WP1 Use Cases, Requirements, Architecture

D1.4 Updated use cases, requirements and architecture

Grant Agreement N°723139
NICT management number: 18301

BIGCLOUT

Big data meeting Cloud and IoT
for empowering the citizen ClouT in smart cities

H2020-EUJ-2016 EU-Japan Joint Call

EU Editor: **ENG** JP Editor: **NII** Nature: Report

Dissemination: PU

Contractual delivery date: 2017-12-31

Submission Date: 2018-03-23

Co-funded by the EU H2020 GA. 723139 and NICT GA. 18301

ABSTRACT

This deliverable reports the final reference use cases of BigClouT, that will be deployed during the project, and the requirements that stem from them. Final version of reference use cases and of requirements come from their initial version, reported in document "D1.2 Citizen centric use cases and requirements" [1]. This deliverable also reports the final architecture of BigClouT, defined starting form its first version, taking into account information reported in the document “D2.1 Data collection tools and architecture” [2] and in the document “D3.1 Big Data Analytics Framework Architecture” [3]. BigClouT architecture is derived from architecture of ClouT, and evolves this last one introducing capabilities related to Big Data Analysis, Self Awareness, Real Time Intelligence and Edge Computing.

Disclaimer

Revision history

Revision	Date	Description	Author (Organisation)
V0.1	24/10/2017	Initial ToC	Giuseppe Ciulla (ENG)
V0.2	30/10/2017	Revised ToC	Giuseppe Ciulla (ENG) Martino Maggio (ENG) Levent Gürgen (CEA) Antonis Litke (ICCS)
V0.3	11/01/2018	Final architecture overview Modules and assets mapping	Giuseppe Ciulla (ENG)
V0.4	29/01/2018	Grenoble updated use cases	Christophe Munilla (CEA)
V0.5	16/02/2018	Fujisawa updated use cases	Akita Tsuge (KEIO) Takuro Yonezawa (KEIO)
V0.6	21/02/2018	Tsukuba updated use	Keiko Doguchi (NTTE)

		cases	Toshiyuki Amagasa (TSU)
V0.7	28/02/2018	Data flow	Giuseppe Ciulla (ENG)
V0.8	02/03/2018	Executive Summary Introduction Conclusions Annex B - Available data sources	Giuseppe Ciulla (ENG)
V0.9	05/03/2018	Various updates on sections. Requirements update Annex A - Reusable assets updates	Antonis Litke (ICCS) Giuseppe Ciulla (ENG)
V0.10	09/03/2018	Sequence diagrams General review of the document	Giuseppe Ciulla (ENG)
V0.11	20/03/2018	Internal review	Levent Gurgen (CEA) Takuro Yonezawa (KEIO)
V1 – Final version	22/03/2018	General updates following internal reviewers comments.	Giuseppe Ciulla (ENG)
Submitted	23/03/2018	Final revision from the coordinator and submission	Levent Gurgen (CEA)

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ACRONYMS

Acronym	Definition
API	Application Programming Interface
CDMI	Cloud Data Management Interface
CDN	Content Delivery Networks
CIaaS	City Infrastructure as a Service
CPaaS	City Platform as a Service
CRUD	Acronym of the four basic functions of persistent storage: create, read, update and delete
CSaaS	City Software as a Service
DBMS	Database Management System
D-NR	Distributed Node-RED
EDMS	Energy Data Management System
EWC	Entombed Web Content
GEs	Generic Enablers
GIS	Geographic Information System
GPS	Global Positioning System
GUI	Graphic User Interface
IoT	Internet of Things
KPI	Key Performance Indicator
LDAP	Lightweight Directory Access Protocol
LED	Light Emitting Diode
M2M	Machine to Machine
NGSI	Next Generation Service Interfaces
OLAP	Online Analytical Processing
PEP	Policy Enforcement Point
REST	REpresentational State Transfer
SAML	Security Assertion Markup Language

SNS	Social Networking Service
SSO	Single-Sign-On
SSL	Secure Sockets Layer
TLS	Transport Layer Security
VM	Virtual Machine
XMPP	Extensible Messaging and Presence Protocol

EXECUTIVE SUMMARY

This document provides the final version of BigClouT reference use cases, requirements and technical reference architecture. In details, it presents the use cases that are studied and implemented during the project, the requirements that stem from them, and the technical architecture, including the binding between its logical modules and technological assets that can be adopted for its implementation.

Eight (8) reference use cases are described adopting a common approach: for each of them a brief description of the use case, involved stakeholders, UML diagrams, a summary of the main requirements, the KPIs to evaluate the impact of its implementation, faced Big Data challenges, and its replication potentiality are reported.

The final requirements are grouped in two categories: functional and non-functional requirements:

- The functional requirements identify what the system must do to produce the required operational behaviour.
- The non-functional identify what other technical features the system must have in order to facilitate the service provision.

The final version of BigClouT architecture is then reported, including an overview about it, how the technological assets are involved in its reference implementation design, and how data go through it and how they are processed, both from a general point of view and a more specific one, considering the reference use cases.

This document is organised in the following sections:

1. **Updated Use Cases**: this section provides information about the final version of reference use cases that will be implemented.
2. **Final Requirements**: this section reports the final version of requirements derived from the analysis of the use cases.
3. **BigClouT Final Architecture**: this section provides description of the final version of the BigClouT architecture, reporting its overview, reference implementation design and data flows.

Finally, conclusions are reported in section 4 whereas section 5 and section 6 report respectively the complete list of reusable technological assets and data sources identified for the implementation of reference use cases.

INTRODUCTION

The current document is the deliverable "D1.4 Updated use cases, requirements and architecture" and its aim is to depict the final version of: reference use cases that are studied and implemented during the project, requirements (functional and non-functional) and reference architecture.

The reference use cases are described based on a common template, highlighting various characteristics such as:

- their innovative nature;
- interaction with stakeholders;
- requirements for the technological base of BigClouT project;
- the specific faced Big Data challenges by each of them, in terms of Volume (the vast amount of data to be processed), Velocity (the "speed" of incoming data to be processed), Variety (the huge diversity of data types to be processed), Veracity (the uncertainty, inconsistency and incompleteness of data to be processed) and Value (the possibility of doing business and of yielding value and business opportunities from massive amount of data) [4];
- KPIs to measure and evaluate their impact;
- their replication potentiality, in order to provide a clear view on the possibility to be replicated in other contexts.

On the basis of the reference use cases, previous version of requirements [1] have been refined; these are reported in two different sets:

- Functional requirements: what BigClouT platform must do to produce the required operational behaviour. They include aspects related to: system functions, tasks or actions to be performed, inter-function relationships, interface requirements, etc.
- Non-functional requirements: what other technical features the system must have in order to facilitate the service provision. They include aspects related to: scalability, performance, reliability and availability, manageability and flexibility, modularity, etc.

Taking into account the final version of reference use cases and of requirements, first version of the BigClouT architecture [5] has been revised including inputs from WP2 and WP3, in particular from documents "D2.1 Data collection tools and architecture"[2] and " D3.1 Big Data Analytics Framework Architecture"[3], that investigate more in deep respectively the data collection and redistribution tools and their integration into the overall architecture, and the Data Analytics Framework of BigClouT that is identified in the general BigClouT architecture by the City Data Processing logical module, providing details about its logical sub components and their relations.

The description of the final BigClouT architecture starts with an overview of the different layers of the platform and their logical modules and components. The description continues pointing out the main differences between the first and the final architecture of the platform. Moreover, sequence diagrams are reported to explain the interactions among the inner components and the data providers and data consumers. Then the mapping among BigClouT logical components and the technical assets is described; finally last section illustrates the expected data flows for the different use cases.

Architecture reported in this document represents the reference technical BigClouT architecture; it is important to underline that it must be intended as a reference architecture that can be implemented at all on in part on the basis of specific needs to be addressed and of specific requirements to be satisfied. Indeed, BigClouT reference architecture reported in this document is not monolithic, but it is designed to be modular, flexible and adaptable, in order to be implanted in different context and for different aims; it is also possible to extend it adding new technological modules, thanks to the definition of clear and well defined relations and interfaces among its logical modules.

1 UPDATED USE CASES

This section provides a detailed description of the updated use cases that are studied and implemented in the BigClouT project. During the last months and since the delivery of the report D1.2 [1], partners have slightly revised the use cases, according to the feedback that they have received from the various stakeholders that were engaged during the pilots. These updated use cases reflect in a better way the goals of the BigClouT. Having now a more concrete and holistic view of the use cases and of the requirements that stem from them, the consortium has proceeded in the update of the use cases and of the requirements that are presented in the sequel, in full accordance with the developments within WP4. It has to be noted that the overall changes are not regarded as substantial and so the BigClouT use cases maintain their core characteristics unchanged. For the sake of the completeness and the readability of the document, Below sections reuse descriptions from the D1.2 and update them with additional sections such as for example KPIs, big data challenges and replication potential of the use cases. Description of use cases is mainly the same as in the deliverable D1.2. The use case providing partners have slightly updated and refined their use cases based on the knowledge gained so far through WP4. Only the use case of Bristol about mobility has been substantially changed. In the updated version the use case is focused on the provision to pedestrians of a service which will identify the healthiest path within the city (section 1.2.2.).

1.1 Grenoble Updated Use Cases

The Greater Grenoble City Area (Grenoble-Alpes Métropole) brings together 49 different municipalities and almost half a million inhabitants who have chosen to work together on key areas for the development of the territory. The City Area is the most important local government structure in charge of areas such as economic development, universities, research, innovation, energy, water and sanitation, rubbish collection, urban planning and transport – all key fields for 'smart cities'.

FIGURE 1: A VIEW OF GRENOBLE

Situated in the heart of the Alps and surrounded by mountain ranges, the City Area has a population that is very sensitive to the environment with higher than average rates of recycling and of use of public transport and bikes increasing annually. The City Area is also home to a unique economic ecosystem, representing industry, research and higher education.

University

- World-class universities (Grenoble Ecole de Management, Grenoble-Alpes University, INP Engineering school…)
- 1/5 inhabitants is a student
- Over 10% of these students are international

- 42% of students study sciences

Industry

- Unique ecosystem with big global players (ST Microelelctronics, Schneider Electric, Xerox, Orange, HP, Caterpillar and others) and dynamic start-ups and SMEs
- Specializing in cutting edge fields: electronics and microelectronics, software, energy, healthcare, chemicals
- All aspects for smart cities are covered

Research

- 25 000 researchers: 15 000 public researchers and 10 000 private researchers
- Fundamental, Applied and Interdisciplinary Research
- World-renowned labs (CEA, ESRF, EMBL, ILL, CNRS…)

Grenoble is lucky to have world-renowned researchers, top universities, big, global companies and cutting edge SMEs but what the city is most proud with is how all the actors from its ecosystem work together.

As a local government structure, the job of the Greater Grenoble City Area is to foster this collaborative spirit and to support technology transfer and joint projects in order to contribute to its economic development which in turn, contributes to improve the quality of life of its citizens.

1.1.1 Use Case 1: Monitoring of Economic Impacts of Events

Description

Grenoble-Alpes Métropole hosts several large events, trade shows and fairs every year in its Alpexpo exhibition centre. In the future, it would like to host an increasing number of events in order to boost the attractiveness of the area and in turn to boost economic development.

Currently, there is no way for the Métropole to measure the economic impact of these events - for example - the use of hotels, shops, restaurants and transport – by the people attending these events.

The Métropole would like to develop a tool that allows this monitoring to take place. The objective is to measure the impact of those events in the local economy, to better attribute public resources to improve public services, as well as to improve the quality of experience of the business tourists in Grenoble (better information, personalised transportation service, tourism information, discounts in shops, etc.).

A typical use case scenario would include for instance an event participant (i.e., business tourist) receiving interesting information about Grenoble city during his/her stay, information such as cultural events, souvenir shops, restaurants, transport information from his/her hotel to the event location, special offers and discounts, etc. The challenge is to be able to collect the necessary information about the tourist such as the stayed hotel, restaurants/shops used, localisation, general profile information, etc. The collected data will be used to obtain statistical information about the event and asses its impact to the city local economy. This implies involvement of various stakeholders in this use case such as listed in the next section.

Stakeholders involved and means of interaction / engagement

The following stakeholders have been identified for the specific use case:

- Grenoble-Alpes Métropole
- Exhibition Centres
    - Alpexpo exhibition centre
    - World Trade Centre
    - Minatec exhibition centre
- Insight Outside (events management company)
- Chamber of Commerce & Industry
- Tourism office
- Club des hoteliers (grouping of hotels)
- Réseau Label Ville (grouping of shopkeepers)
- Business tourists

The majority of these actors have already been contacted concerning the BigClouT project (more information about the trial planning can be found at the Deliverable 4.1). At least one physical meeting per stakeholder has been organised with the participation of the Grenoble Métropole and CEA. A clear interest in the results of the project has been identified. The fact that currently an evaluation tool for the economic impact of events is missing clearly represents a significant problem for event organisers.

Use Case Diagram

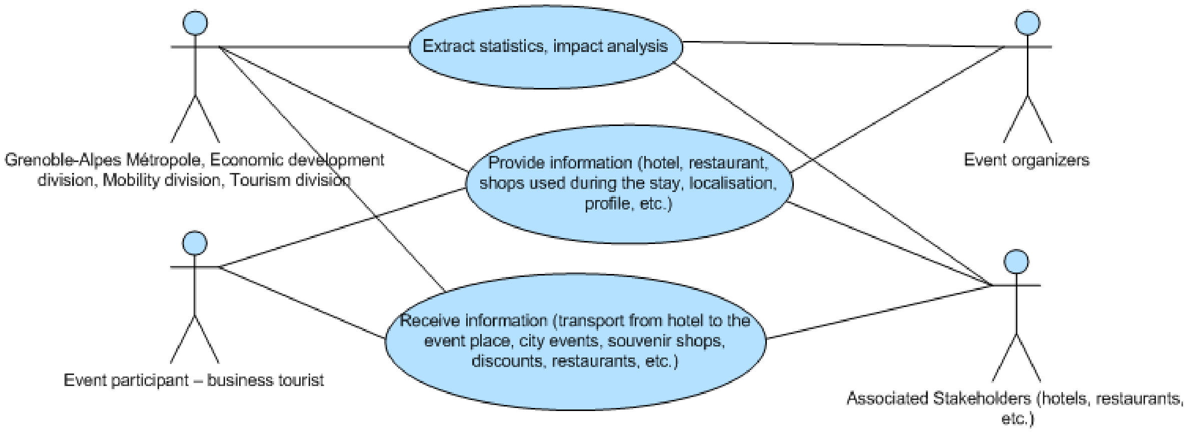

FIGURE 2: GRE-UC1 MONITORING OF ECONOMIC IMPACTS OF EVENTS UML DIAGRAM

Requirements summary

Below we provide a summary of requirements that have been elicited for the specific use case:

- The application for the business tourist should be distributed as a mobile app as an interaction mean with the services based on the BigClouT platform.
- Event organisers and Grenoble tourism office should promote/distribute the mobile application for the event participants/business tourists.
- The hotels, shops and restaurants should be able to share the participant information with the application (how many nights stayed, how much spent, etc.).

- The application may collect this information automatically by using sensors from the mobile phone (GPS localisation, proximity sensors such as NFC or Bluetooth Low Energy).
- The application should provide a tool to analyse data and extract statistics in simple and easily understandable way for the city economic development division and for the event organisers.
- The event organisers may share some information about the participant collected during his/her registration to the event. (hotel stayed, personal profile, etc.).
- The Grenoble mobility service should provide the information about the transportation system in Grenoble (bus/tram stations, real-time traffic, car-sharing, etc.).
- The application should protect the privacy of the end-user and propose several levels of management of personal data, and give the possibility of modifying the privacy parameters any time.
- The application should provide means for shops and restaurants to announce interesting offers to the business tourists, as well as for Grenoble tourism office to notify about city events (cultural, sportive, etc.).
- The application should provide means to gather satisfaction information from the user.

Use Case KPIs

TABLE 1: KPIS OF "MONITORING OF ECONOMIC IMPACTS OF EVENTS" USE CASE OF GRENOBLE

KPI or metric	Target value
Critical mass of downloads	100 users in each event gathering more than 300 of them
Critical mass of users	300 in first year
Daily active users	50
Average length of time spent using app	10 minutes
Frequency of use	Every day of the event

1.1.2 Use Case 2: Monitoring of Industrial Estates

Description

Grenoble-Alpes Métropole owns or manages several different industrial estates on its territory. These estates range in size and in the areas of activities, from high tech companies to artisans to shops and services.

