Real-time environmental monitoring system architecture using distributed networks of low-cost and high-end sensors combined with remote sensing and data assimilation

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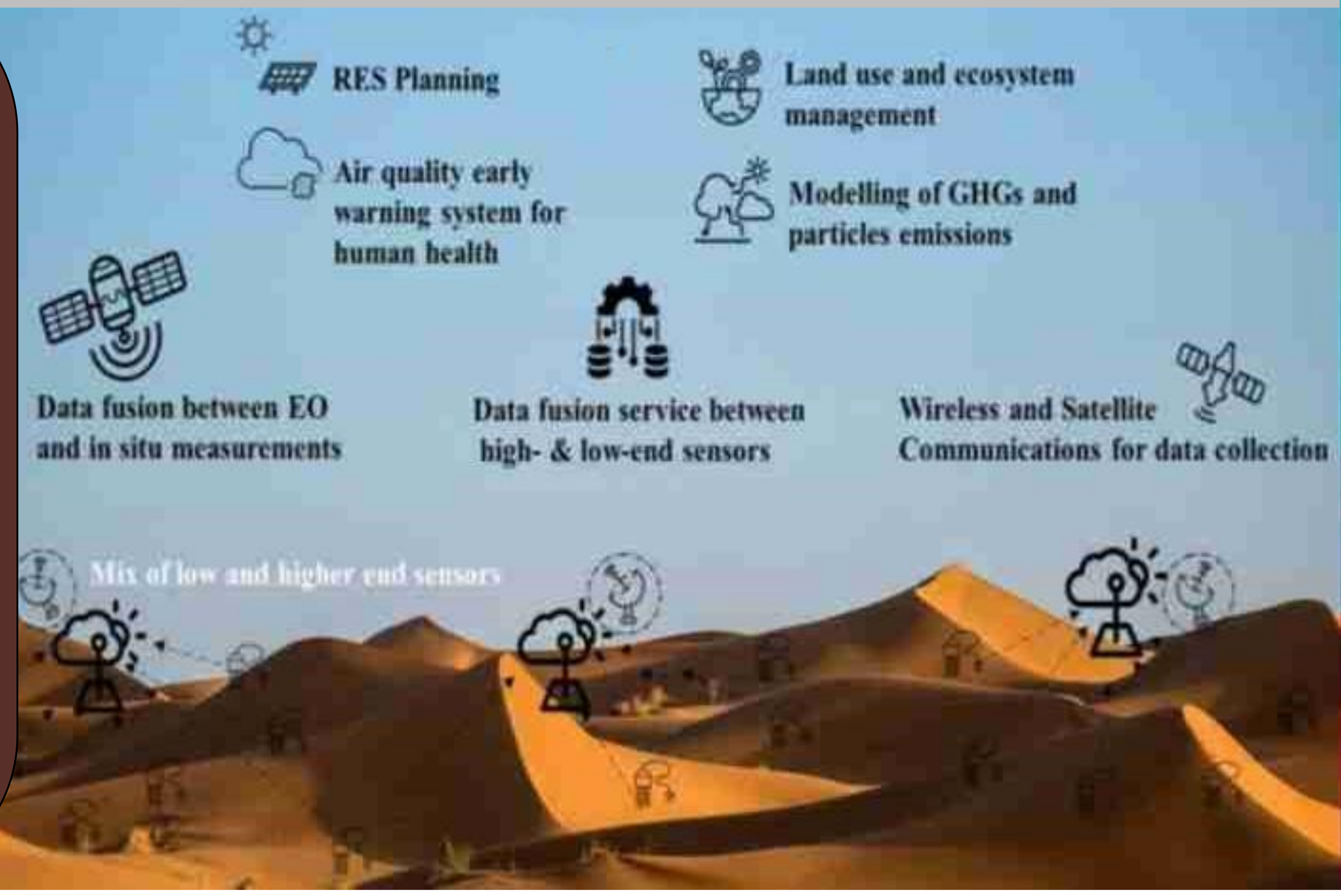
Enhancing the In-situ Environmental Observations across Under-sampled Deserts

