Integrated Management of Internet-of-Things Applications for Smart Cities

Abstract

For more than a decade, modern cities have been been deploying a variety of Internet-of-Things (IoT) systems and applications in areas such as smart energy, smart transport, ambient-assisted living, security and more. These applications have in most cases been developed and deployed independently, which makes their monitoring and management particularly challenging. Indeed, in order to manage the various applications in a unified way and from a single entry point, cities have to deal with multiple IoT systems comprising various technology platforms and devices. The VITAL Smart City platform (also called VITAL Smart City Operating System [VITAL-OS]) provides the means for managing diverse smart cities systems and applications in a unified way and from a single entry point.

1 The Problem

Smart cities represent the ultimate urban development vision of modern cities, which supports cities in confronting severe pressures associated with urbanisation, demographic changes, climate change and public safety. In response to these pressures, cities are gradually deploying IoT infrastructures and applications. These infrastructures 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 are very difficult to manage in an integrated way, as a result of the need to deal with multiple technology platforms and data models for IoT devices, systems and data streams.

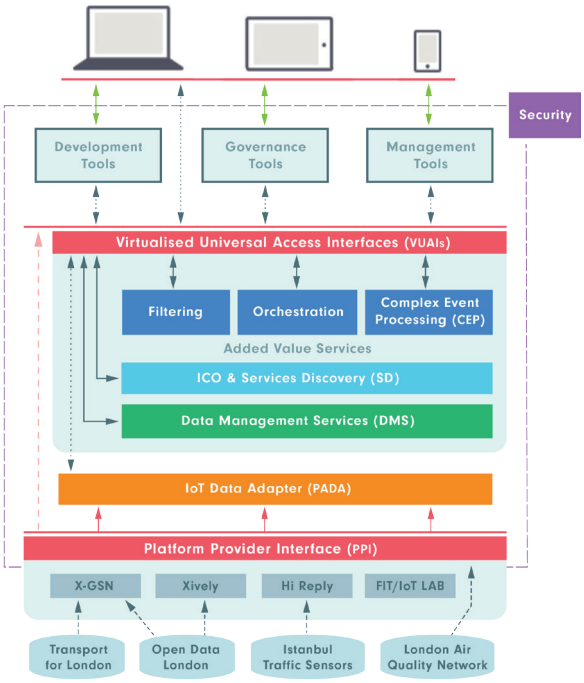
2 The Solution

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. Based on these data models and interfaces, VITAL-OS also provides a management environment, which enables unified management of diverse IoT systems and data streams from a single entry point.

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.

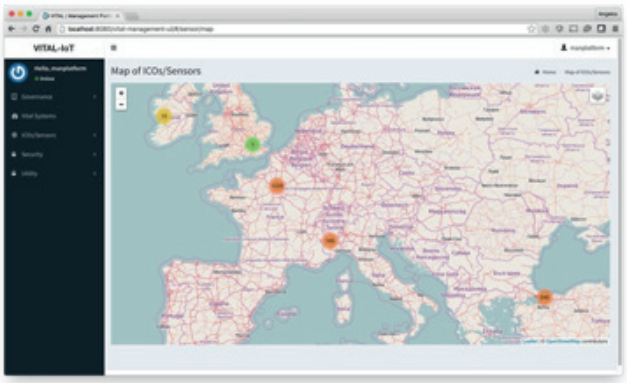
On top of these modules, VITAL-OS provides an integrated unified management environment.

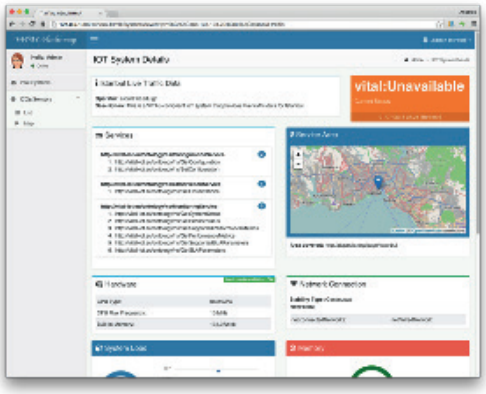
4 VITAL Management Environment

The VITAL management environment comprises a set of powerful tools enabling smart city authorities and service providers to manage the VITAL platform and all individual VITAL sub-systems. It provides a common, unified management view (monitoring and control if allowed) of the different underlying IoT Systems, while integrated with any management hooks provided by these systems and translating data and functionality into the common VITAL management model. The management environment provides the following functionalities:

- **Sub-system / component and overall health monitoring** This provides a "health map" of the IoT platform with the ability to drill down to a level that is practical for monitoring sub-systems and component operational status parameters.
- **Operations management** Provides graphical user interface (GUI) tools for supporting operations management, i.e. basic monitoring and configuration of operational parameters and visual status reporting for individual components (in list or map view).
- **Information strategic planning input** Maintains and processes historical data in order to provide a data store of structured monitoring data of key operational information, Quality of Service (QoS) parameters, and service Key Performance Indicators (KPIs) that can be retrieved via querying/exporting functionalities, and used in strategic planning and similar activities by the city or regional authorities.
- **Critical FCAPS (Fault Configuration Accounting Performance and Security) operations: Cover the complete span of the FCAPS functional model, but focus on Smart City & IoT/VITAL platform specific requirements:**
  - Fault: Provides a health map, a visual representation of fault events with drill down options and alerting.
  - Configuration: Provides a geographical map, configuration parameter monitoring and control for platform components and underlying systems (subject to permissions).
  - Accounting: Monitors and maintains accounting information, i.e. client application usage of platform resources, for enabling the implementation of fairness control policies, etc. SLA monitoring / management is an important aspect that is associated with this area.
  - Performance: Monitors the performance of the platform and of individual sub-systems. The goal is not only to monitor QoS but also to provide early warning insight on developing faulty conditions before they escalate and/or cascade to an actual fault.
  - Security: Monitors operational parameters related to the security and access control of the platform.

Overall, the VITAL management environment provides a common management plane that unifies all the management information of all components and systems as well as management functionality that can be performed in a unified way over the VITAL platform.





5 Business Benefits

The VITAL-OS management environment alleviates the challenges associated with the management of the wide range of heterogeneous IoT systems that are already deployed in smart cities. It provides the means for managing diverse systems and data sources from a single entry point and through ubiquitous web interfaces. In this way, it reduces the effort and costs associated with the management of IoT systems in smart cities. 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 monitoring solutions.