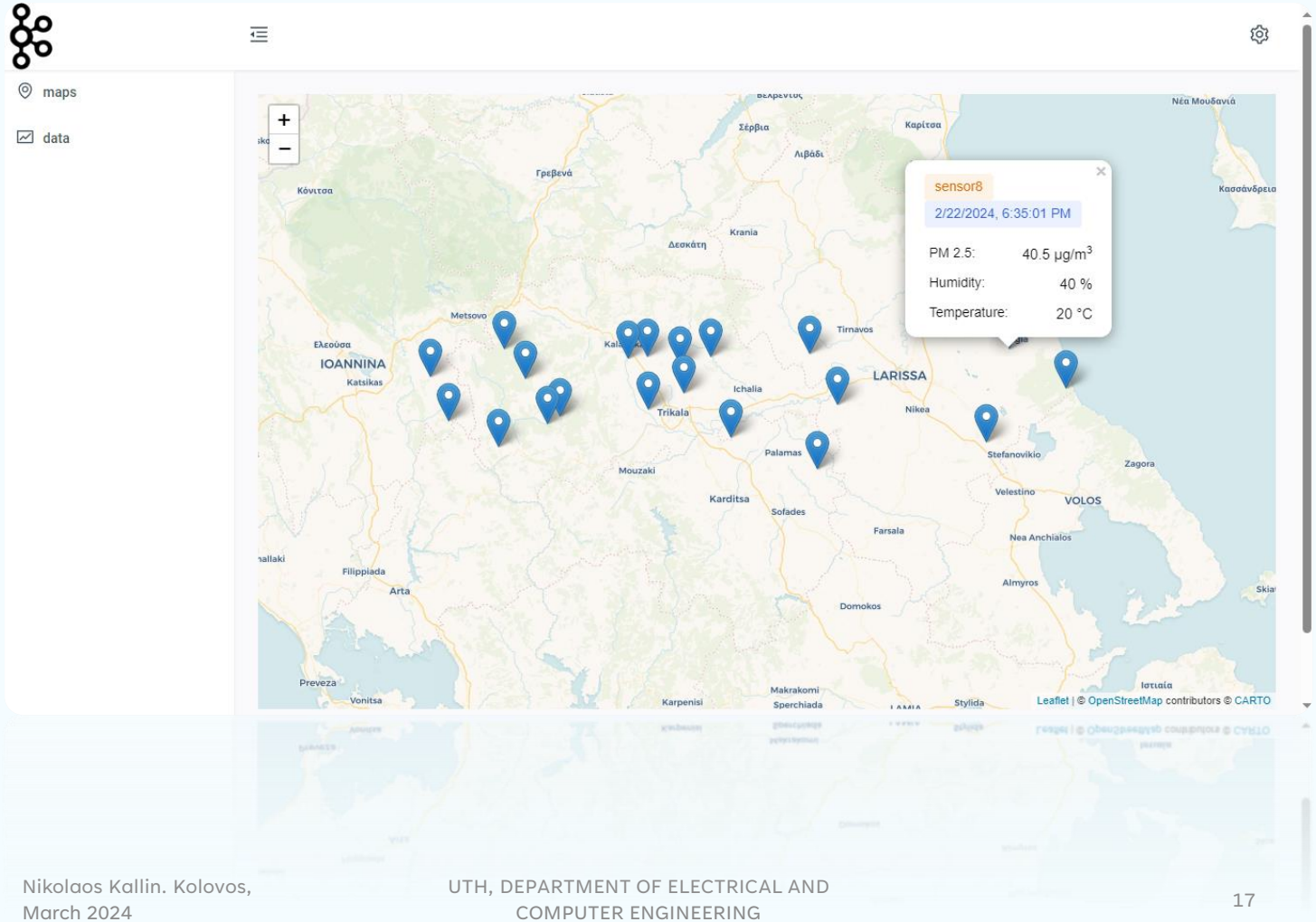
Dynamic, user-friendly **live map page** design.

Dashboard page for historical sensor data display.