The Métropole wants to be able to know who is using these estates and how. For example, how many people arrive each day by different modes of transport, how many people leave the sites for lunch, how many deliveries are received on the site, etc.

The goal is to be able to improve the services proposed by the Métropole in these zones for increasing the quality of experience of its citizens in their daily work life, (for example, is there a need for improved public transport? Or other means of transportation? Is there a need to put in place a new canteen? A concierge service or mail relay service?) and also to create a social network enabling for grouped orders and potentially car-sharing solutions. Moreover, the goal is to be able to better attribute public resources, to improve the working conditions on these zones and also to improve their environmental impact.

Stakeholders involved and means of interaction / engagement

The following stakeholders have been identified and contacted for the specific use case:

- Inovallée Industrial Estate
- Presqu'île group of employers
- Espace Comboire Industrial Estate

As the most organised industrial estate in the city area, it has been decided to use the Inovallée area as a test case. It is therefore with the management of this estate that discussions have progressed the most.

Four (4) physical meetings have been organised with the management of the Inovallée zone. During the discussions, we have steered the project in a direction in which we will mainly focus to put in place a tool which could be used by the people working in the zone.

Several different uses have been identified:

- Plan of the zone with contact details and descriptions of all the companies (which already exists in a paper format)
- Information about the transport options, the location of cars available in the car-sharing programme "Cité Lib", link with the "Métromobilité" app which gives real time information about public transport
- Information about building works/ traffic disruptions in the area
- Information about restaurant options, times and menus
- Information about sporting and cultural activities available
- Events, training, workshops, general communication that could interest employees in the area.

Use Case Diagram

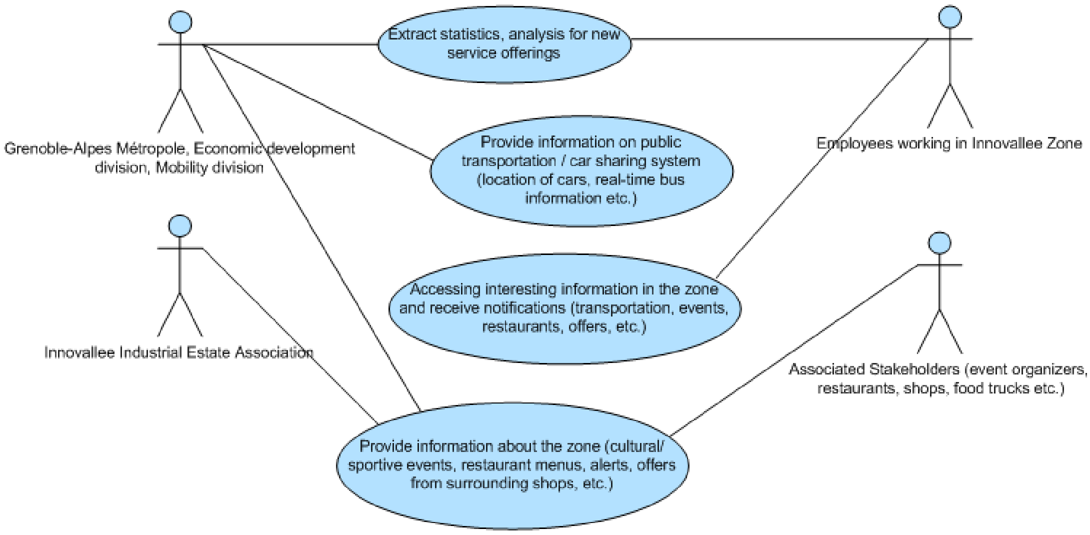

FIGURE 3: GRE-UC2: MONITORING OF INDUSTRIAL ESTATES UML DIAGRAM

Requirements summary

Below we provide a summary of requirements that have been elicited for the specific use case:

- The application should be distributed as a mobile app for the employees of the Innovallée industrial zone.
- Innovallée and Grenoble Metropole should promote/distribute the mobile application for the Innovallée employees.
- The Innovallée association should be able to collect (in real-time when relevant) information from the associated stakeholders (restaurants, shops, company associations, etc.) and provide it to the BigClouT platform
- The application may provide means (via the same mobile app) for associated stakeholders to directly enter necessary information (bypassing Innovallée), such as restaurants announcing menus, waiting time, shops providing interesting offers, food trucks announcing location and offers, etc.
- The Grenoble mobility service should provide the information about the transportation system in Grenoble (bus/tram stations, timetables, real-time traffic information, car-sharing, etc.).
- The user may accept to provide some personal information such as profile, location, company, transportation mode used, etc, for receiving customised information.
- The application should protect the privacy of the end-user and propose several levels of management of personal data, and give the possibility of modifying the privacy parameters any time.
- The application should provide a tool to analyse data and extract statistics in simple and easily understandable way for the city economic development division and for Innovallée Association
- The application should notify the user when interesting events occur and/or customised recommendations to be provided
- The application should provide means to gather satisfaction information from the user.

Use Case KPIs

TABLE 2: KPIS OF "MONITORING OF INDUSTRIAL ESTATES" USE CASE OF GRENOBLE

KPI or metric	Target value
Critical mass of downloads	500 users in first 6 months, 750 in first year
Critical mass of users	300 in first year
Daily active users	150
Average length of time spent using app	10 minutes
Frequency of use	Every working day

1.1.3 Big Data Challenge and Replication Potentiality of Grenoble's Use Cases

Big Data Challenge

Even if the targeted publics of the two Grenoble Metropole use cases are not the same, both of them aim at improving the final users experience, to better use the city resources to reach this satisfaction, to increase the visibility of cultural and sportive events, and to increase the amount of business interactions, with merchants, restaurants, hotels, etc. These use cases do not mobilize a substantial number of sensors or city entities providing a wide amount of data to be handled at any instant. However, they address the issue of searching in a wide and plural data warehouse to provide the expected information services. Moreover, the use cases intend to collect data, over time, which will enable the analysis to be carried out, allowing to take the decisions that will improve the end users experience, and that will increase the number of business interactions. The three Big Data challenges addressed by these use cases are so: **Velocity**, referring to the speed at which data will be accessible to the applications accessible to end users; **Veracity**, referring to trustworthiness of the data on which analyses will be based on; and finally **Value**, because the final objectives will be reached if it is possible to interpret the data in manner of improving the services provided to the end users, and increasing the visibility of cultural institutions and merchants.

Replication Potentiality of the Use Case

As mentioned above the two use cases of Grenoble Metropole aim at improving the way that the city resources can be accessed and used, whatever they are: public, private, transportation, cultural, sportive, commercial, etc. They both consist, on one hand, in the organization, gathering and providing of the available information relative to the Grenoble city life and its breathing to the targeted end users. On the other hand, the objective is to offer a way to be visible to merchants and cultural institutions to make this public coming. It is so perfectly replicable to any other city with similar characteristics wanting to offer shared tool to visitors or citizens, to merchants and to event organizers making the city more welcoming and readable, increasing the cultural and business interactions.

1.2 Bristol Updated Use Cases

Bristol is a city with a population of nearly half a million people in south west England, situated between Somerset and Gloucestershire on the tidal River Avon. It has been among the country's largest and most economically and culturally important cities for eight centuries. The Bristol area has been settled since the Stone Age and there is evidence of Roman occupation. A mint was established in the Saxon burgh of Brycgstow by the 10th century and the town rose to prominence in the Norman era, gaining a charter and county status in 1373. The change in the form of the name 'Bristol' is due to the local pronunciation of 'ow' as 'ol'.

FIGURE 4. A VIEW OF BRISTOL

Bristol is regarded as the capital of the South West of England. Lively yet laid-back, Bristol blends its rich maritime heritage with an innovative, dynamic culture, making it one of the most cosmopolitan centres outside London. It is a leader on the green scene and was proud to be European Green capital 2015 – the only UK city ever to hold the title. It also has an enviable cycling culture. Compact enough to get around on foot, yet big enough to boast an exciting line-up of entertainment, Bristol has much to offer. The city's most celebrated sights include the Clifton Suspension Bridge – which was designed by Isambard Kingdom Brunel and celebrated its 150th anniversary in December 2014.

Bristol's modern economy is built on the creative media, electronics and aerospace industries, and the city-centre docks have been redeveloped as centres of heritage and culture. The city has the largest circulating community currency in the U.K.- the Bristol pound, which is pegged to the Pound sterling. The city has two universities, the University of the West of England and the University of Bristol and has a variety of artistic and sporting organisations and venues including the Royal West of England Academy, the Arnolfini, Spike Island, Ashton Gate and the Memorial Stadium. It is connected to London and other major UK cities by road, rail, sea and air by the M5 and M4 (which connect to the city centre by the Portway and M32), Bristol Temple Meads and Bristol Parkway mainline rail stations, and Bristol Airport.

In 2014 The Sunday Times named it as the best city in Britain in which to live, and Bristol also won the EU's European Green Capital Award in 2015.

1.2.1 *Use Case 1: Smart Energy - predictive analysis of users' power consumption*

Description

This use case is about exploiting BigClouT's novel data-adaptive machine learning techniques for predictive analysis and the power consumption of users. We will use the infrastructure installed for the European project REPLICATE [6].

The objective is to make householders aware about different phenomena, that otherwise would be very difficult to detect for example 'the phantom load' also known as 'vampire power'. This is the electricity consumed by electronic and electrical appliances while they are switched off (but are designed to draw some power) or in a standby mode. Consumption may be of the order of 10% of the electrical energy used by a typical household.

Saving electricity not only will affect the householders' pocket. Electricity is very often generated by combustion of hydrocarbons (oil, coal, gas) or other substances, which release substantial amounts of carbon dioxide, implicated in global warming, and other pollutants such as sulphur dioxide, which produces acid rain, so at the same time the user is helping to take care of the planet.

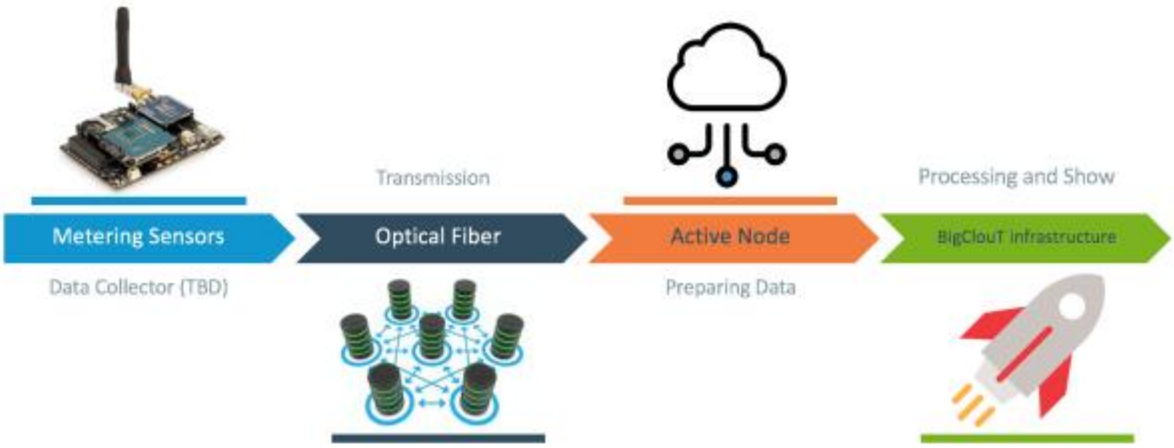

FIGURE 5: DATA FLOW IN USE CASE BIO-UC1

The scenario of the use case would be:

- Collect real time data from the sensors deployed.
- Analyse the citizen involved usage of electricity.
- Predict future behaviour with this information.
- Show this information in an understandable way to the users in a dashboard.
- Merge this information with other available sources (i.e. weather information).
- Compare their usage with other people in similar situations.
- Get feedback from the users, for example: did it change their behaviour in some way?

Stakeholders involved and means of interaction / engagement

The following stakeholders have been identified for the specific use case:

1. Bristol City Council has established contacts at Warm Up Bristol and Bristol Energy.

- Warm Up Bristol is a Bristol City Council scheme designed to make the citizens' home warmer, cozier and cheaper to heat. They are dedicated to tackling cold homes and reducing fuel poverty. Selected homes will be chosen by Warm Bristol.
- Bristol Energy is a gas and electricity company that offers fair and transparent electricity and gas tariffs for domestic and business customers across Bristol, the South West and nationwide. They will survey properties from the ones chosen by Warm Up Bristol, they will calculate the cost of installations and install the sensors in the citizen homes.

2. Bristol Is Open (BIO) is the testbed for the pilots. They are providing and managing the infrastructure of Bristol (i.e. RF-Mesh, Optic Fiber, Blue wireless and Microwave).

3. KWMC - Knowle West Media Centre [1] (who is a partner in the REPLICATE project) will share its knowledge from previous pilots from deploying sensors in citizens' houses.

An engagement workshop between Bristol City Council, University of Bristol and Bristol Is Open has been undertaken which is where the idea of merging Smart Energy with Smart Homes will be further elaborated. Future meetings are being planned. Following steps involve also KWMC, who have previous experience deploying sensors within homes.

Big Data Challenge

In this use case, the big data challenge that Bristol is mainly facing is data **variety**. In the Bristol trial, energy metering data are collected by/from multiple-vendors smart white goods or smart home kits (e.g., smart plug). Their data format, data name schema, and data transmission protocols are varied from one provider to the others. Bristol is Open smart city platform as a generic ICT platform for smart city solution is coping with this challenge in the BigClouT pilot.

[1] http://kwmc.org.uk/

Use Case Diagram

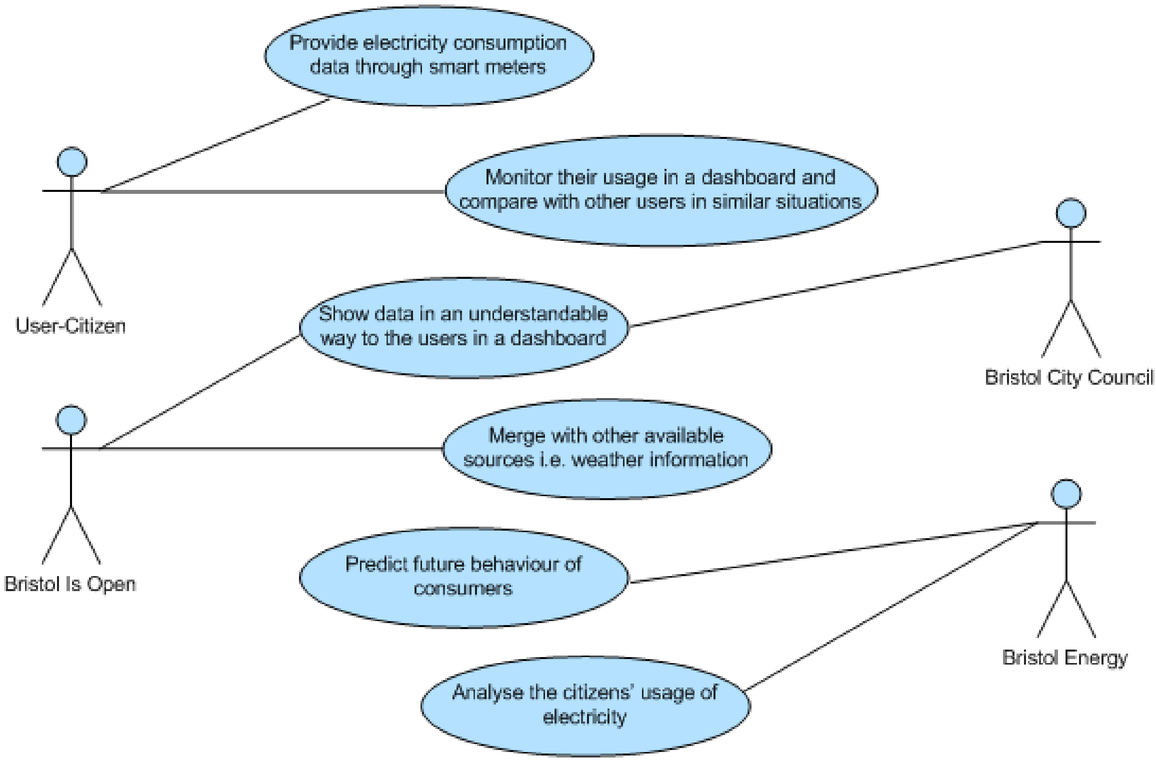

FIGURE 6: BIO-UC1: SMART ENERGY UML DIAGRMAM

Requirements summary

Below we provide a summary of requirements that have been elicited for the specific use case:

- The BigClouT platform should be able to collect information from sensors deployed inside citizen homes.
- The BigClouT platform should be able to collect detailed weather information in a real time and in an accurate way.
- The BigClouT platform should be able to store the information from different sources for post processing.
- The BigClouT platform should be able to provide prediction tools for energy usage mapping for further decision making by the relevant stakeholders.
- The BigClouT platform should be able to provide tools for comparing citizens' energy consumption scenarios.
- The BigClouT platform should be able to provide an easy to use dashboard.
- The BigClouT platform should provide a user management system, where citizens can consult only their data and manage their profiles.
- The BigClouT platform should be compatible with NGSI APIs [7].