Abstract

The impacts of climate change on desert ecosystems are profound and far-reaching, influencing not only local environments but also neighbouring regions, where dust storms transport pollutants and particulate matter over thousands of kilometers. These phenomena pose significant challenges to environmental monitoring and policy-making, requiring innovative approaches to data collection and analysis. In the Horizon Europe CiROCCO project, we have adopted an approach ensuring comprehensive environmental monitoring by leveraging the strengths of high-end sensors offering precise and reliable measurements and low-cost sensors, enabling extensive spatial coverage and high-frequency data acquisition. This integration creates a robust and scalable network, which enhance data accuracy and consistency, can support real-time monitoring and long-term environmental research and conservation efforts. The CiROCCO system architecture has been designed to facilitate the deployment and exploitation of this advanced monitoring framework across diverse environments, addressing the specific needs of four pilot sites in Cyprus, Egypt, Serbia and Spain. It incorporates state-of-the-art data fusion techniques, remote sensing integration, and a flexible modular design, ensuring adaptability to various ecological and socio-economic contexts. Our presentation will provide an overview of the CiROCCO system architecture, emphasising its potential to support not only environmental conservation and research but also evidence-based policy-making and climate adaptation strategies.



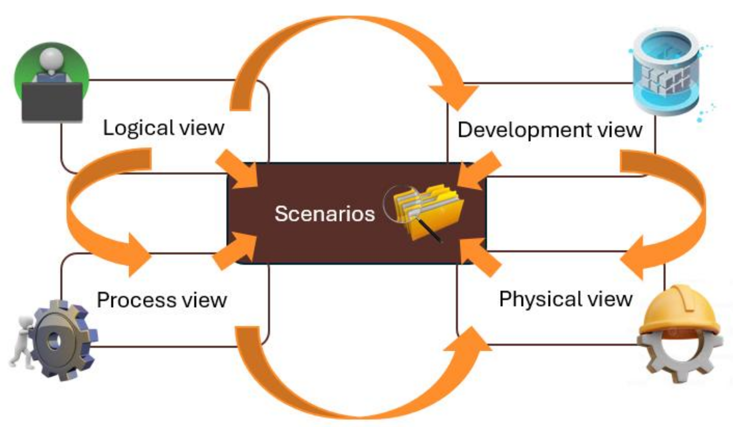
CiROCCO platform key features / requirements

1 Extended network of cost-effective wireless sensors for measuring air quality and local environmental conditions in harsh-to-reach desert ecosystems

2 Robust external connectivity options including satellite IoT, WiFi and LoraWAN networks where edge devices aggregate data and transmits raw or pre-processed data

3 Distributed data streaming platform with hooks for ingesting, storing and processing data and real-time monitoring events (e.g. desert sand storms)