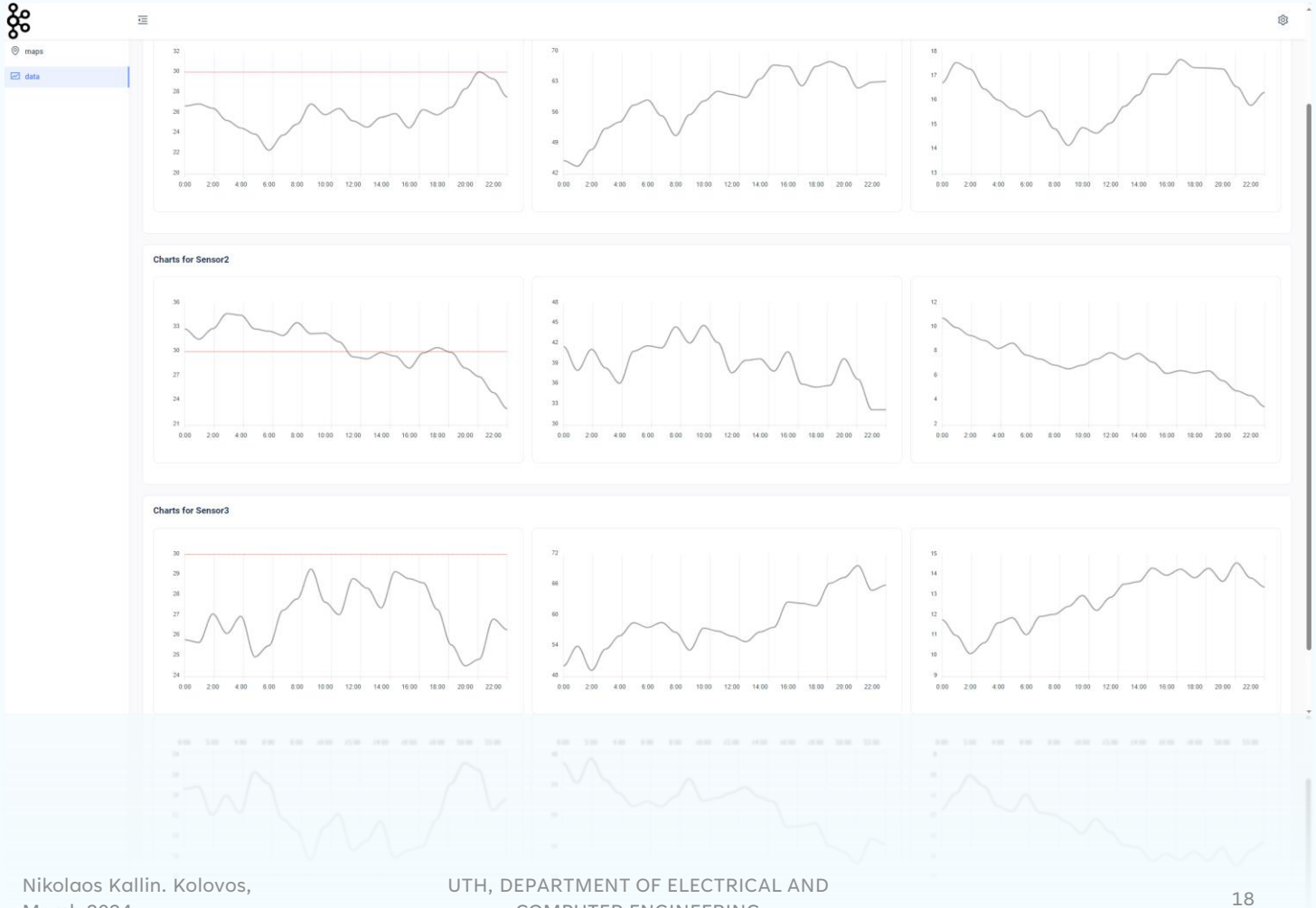
Live updating of points on the map.

Easy management and update of application’s interface.