Use Case KPIs

Bristol is targeting recruiting minimum 150 households in the trial, where 150 smart metering devices will be installed to monitor energy consumption. It is expected that the pilot will involve additional stakeholders i.e. EDMS operator to check if there has been a reduction in consumption within the households. The KPIs that are involved in this use case are reported in Table 3:

TABLE 3: KPIS OF "SMART ENERGY - PREDICTIVE ANALYSIS OF USERS' POWER CONSUMPTION" USE CASE OF BRISTOL

KPI or metric	Target value
Number of households involved in trial	150 min
Representative demographics	Trial participants should represent household demographics of Bristol city area
Daily active users	150

Replication Potentiality of the Use Case

Potentially the Bristol's "Smart Energy - predictive analysis of users' power consumption" use case can be partly replicated by other cities in the settings where the end-users use the same smart white goods from the vendors and/or smart home kits. With limited development work on RESTful APIs, the same methodology used in this use case is transferable to adopt other vendors white goods used in JP and EU (if the vendor provides open API to access the data from the white goods).

This use case may also be able to replicate JP use cases which can be regarded as a sub-system of the BiO ICT platform.

Bristol City Council, the lead from Bristol, will also be looking to develop a business model and service for other cities to replicate the infrastructure and lessons learned from the validation of use cases, from the experience of deploying logistically within a city.

1.2.2 Use Case 2: Smart Mobility

Description

The objective of the use case is offering to pedestrians a service which will identify the healthiest path within the city to follow; for this aim Bristol Is Open (BIO) will deploy a set of air quality sensors around the buildings of the University of Bristol and/or Bristol city.

Bristol is Open infrastructure will host the testbed of this use case. The BigClouT platform will be used for the deployment, management and profiling of this use-case's service. Through the use-case, we will provide experimental answers to the questions: regarding how far from the edge the modelling should happen and how close to the edge the model matching should take place.

Extracting movement knowledge, which would take place in a continuous way, this can be used by network providers and media delivery services and as a result less packet losses, optimized bandwidth will be obtained; in addition, faster performance will minimize timeouts, latency and jitter, while improving overall user experience.

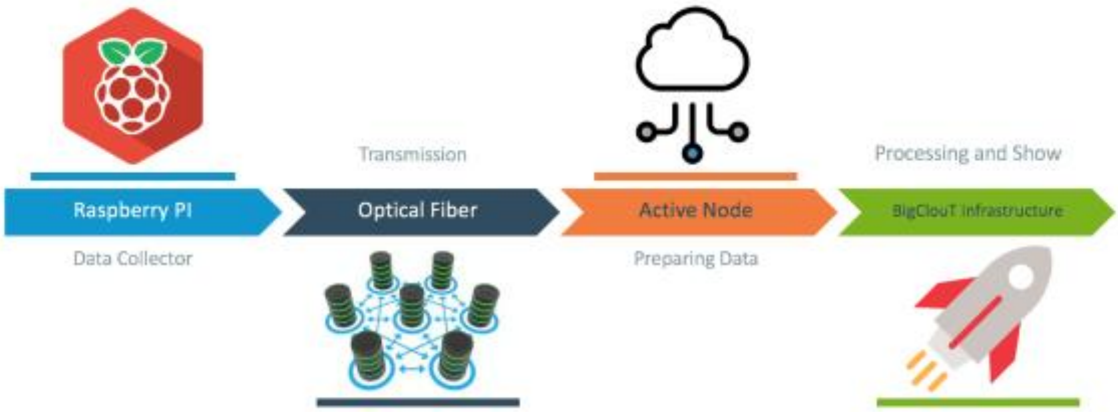

FIGURE 7: DATA FLOW IN USE CASE BIO-UC2

The idea is giving to pedestrians the possibility to choose a "green" path (which basically means a less polluted path) instead of a "red" path (which is the most polluted) by using LEDs screens placed in the middle of potential turning-points.

In the Smart Mobility use case, we collect environmental information from air quality sensors which are then directed to a dedicated instance of the FIWARE IoT Platform. After that, we still use node-RED to manage the dataflow wiring our back end (or an API which represent an abstraction of it) to the BigClouT Repository (CKAN based).

The scenario of the use case contains the following items:

- Collect feedback from the citizens on the air quality on the paths they are using as pedestrians
- Analyse citizens' mobility patterns.
- Use data analytics for the prediction of future citizens' mobility patterns.
- Show real time and future hot paths around the city in a dashboard.
- Merge information with other available sources (i.e. weather information).
- Improve the user experience (UX) of streaming services used by citizens.

Stakeholders involved and means of interaction / engagement

The following stakeholders have been identified for the specific use case:

1. Bristol University: High Performance Networks Group (HPN), specialises in the application of advanced hardware and software technologies, targeting the future optical networks for Internet of Things, data centres, grid/cloud based applications and distributed technologies etc. The Group is equipped with world-class laboratories, including state-of-the-art optical transmission testbeds and software-defined network experimental platforms.

2. Bristol Is Open is the test bed for the pilots. They are providing and managing the infrastructure of Bristol (i.e. RF-Mesh, Optic Fibre, Blue wireless and Microwave).

FIGURE 8: BIO-UC2: TESTBED OVERVIEW

BIO and UoB (University of Bristol) have been working together during the last 2 months, and we are holding several catch-up events weekly. Initial discussion about the legal and ethical approaches had been undertaken and the UoB has triggered the process for the University's Ethics Policy. During this period, some of the proof of concepts already deployed inside the university's lab has been discussed.

Big Data Challenge

In this use case, the big data challenge that Bristol is mainly facing is data **veracity**. In the Bristol trial, air quality sensing data are collected in a reasonable large-scale deployment (data point coverage) and a street-level distribution (data density) to underpin smart mobility solution. However, the data sources are from stockholders or third parties, which may be of pool veracity.

Use Case Diagram

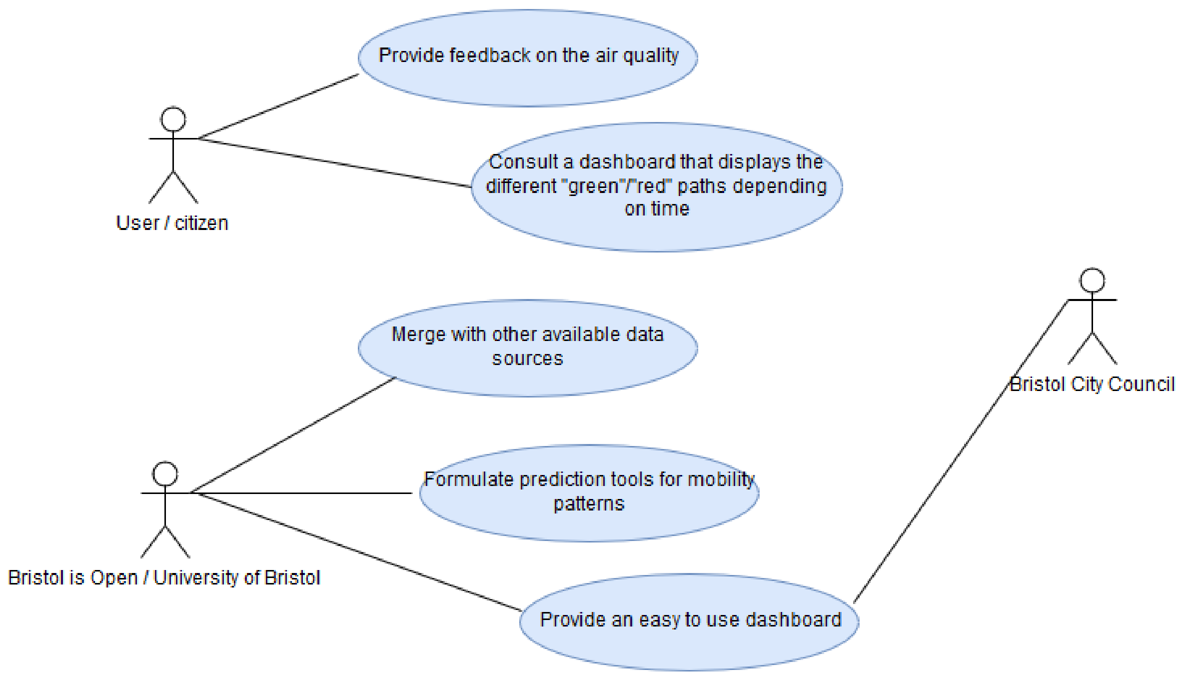

FIGURE 9: BIO-UC2: MOBILITY PREDICTION UML DIAGRMAM

Requirements summary

Below we provide a summary of requirements that have been elicited for the specific use case:

- Users should be able to provide feedback on the air quality related to their location (under informed consent).
- Users should be able to consult a dashboard that displays the current "green" and "red" paths for walking, depending on time of the day.
- The BigClouT platform should be able to collect measurements of air quality from sensors deployed around University of Bristol
- The BigClouT platform should be able to analyse citizens' mobility patterns and use data analytics for the prediction of future citizens' mobility patterns.
- The BigClouT platform should be able to merge information with other available sources (i.e. weather information).
- The BigClouT platform should be able to store data from different sources for post-processing.
- The BigClouT platform should be compatible with NGSI APIs.
- The BigClouT platform should provide a map (Dashboard) that displays the different red/green paths depending on time.

Use Case KPIs

In the trial area where the air quality sensing system is deployed, the BigClouT pilot provides a real-time air quality map displaying in a large LED screen. It has been identified in Millennium Square where there is a large footfall of commuters who can use the data to form their plan. Expected to reach 150 target users with this alone. BIO will need to undertake further engagement around the LED screen and on the front-end system to collect information on the demographics of users. This information will not be stored permanently and will be anonymised. The KPIs that are involved in this use case are reported in Table 4:

TABLE 4: KPIS OF "SMART MOBILITY " USE CASE OF BRISTOL

KPI or metric	Target value
Target user number	150
Critical mass of users	300 in first year
Daily active users	150
Demographics	Representative of general Bristol city
User engagement	Min 25% users respond to questionnaire

Replication Potentiality of the Use Case

Potentially the Bristol trial can be replicated by other cities in the settings where urban-wide real-time air quality and transport information can be obtained from realisable data sources. With limited development work on RESTful APIs, the same methodology used in the Bristol BigClouT trial is transferable to be used in the other regions in JP and EU.

The Bristol trial may also be able to replicate JP use cases which can be regarded as a sub-system of the BiO ICT platform.

Lessons learned from the use case deployment within Bristol can also be provided to JP and EU cities to provide efficient replication i.e. the logistical aspects of deploying sensors on municipal assets (lamp posts).

1.3 Tsukuba Updated Use Cases

Tsukuba city is located in south-western part of Ibaraki prefecture. It is a town spreading out in the south foot of beautiful Mt. Tsukuba in Kanto area with "Science, History and Nature". Area is 287km^2 and population is about 230,000. It is close to Tokyo Metropolitan and takes 45 minutes by Tsukuba Express to get there.

One of the city's special features is Tsukuba Science City. It was approved at cabinet meeting in 1963. There are more than 100 research laboratories including 29 governmental organizations, there are 20,000 researchers and 7,000 people who have doctoral degree. The research field extends from space development to nanotechnology, biotechnology, and robot development. It is one of the biggest research and development bases in Japan.

The city is also known as a place for international conferences. G7 science and technology ministers' meeting was held in Tsukuba city from May 15 to 17, 2016. G7 (Japan, Italy, Canada, France, USA, England, Germany) and EU participated in this meeting and had fruitful discussion regarding science and technology related matters.

The joint statement "Tsukuba Communiqué" was announced to the world on May 17 after discussion about science technology. With these experiences, Tsukuba city is aiming at the further progress as an international technology innovation base.

FIGURE 10: TSUKUBA CITY OVERVIEW

1.3.1 Use Case 1: Provide tourism, traffic and environmental information in real time to visitors

Description

The aim of the use case is to provide useful information, including environmental data collected by IoT in real time in addition to the city's attractive and convenient information to visitors' to Tsukuba by push based delivery, so that visitors will stay longer time to stop by sightseeing points or restaurants and revisit.

<u>Scenario</u>

1. Collect attribute information such as purpose for visiting to Tsukuba, transportation, gender, generation, hobby and tastes.

2. Collect behaviour history of the visitor.

- Collect visitors' satisfaction rate for purpose of the visit and other demands.
- Collect environmental information (weather, temperature and so on).

3. Analyze the trends of visitors' behaviour according to their attribute and environmental information and the trends of satisfaction rate.

4. Collect real time weather information, Social Network Service comments, traffic and facilities' congestion situation, and visitors' location information.

5. Select the best tourism, transportation or restaurant information for the visitor according to their attribute and real-time location information by data of 3 and 4.

- Predict this information for the future by accumulated information.

6. Deliver this information to visitors.

7. Get feedbacks about information delivered by questionnaires and so on.

- Improve recommendation accuracy based on feedbacks.

Stakeholders involved and means of interaction / engagement

Tsukuba use case scenarios are targeting visitors to Tsukuba city. So candidates of stakeholders listed up are organizations in Tsukuba city who are related to tourism or international conference and would cooperate on the project; Identified stakeholders of this use case are reported in Table 5.

TABLE 5: STAKEHOLDERS OF "PROVIDE TOURISM, TRAFFIC AND ENVIRONMENTAL INFORMATION IN REAL TIME TO VISITORS" USE CASE OF TSUKUBA

Stakeholder	Role	Interaction / Engagement
Tsukuba city IT division	Point of contact for BigClouT project, stakeholders etc. Get questionnaires or have meetings with users for the result measurement	Periodical meetings
Tsukuba city tourism section	Point of contact for tourism related stakeholders. Provide comments about use cases	Meetings anytime it is needed
Tsukuba city traffic section	Point of contact for railway companies Provide usage data for Tsukuba taxi on demand Provide comments about use cases	Meetings anytime it is needed Provide usage data by signage if needed
Tsukuba city international division	Provide access data to English pages of Tsukuba city website	Provide data online
Center for Computational Science	Provide weather and environment data	Provide data online if needed
Other Stakeholders in Tsukuba city (under negotiation)	Provide usage data of public transportation	Provide usage data online if needed
	Provide places to install signage at stations	Deploy it according to their rules or laws
	Recommend tour plans	Provide tour information on website
	Provide incentives for users	Provide coupons or novelties

Big Data Challenge

In this use case we attempt to integrate different types of data from different information sources (**Variety**) to make predictive analysis for tourists. Another challenge is to make the prediction as precise and accurate as possible (**Veracity**).