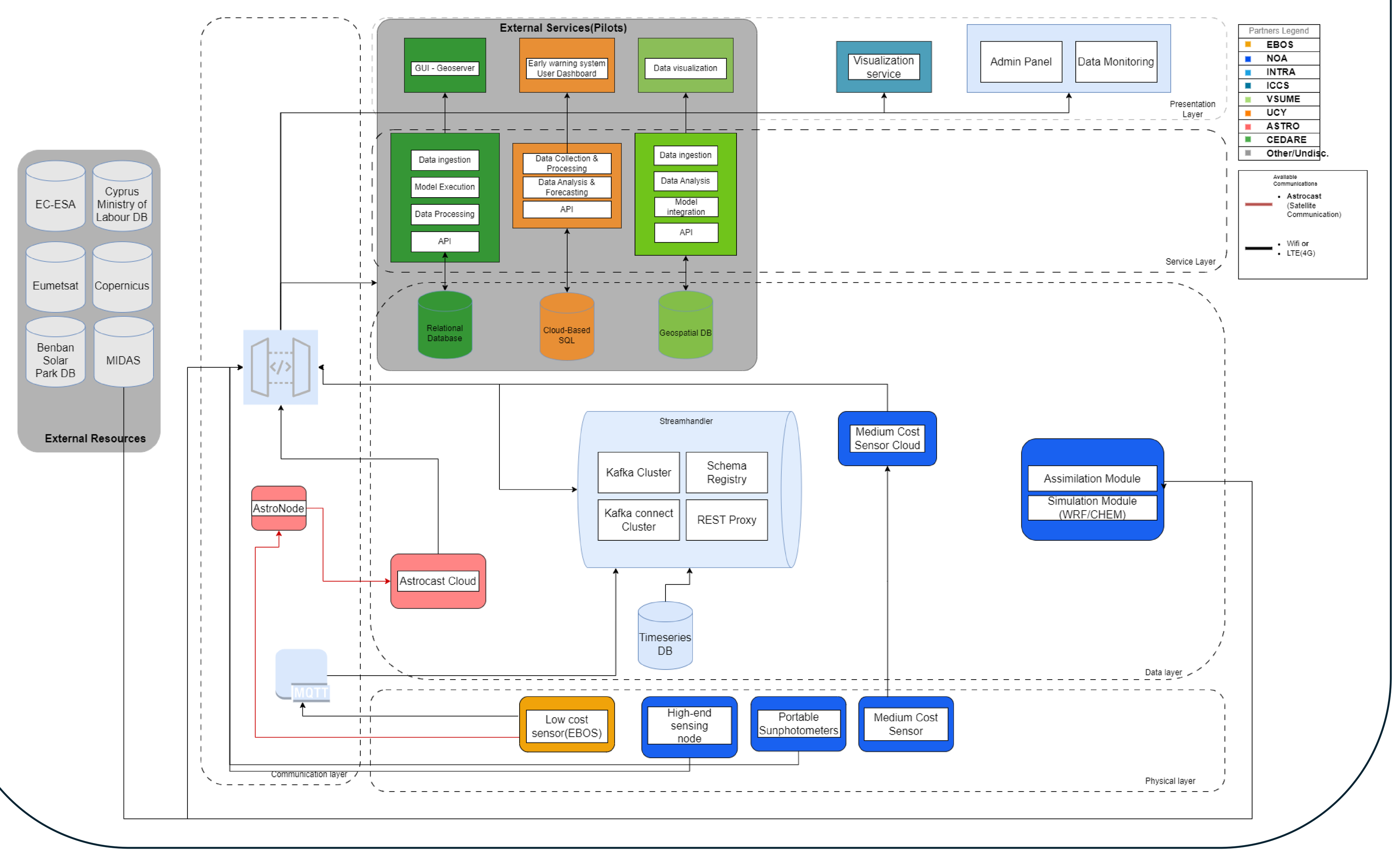
4 Highly scalable Big Data solution coupled with state-of-the-art data fusion remote sensing and data assimilation techniques.



CiROCCO platform concept design

Since requirements describe the problem at hand, the platform architecture outlines the high-level solution. The CiROCCO system architecture design methodology is based on the well-established 4+1 view model of software architecture, developed by Kruchten (1995) and provides a direct and structured way to address the complexity of software architecture

CiROCCO platform logical diagram



Platform architecture design approach

The development of complex systems such as the CiROCCO platform depends heavily on its architecture. We used the layered architectural pattern for system design, also known as the n-tier architecture pattern, which caters for the separation of concerns among components and support modularity and thus flexibility within the platform development. Each layer of this architecture pattern has a specific role within the system and components within a specific layer deal only with logic that pertains to that layer.

For the CiROCCO system architecture, five layers have been defined:

Presentation layer responsible for handling user requests and displaying fetched data. It includes applications, dashboards, UI, and APIs that enable the user to interact with the system.

Service layer acting like a bridge between the presentation layer and the data layer. It handles user requests, as well as data transformation from the data layer to create valuable output based on the business logic of the application.

Data layer responsible for the storage of data and the communication with the system databases.

Communication layer supports the connectivity among remote devices as well as data exchange between applications of the system.

Physical layer, the last layer considered as the "bottom" layer of the system. It includes the sensors and the smart devices that collect information from the surroundings in the CiROCCO pilot sites.

Bibliography

Kruchten, P. B. (1995), *The 4+1 view model of architecture*, IEEE Software, 12(6), 42-50, https://doi.org/10.1109/52.469759
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