

# VITAL: Development of Internet-of-Things Applications for Smart Cities Made Simple

## Abstract

The development and deployment of non-trivial Internet-of-Things (IoT) applications in smart cities is associated with several challenges stemming from the need to integrate a large number of heterogeneous IoT systems and data sources. The VITAL Smart City Operating System (VITAL-OS) provides the means for collecting, interconnecting and processing IoT services and data streams from diverse sources in an interoperable way. Moreover, it provides a set of visual tools for developing applications at an optimal effort and cost.

## 1 The Problem

For over a decade, large numbers of IoT systems have been deployed in smart cities. These systems span different IoT technologies (e.g., Wireless Sensor Networks [WSN], Radio-Frequency Identification [RFID], Cameras) and target different application areas such as smart energy, smart transport and logistics. Hence, they tend to form vertical fragmented application silos, which can barely exchange information or services. Modern cities are increasingly under pressure to develop and deploy more integrated smart city systems, which combine data and services from multiple silos. Examples of such applications are systems that calculate environmental performance across multiple smart city projects, or even applications for integrated urban mobility. In this context, application developers and deployers need tools that can facilitate the development of integrated interoperable applications, notably applications that combine data and services from multiple IoT systems and data sources, including open data sets.

## 2 The Solution

VITAL-OS is a middleware platform, which enables the integration and orchestration of IoT services and IoT data streams from multiple systems. It provides a set of data models and interfaces that enable the collection and annotation of information from diverse systems, in a simple developer-friendly JSON-LD (JavaScript Object Notation) format and in a way that ensures their unified and interoperable representation. The VITAL-OS data models and interfaces are accessed with visual tools, facilitating the task of application development using the VITAL-OS platform. VITAL-OS comes with a visual development environment, which is based on the popular Node-RED IoT development environment and enables developers to combine popular IoT development functionalities with those on the VITAL-OS platform.

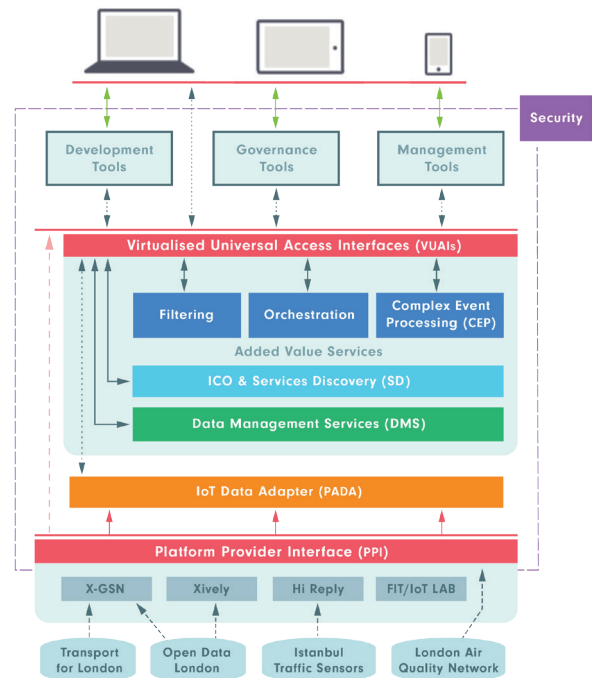
## VITAL-OS Tools for Developers

### 3 VITAL Platform Overview

An overview of the VITAL-OS platform is shown in the figure on the right.

The platform comprises the following components (building blocks):

- The Platform Provider Interface (PPI)**  
 An abstract Interface to IoT Systems, which enables uniform access to their data & metadata, including data & metadata about the IoT system as a whole, its sensors and internet-connected devices, as well as data about the service level agreements (SLA) enabling access to their data.
- The Data Management Service (DMS)**  
 A module in charge of persisting and managing data from all different IoT systems, in accordance with the VITAL semantic models and ontologies. It stores semantically unified data and metadata, thus providing a basis for querying cached data from multiple IoT systems in a uniform and interoperable way.
- IoT Adapter** A middleware component which keeps track and manages IoT systems connected to the DMS. It is in charge of periodically fetching and pulling data to the DMS.
- IoT Service Discovery** Enables the discovery of sensors, internet-connected objects and their services, focusing on composite services developed by the VITAL platform (e.g., the VITAL Orchestrator).
- Filtering and Complex Event Processing (CEP)** Provide functionalities for filtering data streams and generating events. This supports filtering based on thresholds, resampling and dynamic data processing.
- Orchestration:** This component enables the composition of IoT service workflows, based on services from the underlying IoT platforms.
- Virtualized Unified Access Interfaces (VUAIs)** Interfaces for platform-agnostic, virtualized access to the data & services processing functionalities of the platform.