Use Case Diagram

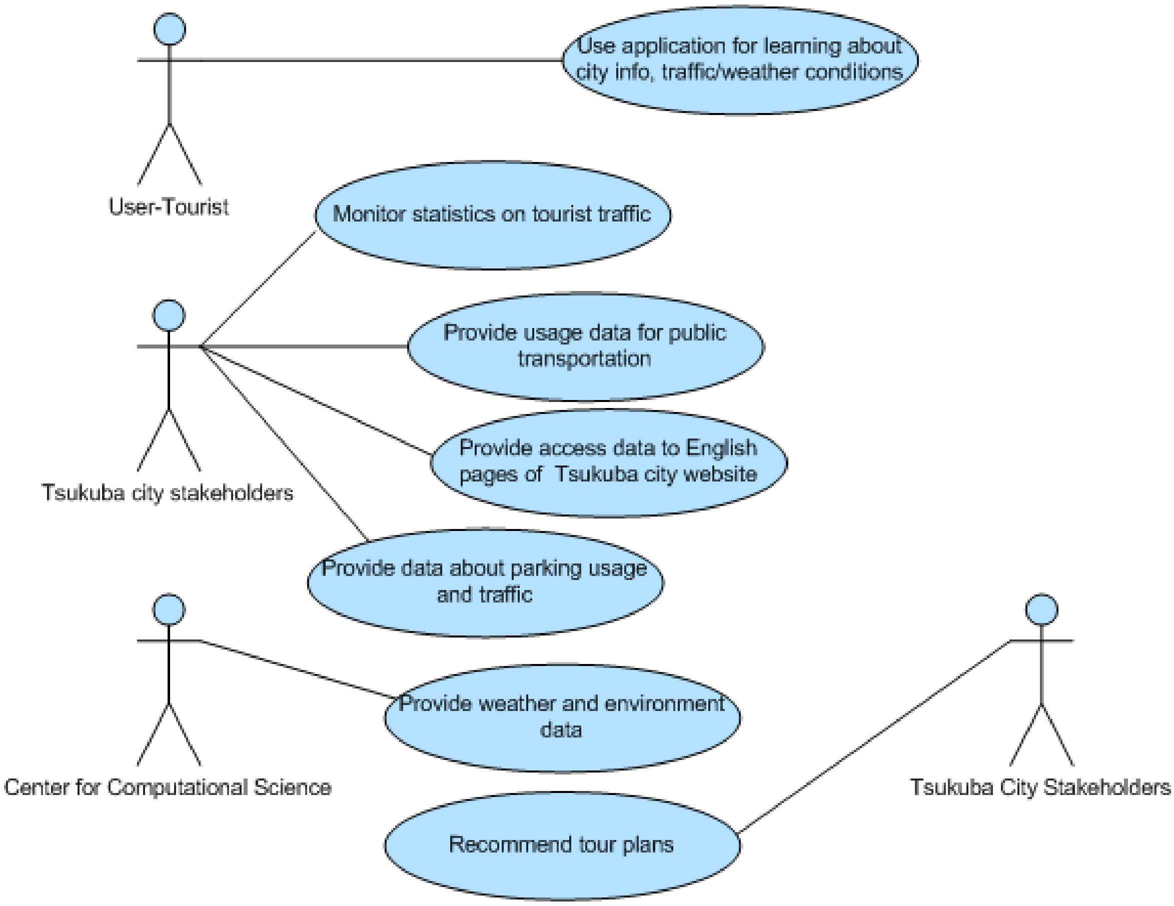

FIGURE 11: TSU-UC1: PROVIDE TOURISM, TRAFFIC AND ENVIRONMENTAL INFORMATION IN REAL TIME TO VISITORS UML DIAGRAM

Requirements summary

Below we provide a summary of requirements that have been elicited for the specific use case:

- The tourist should install a smartphone app as an interaction with the services based on the BigClouT platform
- The city and BigClouT project should promote/distribute the smartphone application for the tourists.
- A method, for instance SNS (Social Networking Service) analysis, questionnaires by smart phone or interactive signage, should be provided for collecting information to analyse visitors' trends below:
  - visitors' attribute
  - visitors' behaviour history
  - location information
  - satisfaction rate for visitors' purpose and their needs
  - environmental information
  - statics from local government
- The application should be able to provide the most suitable information in real time such as weather information, SNS comments, traffic and facilities congestion information by their attribute and location information.

- The application should be able to analyse the trend of satisfaction rate, weather information and visitors' behaviour by their attribute.
- The application should be able to recommend the most suitable information about tourism and transportation by their attribute, real time environmental information and trend of satisfaction rate.
- The application should be able to predict future recommendation information by accumulated information.
- The application should be able to provide the useful information by location and time. (e.g.: SNS, smart phone application and interactive signage).
- The application should be able to provide predicted future information by accumulated information (e.g.: SNS, smart phone application and interactive signage).

Use Case KPIs

TABLE 6: KPIS OF "PROVIDE TOURISM, TRAFFIC AND ENVIRONMENTAL INFORMATION IN REAL TIME TO VISITORS" USE CASE OF TSUKUBA

KPI	Target value
Target number of users	40
Critical mass of users	100
Daily active users	80
Average length of time spent using app	10 minutes
Frequency of use	Every working day

Replication Potentiality of the Use Case

The use case can be replicated to other cities especially Grenoble, because it is a sister city of Tsukuba. Both Tsukuba and Grenoble are famous as a scientific city and have many foreign visitors who visit the cities for not only sightseeing but also international conferences. There are many cities that have similar characteristic in the world, we expect that this use case could be replicated to those cities in terms of data resources and scenario.

1.3.2 Use Case 2: Grasp status about foreign visitors to Tsukuba and provide concierge service to them

Description

The objective of the use case is to provide multilingual concierge service for foreign visitors to Tsukuba to solve their needs and problems such as tourism, emergency, disaster prevention and transportation since Tsukuba city has many international conferences.

Scenario

1. Collect foreign visitors' attribute information such as purpose for visiting to Tsukuba, transportation, gender, generation, hobby, tastes and language.

2. Collect needs and problems of foreign visitors to grasp their situation.

3. Collect behaviour histories of foreign visitors.

4. Collect and accumulate information that would solve the needs and problems.

5. Prepare for the most suitable information for the demands (problems) of foreign visitors to Tsukuba from collected and accumulated data.

Example:

・Instruction to the local destination (for any vague needs such as "I want wine!").

・Guide the instruction to the area including downtown, not a specific shop (e.g.: an area with many sushi restaurants).

・Place (or direction) that is easy to get a taxi.

・Emergency contacts (hospital, police).

・Restroom map (degree of cleanliness).

・Getting information to avoid dangerous areas.

・Waiting time of restaurants and List up of the restaurants by waiting time.

6. Deliver answers for the inquiries from foreign visitors according to their attribute and real time location information.

- Deliver additional recommended information to the person who inquires

7. Get feedbacks about information delivered by questionnaires and so on.

- Improve recommendation accuracy based on feedbacks.

Stakeholders involved and means of interaction / engagement

This use case scenario of Tsukuba is targeting visitors to Tsukuba city. So candidates of stakeholders listed up are organizations in Tsukuba city who are related to tourism or international conference and would cooperate on the project.

Identified stakeholders of this use case are reported in Table 7

TABLE 7: STAKEHOLDERS OF "GRASP STATUS ABOUT FOREIGN VISITORS TO TSUKUBA AND PROVIDE CONCIERGE SERVICE TO THEM" USE CASE OF TSUKUBA

Stakeholder	Role	Interaction / Engagement
Tsukuba city IT division	Point of contact for BigClouT project, stakeholders etc. Get questionnaires or have meetings with users for the result measurement	Periodical meetings
Tsukuba city tourism section	Point of contact for tourism related stakeholders. Provide comments about use cases	Meetings anytime it is needed
Tsukuba city traffic section	Point of contact for railway companies Provide usage data for Tsukuba taxi on demand Provide comments about use cases	Meetings anytime it is needed Provide usage data by signage if needed
Tsukuba city international division	Provide access data to English pages of Tsukuba city website	Provide data online
Center for Computational Science	Provide weather and environment data	Provide data online if needed
Other Stakeholders in Tsukuba city (under negotiation)	Provide usage data of public transportation	Provide usage data online if needed
	Provide places to install signage at stations	Deploy it according to their rules or laws
	Provide data about parking usage and traffic	Provide data online if needed
	Recommend tour plans	Provide tour information on website
	Provide incentives for users	Provide coupons or novelties

Big Data Challenge

In this use case, similar to the use case "Provide tourism, traffic and environmental information in real time to visitors" (section 1.3.1), we exploit different types of data from different sources to grasp activities of foreign tourists (**Variety**). We also attempt to perform predictive analysis over the collected data to provide useful information to the visitors in a precise and accurate manner (**Veracity** and **Value**).

Use Case Diagram

The UML diagram of the specific use case is similar with the one provided for TSU-UC1 as the stakeholders involved (actors) the functionalities and the purpose of interaction are common.

Requirements summary

Below we provide a summary of requirements that have been elicited for the specific use case:

- The foreign tourists should install a smartphone app as an interaction with the services based on the BigClouT platform
- The city and BigClouT project should promote/distribute the smartphone application for the foreign tourists.
- A method, (e.g.: SNS analysis, questionnaires by smart phone or interactive signage) should be provided for collecting information to analyse foreign visitors' trends below:
  - Visitors' attribute
  - Visitors' behaviour history
  - GPS information
  - Location information
  - Satisfaction rate for visitors' purpose and their needs
  - Environmental information
  - Statics from local government
  - Foreign visitors' needs and problems
- The application should be able to collect accumulated information to provide the most suitable information.
- The application should be able to prepare to answer to solve their needs and problems by collected data according to visitors' behaviour and their attribute.
- The application should be able to provide the useful and multilingual information to foreign visitors by their location and time (e.g. SNS, smart phone application and interactive signage).
- The application should be able to provide additional useful information by accumulated information (e.g. SNS, smart phone application and interactive signage).

Use Case KPIs

TABLE 8: KPIS OF "GRASP STATUS ABOUT FOREIGN VISITORS TO TSUKUBA AND PROVIDE CONCIERGE SERVICE TO THEM" USE CASE OF TSUKUBA

KPI	Target value
Critical mass of downloads	50 users in first 1 month, 600 in first year
Critical mass of users	600 in first year
Daily active users	10
Average Length of time spent using app	10 minutes
Frequency of use	Every day

Replication Potentiality of the Use Case

The use case can be replicated to all other pilot cities of this project because it is English version. One of the games will be held in Fujisawa city in Olympic 2020, and the city recognizes that they will have more foreign visitors and this app could be helpful to collect the problems of foreign visitors in preparation for Olympic game. It is also replicable in Grenoble as a sister city of Tsukuba, because it has many foreign visitors with similar reason as use case "Provide tourism, traffic and environmental information in real time to visitors" (section 1.3.1).

1.4 Fujisawa Updated Use Cases

Fujisawa city is about 50km from Tokyo, and it takes about one hour by train. Population is 420,809 and total area is 69.5 km^2. One of the most famous places in Fujisawa is an island, called Enoshima. Enoshima, in recorded history, had already flourished as a tourist spot in the Edo era. Fujisawa is the central city in "Shonan", one of the most popular beach areas in Japan. It is known as a city of residence, sightseeing, business and education.

In addition, Enoshima is chosen in the sailing competition of the 2020 Tokyo Olympic and Paralympic Games as a venue. And in the same year, Fujisawa city will reach the municipal organization enforcement 80th anniversary. The city would like to utilize ICT to treat Olympic participants and visitors from all over the world, and lead this big event success in this memorial year.

FIGURE 12A VIEW AND LOCATION OF FUJISAWA

The city and some of Japan's leading companies established a smart town called "Fujisawa Sustainable Smart Town". The plan is to apply comprehensive solutions for an entire house, entire building and entire town, combining energy technologies to provide a safe and secure environment. They will effectively create an advanced model of a town demonstrating efficient use of energy by promoting widespread use of energy-saving devices and proposing new solutions that integrate measures for energy creation, storage and management.

1.4.1 Use Case 1: Optimizing the incidence on local economy of Fujisawa

Description

The objective of the use case is to enhance local economy in terms of various events where citizens and visitors participate. City needs to provide event, local and environmental information for both citizen and visitors. In terms of visitors, not only domestic visitors but also international visitors must be targeted, especially for coming Tokyo Olympic Paralympics 2020. By providing such city information in real-time, city can solve several problems such as traffic jam, visiting recommendation, or disaster prevention.

Scenario:

(1) Collect physical and virtual information about Fujisawa city by leveraging any information resources such as IoT sensors, Web sensors or human sensors.
(2) Analyze the real-time collected data by comparing it with historical data.
(3) Visualize the analyzed data to optimize the incidence on local economy for stakeholders

Stakeholders involved and means of interaction / engagement

Identified stakeholders of this use case are reported in Table 9.

TABLE 9: STAKEHOLDERS OF "OPTIMIZING THE INCIDENCE ON LOCAL ECONOMY OF FUJISAWA" USE CASE OF FUJISAWA

Stakeholder	Role	Interacting functionalities
Fujisawa city IT division	Point of contact for BigClouT project, stakeholders etc. Get questionnaires or have meetings with users for the result measurement	Periodical meetings
Fujisawa city tourism section	Point of contact for tourism related stakeholders Comments about use cases	Meetings anytime it is needed
Fujisawa city traffic section	Point of contact for railway companies Provide usage data for Fujisawa transportation on demand Comments about use cases	Meetings anytime it is needed
Fujisawa city international division	Provide access data to English pages of Fujisawa city website	Provide data online

We already had several meetings with Fujisawa city staffs and Fujisawa resource association to discuss the use case.

Big Data Challenge

In this use case data coming from more than 100 different types of resources are managed (**Variety**). It is expected to collect and process 1Mbps of data (**Velocity**) for an expected amount of 10GB of sensor data per day (**Volume**). Collected data will be validated (**Veracity**) and will be used to discover city context which has not been discovered previously (**Value**).

Use Case Diagram

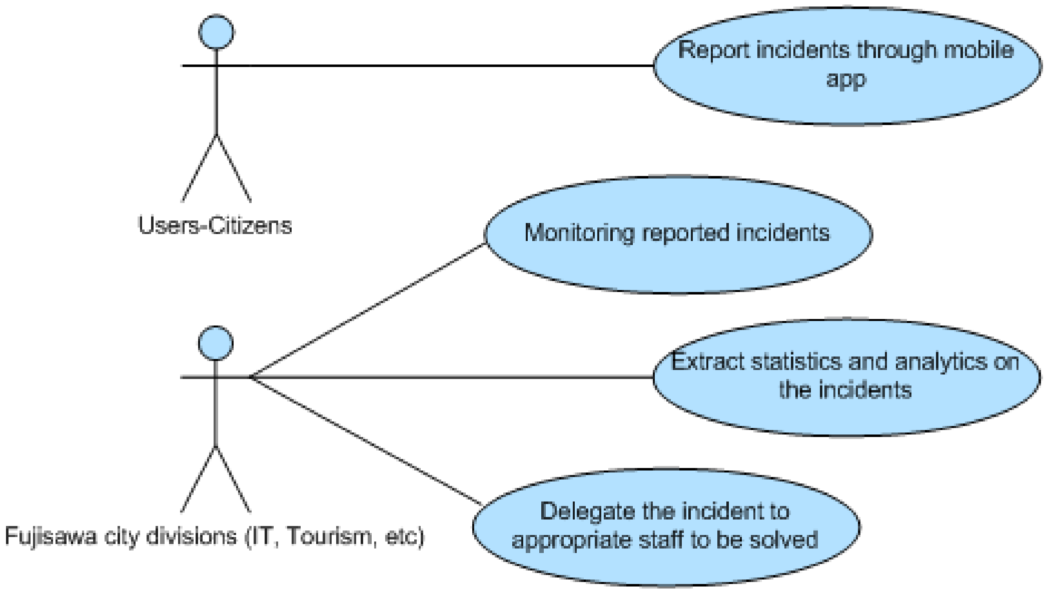

FIGURE 13: FUJ-UC1 UML DIAGRAM

Requirements summary

Below we provide a summary of requirements that have been elicited for the specific use case:

- The citizens and tourists should install a smartphone app as an interaction with the services based on the BigClouT platform
- The city and BigClouT project should promote/distribute the smartphone application for the citizens and tourists.
- Users should be able to report through smart phones various incidents through a dedicated mobile phone application.
- Various city stakeholders (from IT or city tourism division) should be able to monitor these incident reporting.
- The BigClouT platform should be able to collect real-time city data from various information resources with low cost.
- The application should be able to provide and share collected data among various stakeholders.
- The application should be able to analyse real-time data efficiently and effectively.
- The application should be able to visualize analysed data effectively and intuitively.

Use Case KPIs

TABLE 10: KPIS OF "OPTIMIZING THE INCIDENCE ON LOCAL ECONOMY OF FUJISAWA" USE CASE OF FUJISAWA

KPI	Target
Users	250
Critical mass of users	300 in first year
Daily active users	50
Average length of time spent using app	10 minutes
Frequency of use	Everyday
Time until trouble in city event resolved	1 hour

Replication Potentiality of the Use Case

The use case can be replicated to other cities, and also can be collaborated with similar use case in Grenoble and Tsukuba. Especially, participatory sensing application for both citizens and city staffs could be easily replicated. In addition, we plan to use existing data resources in the Internet. To leverage existing data resources, other cities' helps should be needed to identify what kind of data exists at where.