LIVE MAP


maps
data
sensor8
2/22/2024, 6:35:01 PM
PM 2.5: 40.5 µg/m³
Humidity: 40 %
Temperature: 20 °C
IOANNINA
LARISSA
VOLOS
Trikala
Karditsa
Mouzaki
Palamas
Stefanovikio
Velestino
Nea Anchialos
Farsala
Sofades
Domokos
Almyros
Filippiada
Arta
Preveza
Metsovo
Tirnavos
Ichalia
Nikea
Zagora
Leaflet | © OpenStreetMap contributors © CARTO

DASHBOARD



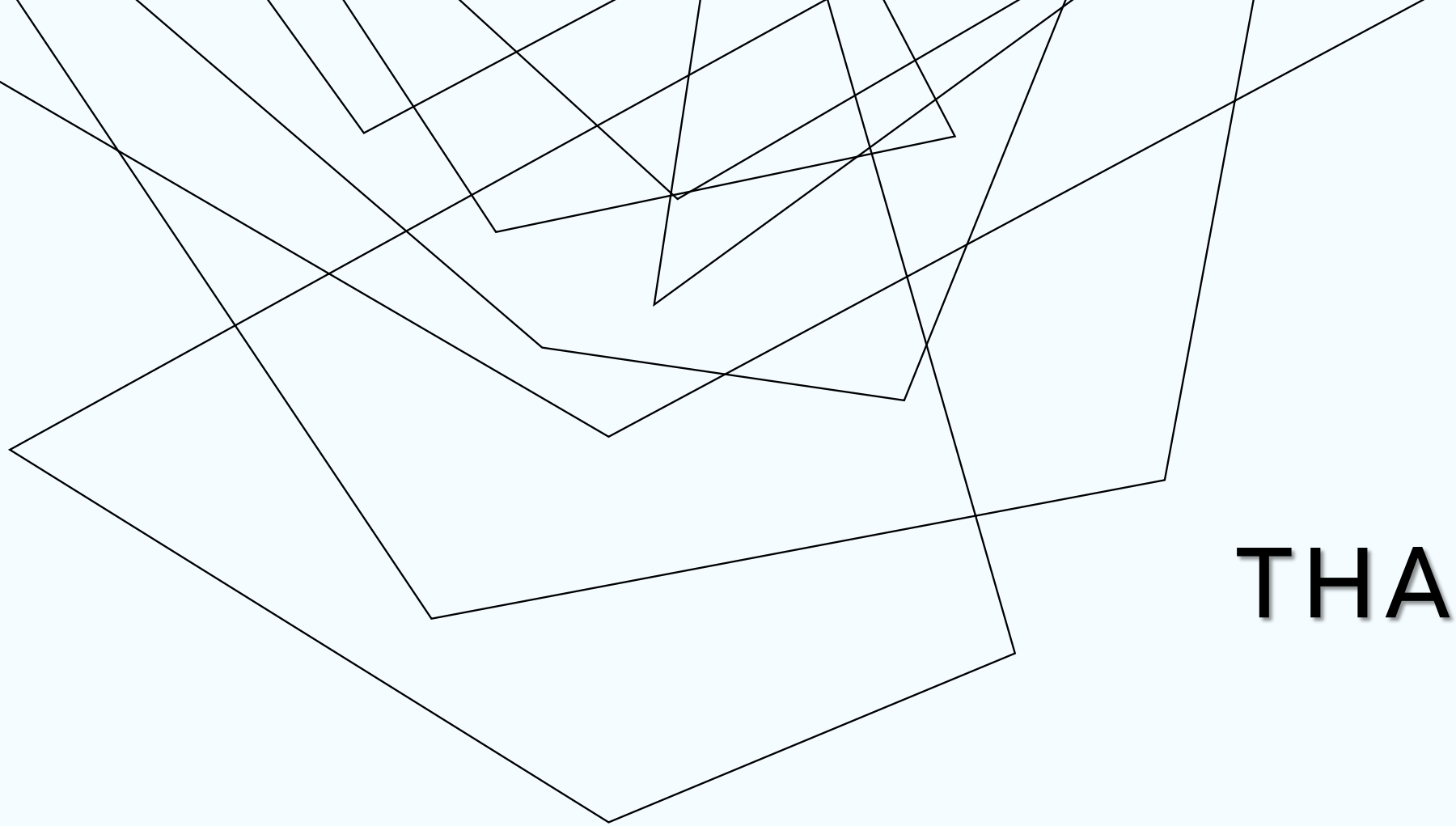
FUTURE WORK

Enterprise-level security using SASL_SSL and TLS(SSL) protocols.

Utilizing SSL for inter-broker communications.

Configuring SASL_SSL for external communications, integrated with a Kerberos server through the GSSAPI authentication mechanism.

Enhancing Kafka's key mapping mechanism for efficient event distribution.



THANK YOU!