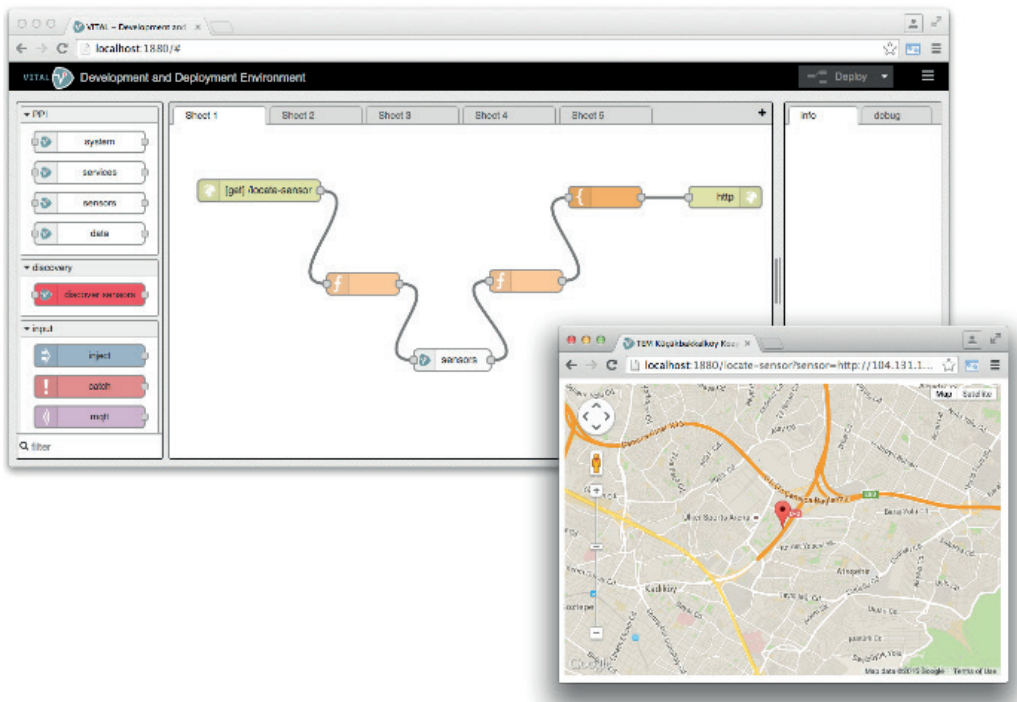
On top of these modules, VITAL-OS provides visual tools for application development and management.

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#### 4 VITAL Development Environment

The VITAL development and deployment environment allows developers to access and compose the various capabilities of the VITAL platform in order to implement smart city applications. It is implemented based on VITAL extensions over the popular NodeRED (nodered.org) environment. Specifically, VITAL implements nodes that map to the platform’s functionalities for services discovery, CEP, filtering and orchestration. These nodes are combined with the function blocks and other nodes that are built-in in NodeRED, thus offering developers great flexibility and rich functionalities stemming from the ability to combine all of NodeRED’s development features with the capabilities of the VITAL platform. The VITAL Development Environment is ideal for the rapid development of back-end IoT services over the VITAL platform. Based on the use of the development environment as a front end to the VITAL-OS, service developers can economise up to 50% of the effort required in order to integrate IoT services from multiple heterogeneous IoT systems and deployments.



#### 5 Business Benefits

The VITAL-OS development tools facilitate the tasks of developing and deploying smart city applications, thus lowering the respective development and deployment efforts (including associated costs). VITAL-OS is an open source solution, which ensures a reasonable total cost of ownership (TCO). It is therefore an affordable solution for small and medium cities that cannot contemplate the high licensing costs of proprietary smart city software solutions. VITAL-OS provides the means for developing and integrating interoperable IoT solutions in smart cities, thus alleviating the complexity associated with the integration of existing silo applications.