1.4.2 Use Case 2: Fine-grained city infrastructure management

Description

Managing city infrastructure is one of very important tasks for city operation. Thus, the objective of the use case is to provide optimized city infrastructure management. As the first step of managing the city infrastructure, understanding current condition such as road damage or road mark damage is necessary. To solve the problem, we leveraged sensorized garbage trucks to collect massive information about city infrastructure. Several sensors such as accelerometer, temperature, humidity, sound and camera captures information of city infrastructure in a way of high frequent sensing rate. Such information is analysed at edge-side first to reduce data size, and then send to the cloud-side.

Stakeholders involved and means of interaction / engagement

Identified stakeholders of this use case are reported in Table 11

TABLE 11: STAKEHOLDERS OF "FINE-GRAINED CITY INFRASTRUCTURE MANAGEMENT" USE CASE OF FUJISAWA

Stakeholder	Role	Interacting functionalities
Fujisawa city IT division	Point of contact for BigClouT project, stakeholders etc. Get questionnaires or have meetings with users for the result measurement	Periodical meetings
Fujisawa city environmental section	Point of contact for garbage collection related stakeholders. Comments about use cases	Meetings anytime it is needed
Fujisawa resource association	Point of contact for garbage collection related stakeholders.	Meetings anytime it is needed

Fujisawa had already several meetings with above stakeholders and has formed a regional consortium for engaging stakeholders towards smart city services.

Big Data Challenge

In this use case data coming from more than 10 types of sensors are managed (**Variety**). Data will be gathered from 50 car sensors for 6 hours per day at 100Hz rate (**Velocity**) for an expected amount of 5GB of sensor data per day (**Volume**). Collected data will be validated (**Veracity**) and, through analysis, it will lead to obtain new city information (**Value**).

Use Case Diagram

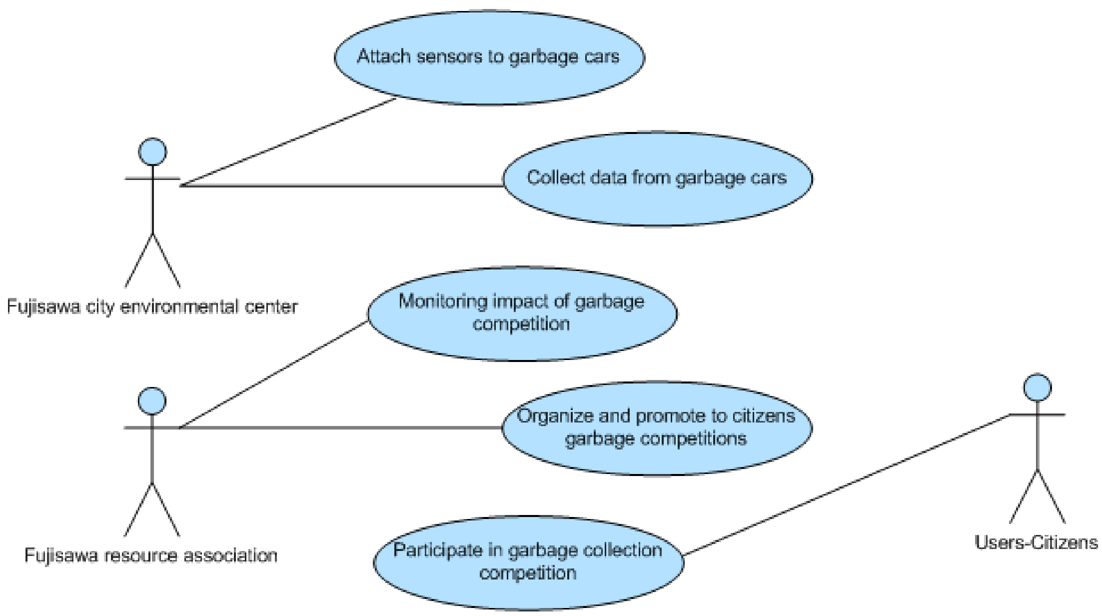

FIGURE 14: FUJ-UC2 UML DIAGRAM

Requirements summary

Below we provide a summary of requirements that have been elicited for the specific use case:

- BigClouT project should install sensors on garbage collection trucks as an interaction with the services based on the BigClouT platform.
- City stakeholders should be able to collect data from sensors attached to garbage collection trucks.
- City stakeholders should be able to organize and promote various competitions related to garbage saving and or collection.
- The BigClouT platform should provide a method to visualize analysed data effectively and intuitively.
- The BigClouT platform should provide a method to collect real-time city data from various information resources with low cost.
- The BigClouT platform should provide edge-side computing technology to reduce data size with finding important aspect of the data.
- The BigClouT platform should provide cloud-side computing technology to store massive data effectively and analyse the data for city infrastructure management.
- The BigClouT platform should provide a method to share collected data among various stakeholders.
- The BigClouT platform should provide a method to analyse real-time data efficiently and effectively.

Use Case KPIs

TABLE 12: KPIS OF "FINE-GRAINED CITY INFRASTRUCTURE MANAGEMEN" USE CASE OF FUJISAWA

KPI	Target
Garbage trucks used	Min 50
Critical mass of data	5GB per day
Frequency of use	Every working day
Cost reduced for city infrastructure management	1,000,000 yen per yaer

Replication Potentiality of the Use Case

The use case is easily replicated to Tsukuba and other cities in Japan because social infrastructure is similar. However, there are several differences between JP cities and EU cities for city management way, replication from JP to EU requires effort to identify the differences and how to fill the differences.

2 FINAL REQUIREMENTS

This section provides a consolidated view of the requirements described above so as to conclude to a unique coding of all individual requirements in order to be tracked throughout the lifecycle of the project.

Tables reported in sections 2.1 and 2.2 provide an overview of the elicited requirements of the BigClouT project. It has to be underlined that the requirements are derived not only from the use cases, but also from a range of other factors including the partners' background projects, state-of-the-art projects and requirements expressed by the project stakeholders. The selection of requirements has been also driven by:

- The need to address, design and implement the innovative features of the BigClouT framework.
- The functionalities that have to be offered in the use cases.
- Non-functional features that the final BigClouT system has to include.

The first column of these tables provide the unique coding of the requirement that will make it traceable within the lifecycle of the project. The second column gives the description of the requirement while the third column describes any dependencies or comments. The fourth and fifth columns provide the details on the origin of the document and the relevant stakeholder respectively, linking it thus with the requirements summary as this has been provided by the partners in section 1 of this document. In same table the fourth column is not present, because for the specific reported requirements the origin is the same; in these case a note is reported at the bottom of the tables. Moreover, these specific table have been further updated and extended in the current version of this document. In particular, they contain additionally a column on the prioritization of the requirements distinguishing between ***High*** (critical for the implementation of many other functionalities within the project), ***Medium*** (can be implemented in a second iteration) and ***Low*** (must be implemented but it is not critical for other components) priority based on whether the specific requirement is to be addressed in the first version of the prototype release or in next iterations. Last but not least, for a better traceability of the requirements from the inception to the implementation, the requirements have a mapping to the specific asset coverage (last column of the tables; complete list of assets is reported in section 5).

2.1 Functional requirements

The **functional** view of a requirements analysis process focuses on what the system must do to produce the required operational behaviour. The functional requirements are the primary sources of the requirements that will eventually be reflected in the system specification.

Functional view information includes:

- System functions,
- Tasks or actions to be performed,
- Inter-function relationships,
- Hardware and software functional relationships,
- Functional constraints,
- Interface requirements.

BigClouT is a complex project, with many different components that should work together to offer interesting services to the users. In order to construct an integrated system, the development process must fulfil some requirements. These functionalities requirements are intended for developers and integrators as well as for final users. Each component of BigClouT must be developed according accepted good programming practices, in order to reduce the complexity of code comprehension and difficulty of maintenance tasks. For instance, the code must be well documented, well indented and clear in general. The architecture must be modular with a clear separation between the modules. The components should be loosely coupled, allowing the development of new components that can be easily added. The architecture of BigClouT must be layered, providing separation of concerns.

In turn, functional requirements are divided in two groups:

- **BigClouT Platform generic functional requirements**: this group includes functional requirements that are directly related to BigClouT platform itself (Table 13).
- **BigClouT Use Case specific functional requirements**: this group includes functional requirements that are related to use cases reported in section 1 (Table 14); the following codes are reported in order to keep trace of the use case related to a specific requirement:
    - **GRE-UC1**: Monitoring of Economic Impacts of Events (section 1.1.1).
    - **GRE-UC2**: Monitoring of Industrial Estates (section 0).
    - **BIO-UC1**: Smart Energy - predictive analysis of users' power consumption (section 1.2.1).
    - **BIO-UC2**: Smart Mobility (section 1.2.2).
    - **TSU-UC1**: Provide tourism, traffic and environmental information in real time to visitors (section 1.3.1).
    - **TSU-UC2**: Grasp status about foreign visitors to Tsukuba and provide concierge service to them (section 1.3.2).
    - **FUJ-UC1**: Optimizing the incidence on local economy of Fujisawa (section 1.4.1).
    - **FUJ-UC2**: Fine-grained city infrastructure management (section 1.4.2).

TABLE 13: BIGCLOUT PLATFORM GENERIC FUNCTIONAL REQUIREMENTS

Functional Requirements - Group 1: BigClouT Platform generic functional requirements					
Code	**Description**	**Dependencies with other requirements and Comments**	**Relevant Stakeholders**	**Prority**	**Coverage**
R1.1.1	The platform should be able to access data from sensors on demand and through subscriptions.	*The generic functional requirements of the BigClouT platform have been derived as system requirements from the technical partners of the consortium after analysing the use case requirements from the end users. For this reason there is a strong dependency with functional requirements under Group 2: Use Case specific requirements, reported in* Table 14*.*	Service providers, IoT infrastructures	High	sensiNact
R1.1.2	The platform should provide big data analytics functionalities.		Service providers & Integrators	High	StreamOLAP
R1.1.3	The platform should be able to perform predictive analysis.		Service providers & Integrators	High	KNOWAGE
R1.1.4	The platform should be able to perform recommendations as part of predictive analysis		Service providers & Integrators	High	Recommendation Service
R1.1.5	The platform should provide a dashboard in order to present results of analysis.		Service providers & Integrators	High	KNOWAGE
R1.1.6	The platform should provide real-time data processing functionalities.		Service providers & Integrators	High	sensiNact Studio
R1.1.7	The platform should be able to access online data, e.g. from web sites and social networks.		Service providers & Integrators	High	Sensorizer
R1.1.8	The platform should provide data machine learning functionalities.		Service providers & Integrators	High	Deep on Edge

R1.1.9	The platform should provide distributed machine learning functionalities.		Service providers & Integrators	High	StreamOLAP
R1.1.10	The platform should provide edge processing functionalities.		Service providers & Integrators, IoT infrastructure providers	High	Distributed Node-RED
R1.1.11	The platform should be able to collect and store data.		Service providers & Integrators	High	CDMI Storage, sensiNact
R1.1.12	The platform should be able to provide stored historical data.		Service providers & Integrators	High	CDMI Storage
R1.1.13	The platform should be able to be integrated with existing sensor networks.		Service providers & Integrators, IoT infrastructure providers	High	sensiNact
R1.1.14	BigClouT should be able to collect data from heterogeneous data sources (open data from the city, real-time traffic information, localisation of users, etc.)		Service providers & Integrators, IoT infrastructure providers	High	sensiNact
R1.1.15	BigClouT should provide means to push data from the users and relevant stakeholders into the platform.		Service providers & Integrators, IoT infrastructure providers	High	sensiNact Studio
R1.1.16	BigClouT should be able to issue notifications to end users when interesting events occur.		Smart Cities, End Users	Medium	sensiNact
Note: requirements reported in this table have the same origin: all use cases					

TABLE 14: BIGCLOUT USE CASE SPECIFIC FUNCTIONAL REQUIREMENTS

Functional Requirements - Group 1: BigClouT Use Case specific functional requirements						
Code	**Description**	**Dependencies with other requirements and Comments**	**Origin of requirement**	**Relevant Stakeholders**	**Priority**	**Coverage**
R1.2.1	The application for the business tourist should be distributed as a mobile app as an interaction mean with the services based on the BigClouT platform.		GRE-UC1	Smart Cities, End Users	Low	Not yet covered. Application to be developed.
R1.2.2	Hotels, shops and restaurants should be able to share the participant information with the application (how many nights stayed, how much spent, etc.).	R1.1.15	GRE-UC1	Smart Cities, End Users	Low	sensiNact Studio
R1.2.3	The application may collect this information automatically by using sensors from the mobile phone (GPS localisation, proximity sensors such as NFC or Bluetooth Low Energy).	R1.1.14	GRE-UC1	Smart Cities, End Users	Low	Application to be developed.
R1.2.4	The application should provide a tool to analyse data and extract statistics in simple and easily understandable way for the city economic development division and for the event organisers.	R1.1.5 R1.1.8	GRE-UC1	Smart Cities, End Users	Low	KNOWAGE
R1.2.5	The event organisers may share some information about the participant collected during his/her registration to the event. (hotel stayed, personal profile, etc.).	R1.1.15	GRE-UC1	Smart Cities, End Users	Low	Application to be developed.
R1.2.6	The Grenoble mobility service should have the means to provide the information about the transportation	R1.1.7	GRE-UC1	Smart Cities, End Users	Low	KNOWAGE

	system in Grenoble (bus/tram stations, real-time traffic, etc.).					
R1.2.7	The application should protect the privacy of the end-user and propose several levels of management of personal data, and give the possibility of modifying the privacy parameters any time.		GRE-UC1	Smart Cities, End Users	Low	Application to be developed.
R1.2.8	The application should provide means for shops and restaurants to announce interesting offers to the business tourists, as well as for Grenoble tourism office to notify about city events etc.	R1.1.15 R1.1.16	GRE-UC1	Smart Cities, End Users	Low	Application to be developed.
R1.2.9	The application should provide means to gather satisfaction information from the user.		GRE-UC1	Smart Cities, End Users	Low	Application to be developed.
R1.2.10	The application should be distributed as a mobile app for the employees of the Innovallée industrial zone.		GRE-UC2	Smart Cities, End Users	High	Application to be developed.
R1.2.11	The Innovallée association should be able to collect (in real-time when relevant) information from the associated stakeholders (restaurants, shops, company associations, etc.) and provide it to the BigClouT platform	R1.1.14	GRE-UC2	Smart Cities, End Users	High	SensiNact
R1.2.12	The application should provide means (via the same mobile app) for associated stakeholders to directly enter necessary information (bypassing Innovallée), such as restaurants announcing menus, waiting time, shops providing interesting offers, food trucks	R1.1.15	GRE-UC2	Smart Cities, End Users	High	Application to be developed.

	announcing location and offers, etc.					
R1.2.13	The Grenoble mobility service should provide the information about the transportation system in Grenoble (bus/tram stations, timetables, real-time traffic information, car-sharing, etc.).	R1.1.14	GRE-UC2	Smart Cities, End Users	High	Application to be developed.
R1.2.14	The user may accept to provide some personal information such as profile, location, company, transportation mode used, etc., for receiving customised information.		GRE-UC2	Smart Cities, End Users	Medium	Recommendation service
R1.2.15	The application should protect the privacy of the end-user and propose several levels of management of personal data, and give the possibility of modifying the privacy parameters any time.		GRE-UC2	Smart Cities, End Users	High	Application to be developed.
R1.2.16	The application should provide a tool to analyse data and extract statistics in simple and easily understandable way for the city economic development division and for Innovallée Association	R1.1.2 R1.1.4	GRE-UC2	Smart Cities, End Users	Medium	KNOWAGE
R1.2.17	The application should notify the user when interesting events occur and/or customised recommendations to be provided		GRE-UC2	Smart Cities, End Users	High	Application to be developed.
R1.2.18	The application should provide means to gather satisfaction information from the user.		GRE-UC2	Smart Cities, End Users	Medium	Application to be developed.
R1.2.19	BigClouT should collect information from sensors deployed inside citizen homes.	R1.1.1	BIO-UC1	Smart Cities, End Users	Medium	Application to be developed.
R1.2.20	BigClouT should collect detailed weather information in a real time	R1.1.10	BIO-UC1 BIO-UC2	Smart Cities, End Users	High	Application to be developed.

	and in an accurate way.					
R1.2.21	BigClouT should store the information from different sources for post processing.	R1.1.10	BIO-UC1	Smart Cities, End Users	Medium	CDMI storage
R1.2.22	Provide prediction tools for energy usage mapping.	R1.1.3	BIO-UC1	Smart Cities, End Users	High	Recommendation service
R1.2.23	Provide tools for comparing citizens' energy consumption scenarios.		BIO-UC1	Smart Cities, End Users	High	KNOWAGE
R1.2.24	Provide an easy to use dashboard.	R1.1.4	BIO-UC1 BIO-UC2	Smart Cities, End Users	High	Application to be developed.
R1.2.25	Collect measurements of air quality from sensors deployed around University of Bristol		BIO-UC2	Smart Cities, End Users	High	Application to be developed.
R1.2.26	Measure concentration of carbon monoxide (CO) in the air as a main pollutant and measurements related to the temperature, humidity and light level which will be processed along with the pollutant concentration.		BIO-UC2	Smart Cities, End Users	High	Application to be developed.
R1.2.27	The platform should be able to store the information from different sources for post processing.	R1.1.10	BIO-UC2	Smart Cities, End Users	High	CDMI storage
R1.2.28	Provide prediction tools for citizens' mobility patterns.	R1.1.3	BIO-UC2	Smart Cities, End Users	High	Recommendation service
R1.2.29	NGSI API compliance should be provided.		BIO-UC1 BIO-UC2	Smart Cities, End Users	Medium	
R1.2.30	A User Management System should be available for citizens to consult only their data and manage their profiles.		BIO-UC1	Smart Cities, End Users	High	Application to be developed.
R1.2.31	A Map (dashboard) should be provided showing different hot paths around the city.	R1.1.4	BIO-UC2	Smart Cities, End Users	High	Application to be developed.

R1.2.32	The tourist should install a smartphone app as an interaction with the services based on the BigClouT platform.		TSU-UC1	Smart Cities, End Users	High	Application to be developed.
R1.2.33	The city and BigClouT project should promote/distribute the smartphone application for the tourists.		TSU-UC1	Smart Cities, End Users	High	Application to be developed.
R1.2.34	The application should be able to provide the most suitable information in real time such as weather information, SNS comments, traffic and facilities congestion information by their attribute and location information.	R1.1.7	TSU-UC1	Smart Cities, End Users	High	Application to be developed.
R1.2.35	The application should be able to analyse the trend of satisfaction rate, weather information and visitors' behaviour by their attribute.	R1.1.7	TSU-UC1	Smart Cities, End Users	Medium	Application to be developed.
R1.2.36	The application should be able to recommend the most suitable information about tourism and transportation by their attribute, real time environmental information and trend of satisfaction rate.	R1.1.7	TSU-UC1	Smart Cities, End Users	Medium	Application to be developed.
R1.2.37	The application should be able to predict future recommendation information by accumulated information.	R1.1.7	TSU-UC1	Smart Cities, End Users	High	Application to be developed.
R1.2.38	The application should be able to provide the useful information by location and time. (e.g.: SNS, smart phone application and interactive signage).	R1.1.7	TSU-UC1	Smart Cities, End Users	High	Application to be developed.
R1.2.39	The application should be able to provide predicted future information by accumulated information (e.g.:	R1.1.7	TSU-UC1	Smart Cities, End Users	High	Application to be developed.

	SNS, smart phone application and interactive signage).					
R1.2.40	The foreign tourists should install a smartphone app as an interaction with the services based on the BigClouT platform		TSU-UC2	Smart Cities, End Users	High	
R1.2.41	The city and BigClouT project should promote/distribute the smartphone application for the foreign tourists.		TSU-UC2	Smart Cities, End Users	High	
R1.2.42	The application should be able to collect accumulated information to provide the most suitable information.	R1.1.2 R1.1.3	TSU-UC2	Smart Cities, End Users	High	SoxFire
R1.2.43	The application should be able to prepare to answer to solve their needs and problems by collected data according to visitors' behaviour and their attribute.	R1.1.3	TSU-UC2	Smart Cities, End Users	Medium	SoxFire
R1.2.44	The application should be able to provide the useful and multilingual information to foreign visitors by their location and time (e.g. SNS, smart phone application and interactive signage).		TSU-UC2	Smart Cities, End Users	Medium	SoxFire
R1.2.45	The application should be able to provide additional useful information by accumulated information (e.g. SNS, smart phone application and interactive signage).	R1.1.5	TSU-UC2	Smart Cities, End Users	High	SoxFire
R1.2.46	Collect information to analyze visitors' trend (e.g. GPS information, visitors' behaviour history etc.).	R1.1.5	TSU-UC1 TSU-UC2	Smart Cities, End Users	High	SoxFire
R1.2.47	Collect other real time information from third sources such as weather information, social network	R1.1.5	TSU-UC1 TSU-UC2	Smart Cities, End Users	High	SoxFire

	comments etc.					
R1.2.48	Provide recommendation services about tourism related issues and transportation.	R1.1.5 R1.1.7	TSU-UC1 TSU-UC2	Smart Cities, End Users	High	Application to be developed.
R1.2.49	Provide useful information by location and time.	R1.1.7	TSU-UC1 TSU-UC2	Smart Cities, End Users	High	Application to be developed.
R1.2.50	Provide useful and multilingual information to foreign visitors by their location and time.	R1.1.7	TSU-UC2	Smart Cities, End Users	Low	Application to be developed.
R1.2.51	The citizens and tourists should install a smartphone app as an interaction with the services based on the BigClouT platform		FUJ-UC1	Smart Cities, End Users	High	Lokemon
R1.2.52	The city and BigClouT project should promote/distribute the smartphone application for the citizens and tourists.		FUJ-UC1	Smart Cities, End Users	High	Lokemon
R1.2.53	Users should be able to report through smart phones various incidents through a dedicated mobile phone application.		FUJ-UC1	Smart Cities, End Users	High	Lokemon
R1.2.54	Various city stakeholders (from IT or city tourism division) should be able to monitor these incident reporting.		FUJ-UC1	Smart Cities, End Users	High	Lokemon
R1.2.55	Collect real-time city data from various information resources with low cost.	R1.1.10	FUJ-UC1	Smart Cities, End Users	High	Minarepo
R1.2.56	Share collected data among various stakeholders.		FUJ-UC1	Smart Cities, End Users	High	Minarepo
R1.2.57	Analyse real-time data efficiently and effectively.	R1.1.2 R1.1.5	FUJ-UC1	Smart Cities, End Users	High	Minarepo
R1.2.58	Visualize analysed data effectively and intuitively.		FUJ-UC1 FUJ-UC2	Smart Cities, End Users	High	Minarepo

R1.2.59	BigClouT project should install sensors on garbage collection trucks as an interaction with the services based on the BigClouT platform.		FUJ-UC2	Smart Cities, End Users	High	Deep on Edge
R1.2.60	City stakeholders should be able to collect data from sensors attached to garbage collection trucks.	R1.1.12	FUJ-UC2	Smart Cities, End Users	High	Deep on Edge
R1.2.61	City stakeholders should be able to organize and promote various competitions related to garbage saving and or collection.		FUJ-UC2	Smart Cities, End Users	High	Deep on Edge
R1.2.62	The BigClouT platform should provide a method to collect real-time city data from various information resources with low cost.	R1.1.5	FUJ-UC2	Smart Cities, End Users	Medium	Deep on Edge
R1.2.63	The BigClouT platform should provide edge-side computing technology to reduce data size with finding important aspect of the data.	R1.1.8	FUJ-UC2	Smart Cities, End Users	Medium	Deep on Edge
R1.2.64	The BigClouT platform should provide cloud-side computing technology to store massive data effectively and analyse the data for city infrastructure management.	R1.1.2 R1.1.8	FUJ-UC2	Smart Cities, End Users	High	Deep on Edge
R1.2.65	The BigClouT platform should provide a method to share collected data among various stakeholders.		FUJ-UC2	Smart Cities, End Users	Medium	Deep on Edge
R1.2.66	The BigClouT platform should provide a method to analyse real-time data efficiently and effectively.	R1.1.2	FUJ-UC2	Smart Cities, End Users	Medium	Deep on Edge
R1.2.67	End users should be able to download the mobile application and learn about the various events that are happening in the area.		GRE-UC1 GRE-UC2 FUJ-UC1 TSU-UC1 TSU-UC2	Smart Cities, End Users	High	Deep on Edge

2.2 Non-functional requirements

The **non-functional** view of a requirements analysis process focuses on what other technical features the system must have in order to facilitate the service provision.

Non-functional requirements are very important in setting the foundation of a complex integrated system as is the case of BigClouT. They are divided in seven groups:

- Security & Privacy (Table 15)
- Scalability (Table 16)
- Performance (Table 17)
- Reliability and availability (Table 18)
- Manageability and flexibility (Table 19)
- Openness and extensibility (Table 20)
- Design and implementation (Table 21)

TABLE 15: BIGCLOUT SECURITY & PRIVACY NON FUNCTIONAL REQUIREMENTS

Non Functional Requirements - Group 1: Security & Privacy					
Code	**Description**	**Dependencies and Comments**	**Relevant Stakeholders**	**Priority**	**Coverage**
R2.1.1	The BigClouT platform should be capable of managing different users profiles distinguishing between stakeholders, actors and roles.		All	High	sensiNact
R2.1.2	The platform should store privacy covered data in a protected way. Access to protected data should be possible only to authorized users.	R2.1.4	All	High	Assets already brought
R2.1.3	The BigClouT platform, in accordance to local security policies, should be capable of applying digital signature to content before storing them.	R2.1.4	All	High	to be developed
R2.1.4	The applications and technologies used in BigClouT must respect all regulations concerning the ethical aspects, especially those related with data protection and privacy.	R1.2.7 R1.2.25	All	High	to be developed
R2.1.5	BigClouT should cover with state-of-the-art technologies all the aforementioned security aspects.		All	High	Assets already brought
R2.1.6	BigClouT security and privacy parameters should be (re-) configurable.		Smart Cities, End Users	High	to be developed
Note: requirements reported in this table have the same origin: all use cases					

TABLE 16: BIGCLOUT SCALABILITY NON FUNCTIONAL REQUIREMENTS

Non Functional Requirements - Group 2: Scalability					
Code	**Description**	**Dependencies and Comments**	**Relevant Stakeholders**	**Priority**	**Coverage**
R2.2.1	The BigClouT system must be able to scale with respect to more input sensors. In this way, the number of edge nodes within a BigClouT system should not be limited, such that more edge nodes can be deployed to handle more sensors.		Infrastructure and Service Providers, Integrators	Medium	Distributed Node-RED
R2.2.2	The big data analytics engine should be able to scale to more input data from more edge nodes.		Infrastructure and Service Providers, Integrators	Medium	JsSpinner,
R2.2.3	The dashboard should be able to respond to user queries from the use cases, and moreover should be able to handle multiple users of the use cases at once, such that results are obtained quickly even under load.		Infrastructure and Service Providers, Integrators	Low	KNOWAGE
Note: requirements reported in this table have the same origin: all use cases					

TABLE 17: BIGCLOUT PERFORMANCE NON FUNCTIONAL REQUIREMENTS

Non Functional Requirements - Group 3: Performance					
Code	**Description**	**Dependencies and Comments**	**Relevant Stakeholders**	**Priority**	**Coverage**
R2.3.1	The BigClouT system deploys various big data analytics frameworks that have demands in computational power. They should be regularly evaluated during development, such that they are shown to be accurate with real-time data.		Infrastructure and Service Providers, Integrators	Medium	OpenStack Cloud computing
R2.3.2	Statistics and reports that should be displayed through the dashboard is a process with high performance needs.	R1.1.2	Infrastructure and Service Providers, Integrators	Medium	OpenStack Cloud computing
Note: requirements reported in this table have the same origin: all use cases					

TABLE 18: BIGCLOUT RELIABILITY AND AVAILABILITY NON FUNCTIONAL REQUIREMENTS

Non Functional Requirements - Group 4: Reliability and availability					
Code	**Description**	**Dependencies and Comments**	**Relevant Stakeholders**	**Priority**	**Coverage**
R2.4.1	The BigClouT system should have a high availability and reliability (e.g. more than 98% in regular operation during the pilots) that can be monitored, measured and audited.		Infrastructure and Service Providers, Integrators	Medium	to be developed
R2.4.2	In case of failures, measures have to be taken in order to overcome these in short notice and additional measures for preventing their occurrence.		Infrastructure and Service Providers, Integrators	Medium	to be developed
Note: requirements reported in this table have the same origin: all use cases					

TABLE 19: BIGCLOUT MANAGEABILITY AND FLEXIBILITY NON FUNCTIONAL REQUIREMENTS

Non Functional Requirements - Group 5: Manageability and flexibility					
Code	**Description**	**Dependencies and Comments**	**Relevant Stakeholders**	**Priority**	**Coverage**
R2.5.1	The BigClouT system should have a high manageability and flexibility even for users that are not considered experts.		Infrastructure and Service Providers, Integrators	Low	to be developed
R2.5.2	Common management attributes such as add/delete/update should be intuitive and easy to be performed.	R1.1.4	Infrastructure and Service Providers, Integrators	Low	to be developed
R2.5.3	The BigClouT modularity level should allow enough independence of all modules so as if any module needs to be replaced, this will have no consequences to the other modules.		Infrastructure and Service Providers, Integrators	Low	to be developed
Note: requirements reported in this table have the same origin: all use cases					

TABLE 20: BIGCLOUT OPENNESS AND EXTENSIBILITY NON FUNCTIONAL REQUIREMENTS

Non Functional Requirements - Group 6: Openness and extensibility					
Code	**Description**	**Dependencies and Comments**	**Relevant Stakeholders**	**Priority**	**Coverage**
R2.6.1	The various components of BigClouT should be ideally portable across major operating systems.		Service Providers, Integrators, OS Community	Medium	See related assets
R2.6.2	The various components of BigClouT should be interoperable with other services implementing common and open standards		Service Providers, Integrators, OS Community	Medium	See related assets
R2.6.3	The core components of the BigClouT framework should be extensible to new	R1.1.12	Service Providers, Integrators, OS Community	Medium	sensiNact

	unforeseen types of sensors and events captured.				
R2.6.4	BigClouT APIs should rely on open standards and built upon other existing open standards where possible.		Service Providers, Integrators, OS Community	High	See related assets
R2.6.5	BigClouT should provide programming interfaces for application developers to gather real-time and historic data	R2.6.4	Service Providers, Integrators, OS Community	Medium	sensiNact Studio
Note: requirements reported in this table have the same origin: all use cases					

TABLE 21: BIGCLOUT DESIGN AND IMPLEMENTATION REQUIREMENTS NON FUNCTIONAL REQUIREMENTS

Non Functional Requirements - Group 7: Design and implementation					
Code	**Description**	**Dependencies and Comments**	**Relevant Stakeholders**	**Priority**	**Coverage**
R2.7.1	BigClouT should reuse existing open source software and tools, where it is appropriate and possible according the license.	R2.6.*	Service Providers and Integrators	Medium	See related assets
R2.7.2	The architecture of BigClouT must be layered, providing separation of concerns.		Service Providers and Integrators	Medium	See related assets
R2.7.3	The components of BigClouT must be developed according accepted good programming practice.		Service Providers and Integrators, OS Community	Medium	See related assets
R2.7.4	The components should be developed using proven and trusted languages.	R2.6.4	Service Providers and Integrators, OS Community	Low	See related assets
Note: requirements reported in this table have the same origin: all use cases					

3 BIGCLOUT FINAL ARCHITECTURE

BigClouT architecture is derived from architecture defined by the ClouT project [8], that is strongly cloud-centric and based on the typical three layers of the cloud stack: IaaS, PaaS and SaaS. BigClouT extends this last one introducing new capabilities, such as Edge Computing, Big Data analysis, Self-Awareness, Real Time Intelligence, etc.

An initial version of BigClouT architecture is presented in “D1.3 First BigClouT Architecture” [5]. This section reports and describe the final version of BigClouT architecture; in particular, this section provides:

- an overview of BigClouT final architecture and its functionalities (section 3.1);
- the main differences between the first and the final version of the architecture (section 3.2);
- a set of sequence diagrams describing how logical modules of BigClouT architecture interact (section 3.3);
- the mapping among modules of the architecture and the technological assets provided by BigClouT partners (section 3.4);
- BigClouT overall data flow and the specific data flow for each use case (section 3.5).

3.1 BigClouT final architecture overview

The final BigClouT architecture follows the typical cloud stack made mainly by three layers:

- CIaaS layer: whose main role is to provide the capabilities to access and perform actions on the City Entities;
- CPaaS layer: whose main role is to provide functionalities to: compose services and applications; process, analyse and visualize data; access data and execute action through a uniform approach;
- CSaaS layer: this layer will contain application made on top of functionalities exposed by components of the two previous layers.

Figure 15 illustrates BigClouT final architecture. As depicted, BigClouT functionalities will be provided by CIaaS and CPaaS layers. City Entities layer represents external entities, such as data sources, IoT deivices, etc., whereas applications made on top of functionalities provided by CPaaS and CIaaS layers are part of the CSaaS layer. These applications are considered external to BigClouT because they will use its functionalities obtaining the proper authorizations through BigClouT *Security and Dependability* layer that is cross to CIaaS, CPaaS and CSaaS.

The BigClouT reference architecture presented in this section defines relations among the logical modules and the functionalities they provide. The platform is not intended to be deployed as a single centralized one, but it will be customized, tailored and instantiated for specific needs.

Next sections provide more details about layers of BigClouT reference architecture.

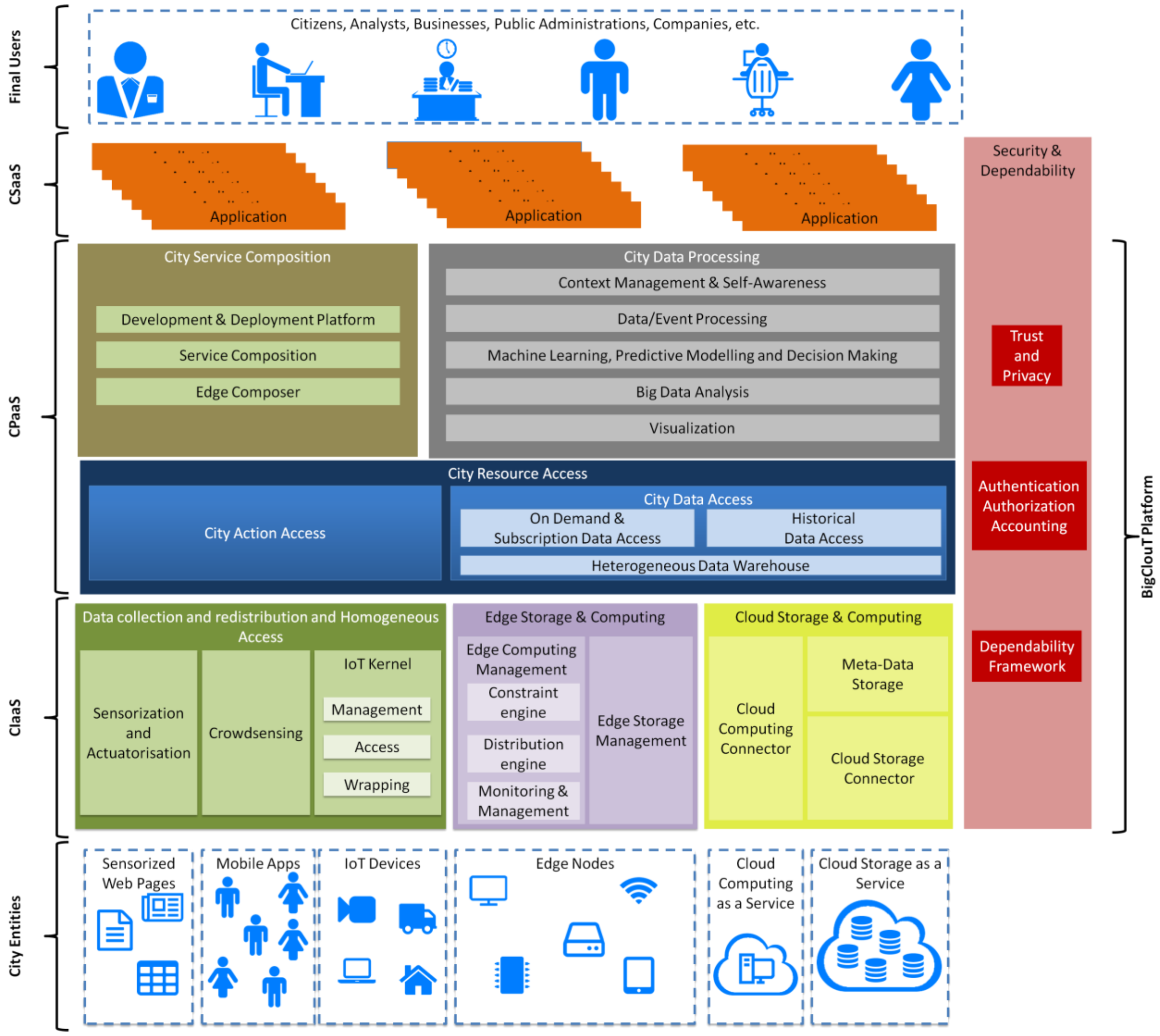

FIGURE 15: FINAL BIGCLOUT ARCHITECTURE OVERVIEW

3.1.1 BigClouT - CIaaS

CIaaS layer will provide capabilities to:

- access entities of City Entities layer such as Sensorized Web Pages and IoT devices in order to retrieve data and to perform actions on actuators;
- access edge devices in order to execute specific process and task on them;
- access Cloud Storage and Cloud Computing to manage cloud resources.

These capabilities are grouped in three logical modules:

- **Data Collection and redistribution and Homogenous access**: this module is in charge of collecting heterogeneous city data, of providing access to it (both in a synchronous and asynchronous way through subscriptions) and of managing the interactions with actuators. It is made by three sub components that will provide its functionalities for different kind of city entities:
    - **Sensorisation and Actuatorisation**: this sub component will provide capabilities to manage sensorized web pages; it is in charge of transforming

legacy devices and web resources, such as social network data or generic web application, in IoT compliant sensors and/or actuators.
    - **Crowdsensing**: this sub component will provide capabilities to manage participatory citizen/public officers tool.
    - **IoT Kernel**: it is in charge of providing capabilities to access IoT devices and to manage them, in order to make these resources accessible to the upper layers; in turn it is made of three modules: *Wrapping* (it provides a multi-protocol implementation level compliant with different IoT transmission protocol standards), *Management* (it is in charge of managing the settings of IoT devices and to track the relevant parameters for device configuration) and *Uniform Access* (it provides an abstraction level, using uniform Device Access APIs, that allows upper layers to access in unique way to IoT devices).
- **Edge Storage & Computing**: this module is in charge of managing edge storage and edge processing capabilities that will be offered by BigClouT; it is composed by the following sub components:
    - **Edge Computing Management**: it is in charge of managing the activities related to *distributed data processing* by applying the Edge Computing paradigm; in turn it is made of three modules: *Constraint engine* (it manages application constraints and edge processing capabilities), *Distribution engine* (it partitions code and distributes it to remote processing nodes) and *Monitoring & Management* (it monitors status of remote nodes, accepts new nodes to the cluster and removes nodes).
    - **Edge Storage Management**: it is in charge of managing the activities related to *data storage* by applying edge storage paradigm.
- **Cloud Storage & Computing**: this module is in charge of managing cloud computational and storage resources and to provide the necessary connectors to interact with them. It is composed by three sub components:
    - **Cloud Computing Connector**: it is in charge of providing the functionalities to access a generic Cloud Computing (i.e.: an IT infrastructure providing computing capabilities through Virtual Machines) and use its resources (e.g.: instantiate and run Virtual Machines).
    - **Cloud Storage Connector**: it is in charge of providing the other modules of BigClouT with the functionalities to access a generic Cloud Storage compliant with CDMI specifications[9].
    - **Meta-Data Storage**: it is in charge of providing capabilities to manage meta-data used and produced by the BigClouT modules to provide their functionalities. This sub component is intended to be purely logical; from a technical point of view, its functionalities and capabilities will rely on Cloud Storage Connector and on Cloud Storage.

3.1.2 BigClouT - CPaaS

CPaaS layer will provide capabilities to:

- access data and execute actions on actuators through a uniform approach;
- compose services and applications;
- process and analyse data (big data analysis, events detections, etc.).

These capabilities are grouped in three modules:

- **City Resource Access**: this module provides an access to some of the functionalities of CIaaS layer. In details, it allows to perform actions on city entities such as IoT devices (e.g. actuators) and to access historical data and (near) real-time data. It is composed by the following two sub components:
  - **City Action Access**: it is in charge of providing capabilities to perform actions on cities entities such as actuators that can be accessed through CIaaS layer.
  - **City Data Access**: it is in charge of providing capabilities to access data such as sensor data and historical data that can be accessed through CIaaS layer; in turn it is made of three modules: *On Demand & Subscription Data Access* (to access on demand data, such as data from sensor, and to create subscription), *Historical Data Access* (to access historical data) and *Heterogeneous Data Warehouse* (to access data coming from heterogeneous data sources).
- **City Service Composition**: this module provides capabilities to develop and deploy applications on top of the CIaaS layer. It is composed by three sub components:
  - **Development & Deployment Platform**: it is in charge of providing capabilities to create, test and deploy applications made on top of resources accessed though BigClouT and on the functionalities it will offer.
  - **Service Composition**: it is in charge of providing capabilities to create new services that can then be used to create end user applications.
  - **Edge Composer**: it is in charge of providing functionalities to build and manage application offering edge capabilities.
- **City Data Processing**: this module provides capabilities to perform data/events processing and context information management. It is composed by five sub components:
  - **Context Management & Self-Awareness**: it is in charge of providing capabilities to manage high-level context information obtained from processed data and events.
  - **Data/Event Processing**: it is in charge of providing capabilities and functionalities to process collected data and events, in order to extract new knowledge, context information, to derive recommendations useful for the users, and to detect in real time events of interest.
  - **Machine Learning, Predictive Modelling and Decision Making**: it is in charge of providing capabilities for prediction analysis and to improve the process of decision-making.
  - **Big Data Analysis**: it is in charge of providing capabilities for analytics over big data in order to extract knowledge and to support decision making.
  - **Visualization**: it is in charge of providing capabilities for the creation of charts and graph in order to visualize data and information.

3.1.3 BigClouT - CSaaS

CSaaS layer will host applications made on top of functionalities provided by components of both CPaaS and CIaaS layers; these applications will be offered to the end users following the SaaS (Software as a Service) paradigm; through this approach end users will not care about their installation and configuration.

3.1.4 BigClouT - Security and Dependability

The Security & Dependability is a cross layer to the CSaaS, CPaaS and CIaaS dealing with all security aspects for the entire platform and its components will provide their functionalities to all the other ones of BigClouT. It provides necessary functionalities to check and authorize the access to the modules of the platform in a secure way for the end users and for the applications of CSaaS layer. It includes three sub components:

- **Trust and Privacy**: this module is in charge of reifying and maintaining the data structures holding access rights to existing resources as well as their level of trust according to who is providing them.
- **Authentication Authorization Accounting**: this module provides functionalities to mainly support authentication, authorization and accounting for BigClouT platform including application that will be placed in CSaaS layer. Moreover, it keeps update a log of access to the platform allowing to identify the fraudulent access attempts.
- **Dependability Framework**: this module will maintain a state of the platform and generate rules to be applied in order to keep the expected level of availability and ensure the reliability of the different resources of the system.

3.1.5 BigClouT - City Entities

This layer is not strictly a part of BigClouT architecture, because it does not contain modules that provide functionalities to the end users, except for edge nodes those provide capabilities to store data and to execute process following the Edge Computing paradigm. This layer is reported in the BigClouT architecture in order to provide a clear view of relations between its entities and modules of CIaaS layer. The City Entities layer is composed by six sub components:

- **Sensorized Web Pages**: these entities represent legacy web pages that does not provide any APIs.
- **Mobile Apps**: these entities represent end-users mobile applications. For instance, through mobile applications end users could provide traffic information in real-time and at the same time it could be also possible to provide this information to the same end users.
- **IoT Devices**: these entities represent the physical apparatus feeding the platform with the data they produce (e.g. sensors). For those providing these features, they can also accept incoming commands requiring actuation, or configuration update (e.g. actuators).
- **Edge Nodes**: these entities represent distributed nodes providing computing and/or storage functionalities in different physical locations and with different features.
- **Cloud Storage as a Service**: this entity represent a generic cloud storage service compliant with CDMI specification providing elastic storage capabilities for the other BigClouT's layers in order to store data collected from BigClouT platform and to support application that will be part of CSaaS layer to store their relevant data.
- **Cloud Computing as a Service**: this entity represent a generic cloud computing service providing computing capabilities to support application that will be part of CSaaS layer.

3.2 Main differences between first and final BigClouT architectures

This section reports information about how BigClouT architecture has been evolved from its first version, described in [5], to its final one, describe in this document; in particular, Figure 16 underlines the main differences between first and final version of the BigClouT reference architecture (red marked elements).

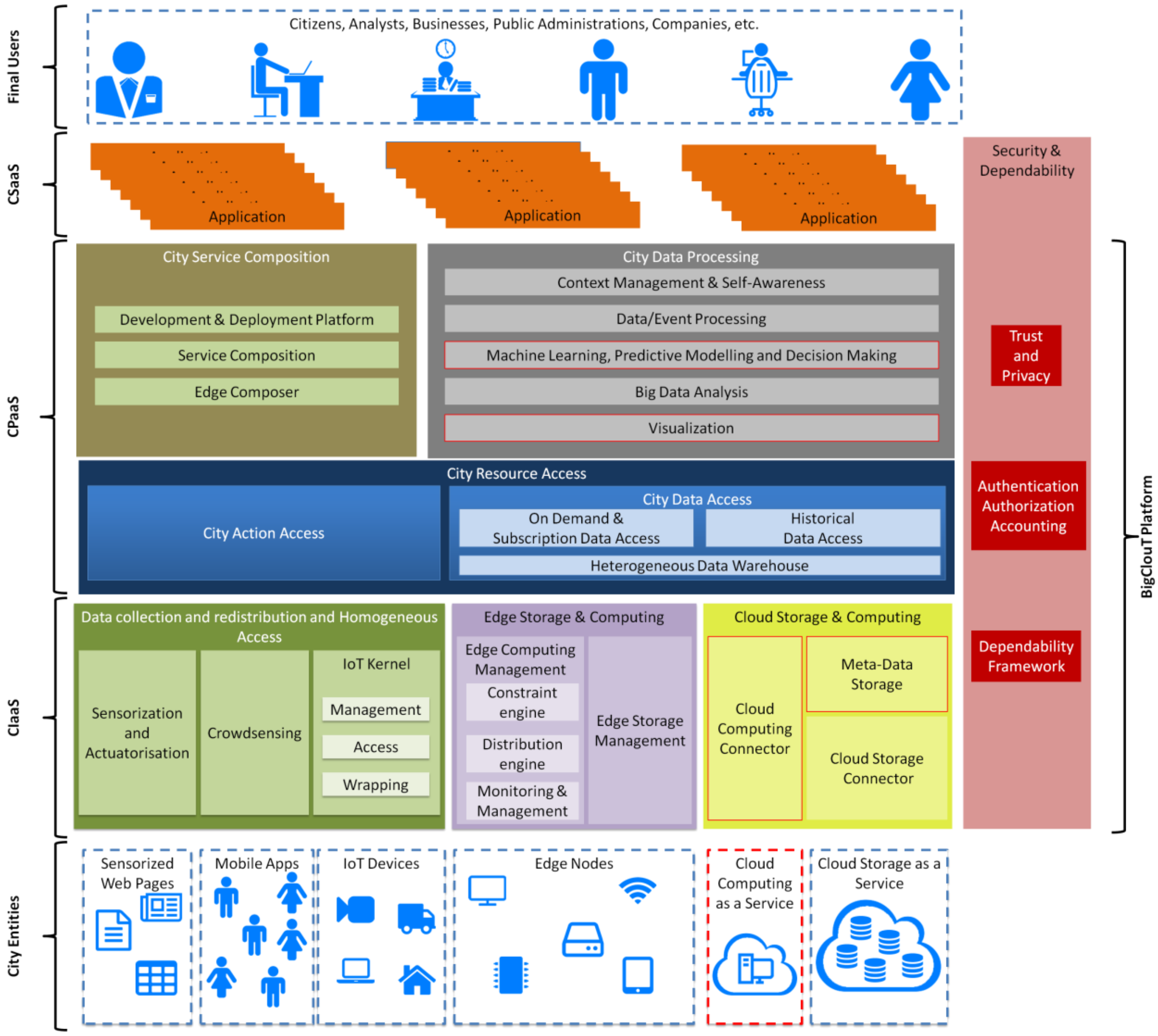

FIGURE 16: DIFFERENCES BETWEEN FIRST AND FINAL ARCHITECTURE

3.2.1 BigClouT - CPaaS Layer changes

In the City Data Processing module, a new logical sub component, *Visualization*, has been introduced. This new component will cover all the aspect related to the visualization of analysis results, context information, recommendation etc. and the production of graphical reports such as charts and maps to visualize data and information. It will receive in input data from most of the City Data Processing sub components and will also interact with sub components of City Resource Access to visualize real-time, near real-time data and historical data.

The denomination of the *Machine Learning* component has been updated with the new denomination *Machine Learning, Predictive Modelling and Decision Making* to underline that machine learning techniques provided by BigClouT platform will be used to support predictive analysis and to improve decision-making processes. This sub component will receive in input context information, detected events, provided respectively by *Context Management & Self-Awareness* and *Data/Event Processing* sub components, and historical data retrieved through *City Resource Access* module.

3.2.2 BigClouT - CIaaS layer changes

Cloud Storage & Computing module now includes a new sub component: *Meta-Data Storage*; this sub components will manage meta-data used and produced by the BigClouT modules to provide their functionalities. This sub component is intended to be purely logical, because its functionalities and capabilities relies on *Cloud Storage Connector* and on *Cloud Storage.*

The denomination of the *Cloud Computing as a Service* sub component is updated with the new denomination *Cloud Computing Connector* to underline it will provide capabilities to access and use capabilities offered by a generic Cloud Computing infrastructure; indeed, similarly to Cloud Storage Connector that will allow to interact with an external Cloud Storage service, it will allow to interact with an external Cloud Computing service.

3.2.3 City Entities changes

A new component *Cloud Computing as a Service* is introduced among the City Entities to specify the environment where application developed on top of BigClouT functionalities could be executed. This new external component will interact with CIaaS component *Cloud Computing Connector*.

3.3 Sequence diagrams

This section reports and describes sequence diagrams depicting how elements of BigClouT architecture interact; in particular some typical and representative processes are taken into account and reported in the sequence diagrams; these are:

- *Data Dissemination*: this sequence diagram describes the interaction among BigClouT components that brings data from City Entities to data consumers, passing through an analytical process.
- *Edge Computing*: this sequence diagram explains the expected usage of *Deep Computing capabilities*.
- *Edge Management*: this sequence diagram shows the management of edge devices taking advantage of the *Edge Composer* component of the *City Service Composition* module.
- *Service Creation and Execution:* this sequence diagram describes the interaction among a user of the platform and its components in order to build and execute a new service that will use edge devices.

It is necessary to underline that all of the communications between external actors and internal components of BigClouT platform are secured, therefore external actors must be authenticated and must have the rights to access to BigClouT functionalities. The Security & Dependability layer, in the following diagrams, is represented as a red box containing BigClouT inner components.

3.3.1 Data Dissemination

Figure 17 depicts the flow of operations that brings data, produced from City Entities, to users or CsaaS layer's applications. Data, anonymized by the City Entity itself, is delivered to the *IoT Kernel* component. This component is in charge of dispatching the real time data to other components of BigClouT platform and to store the data in the *Cloud Storage Repository* taking advantage of the *Cloud Storage Connector* component. Real time data is sent to the *On Demand & Subscription Data Access* component that will deliver the data to the proper user or application that was previously subscribed to this particular *City Entity.* Moreover, the *On Demand & Subscription Data Access* will deliver the data to the *Big Data Analysis* component that will extract knowledge by combining and analysing the real time data with historical data retrieved from the *Cloud Storage Repository* through the *Cloud Storage Connector*. The results of the analysis will be used to create graphical reports using the *Visualization* component and then will be dispatched to users or applications of the *CSaaS* layer. In order to communicate with inner components of BigClouT platform, all of the external actors must be authenticated and must have granted the specific privileges.

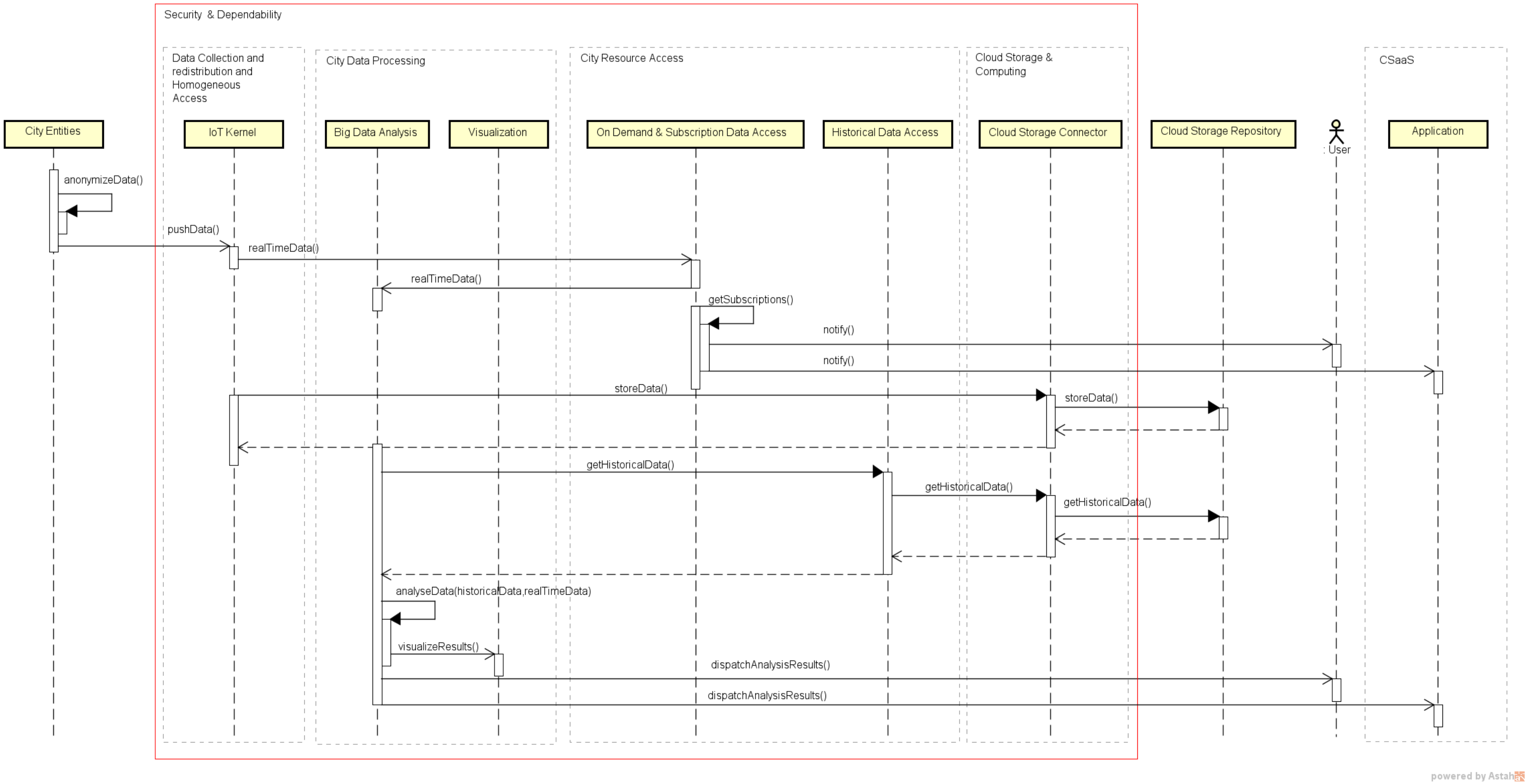

FIGURE 17: DATA DISSEMINATION SEQUENCE DIAGRAM

3.3.2 Edge Computing

Figure 18 illustrates the usage of *Edge Computing and of edge devices*. Edge devices are able to collect and analyse data and to extra new information. Results coming from this processes results are dispatched to the *IoT Kernel* component that is in charge of:

- historicize the results into *Cloud Storage Repository* through the *Cloud Storage Connector* component for further analysis.
- deliver the results to user or applications of the CSaaS layer through the *On Demand & Subscription Data Access* component.

Data stored in Cloud Storage Repository then can be accessed by the other modules of BigClouT for further elaboration.

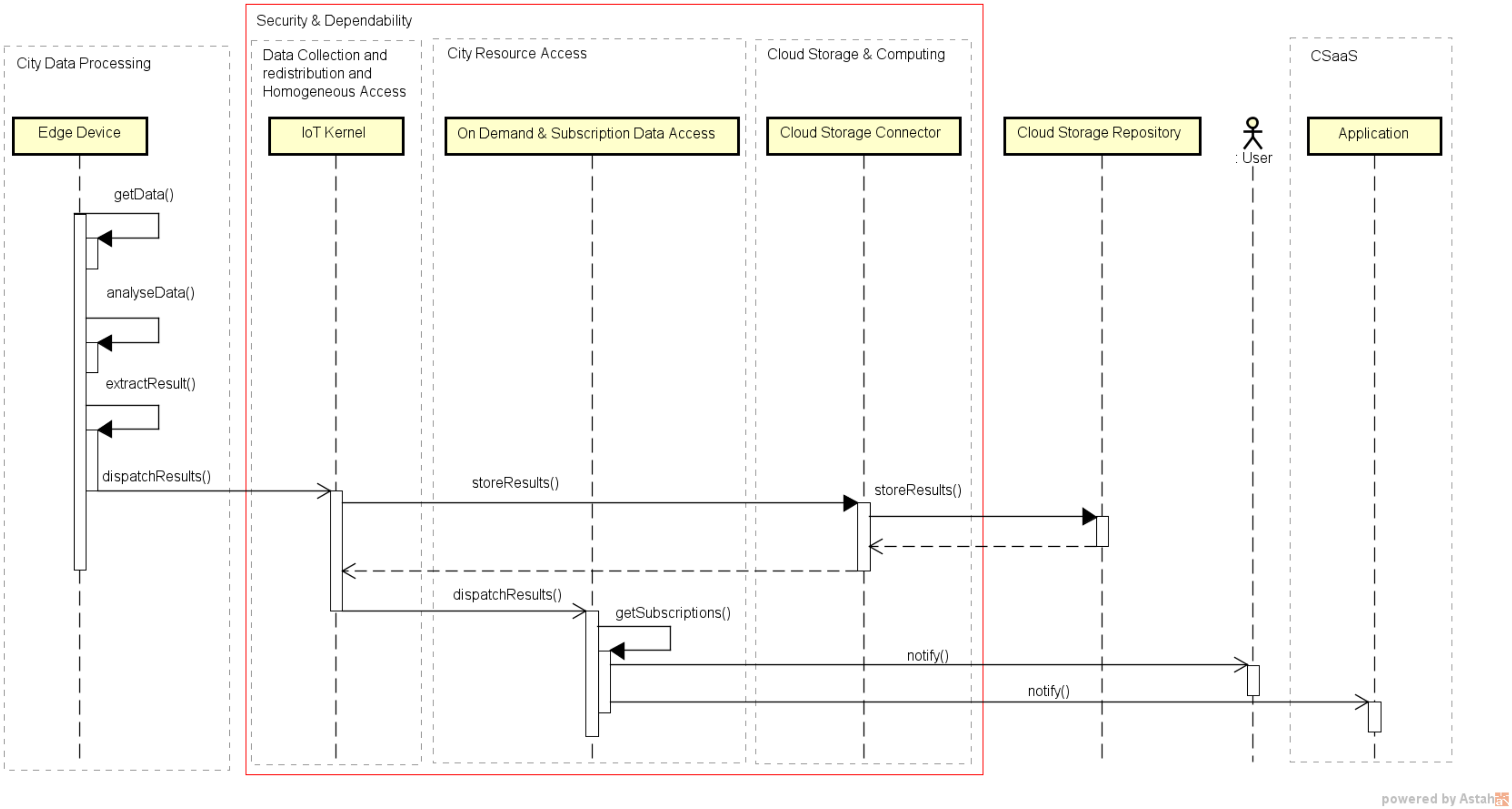

FIGURE 18: EDGE COMPUTING SEQUENCE DIAGRAM

3.3.3 Edge Management

Figure 19 depicts the process for the management of *Edge Devices* from an authenticated and authorized BigClouT user. The management of the devices is performed taking advantage of the *Edge Composer* component of the *City Service Composition* module. The user defines the edge storage and edge computing management policies in term of processes to executed by the desired edge devices. The *Edge Composer* is in charge of delivering the configuration policies to the proper component of the *Edge Storage & Computing* module which will propagate the management instructions to the edge devices.

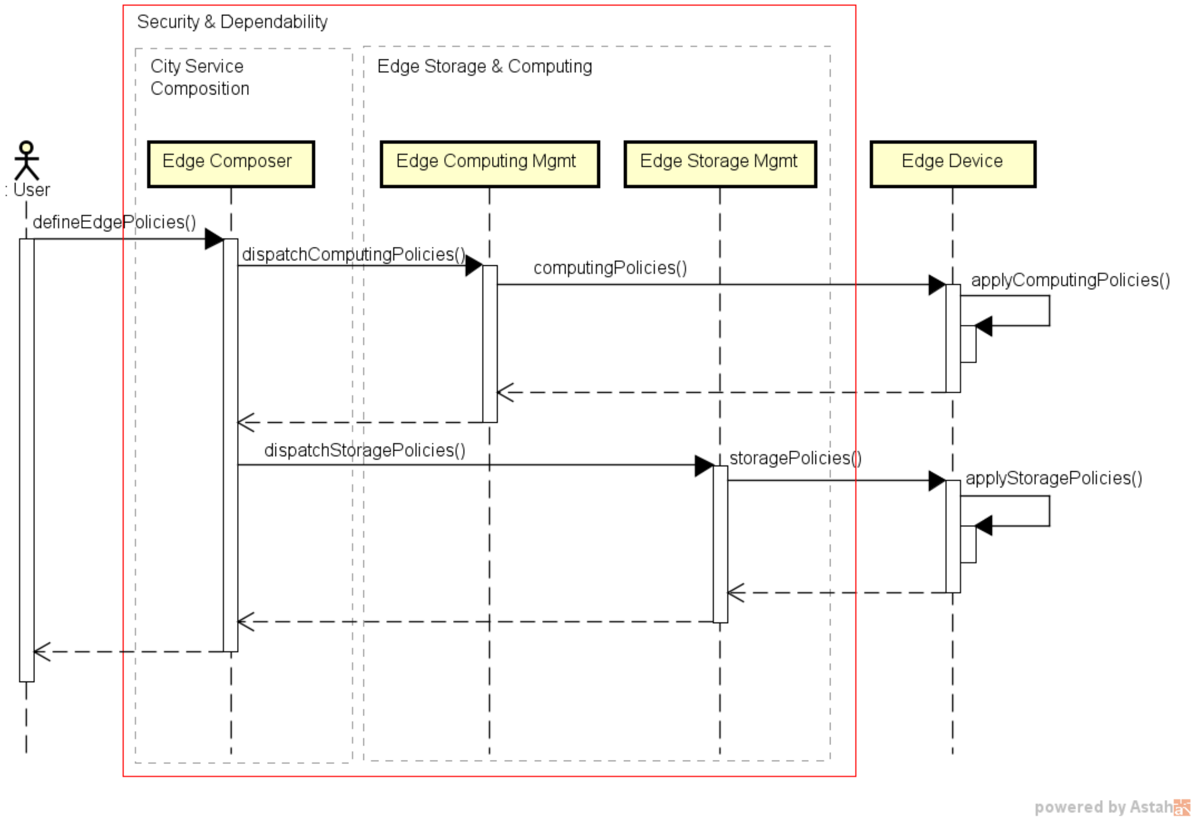

FIGURE 19: EDGE MANAGEMENT SEQUENCE DIAGRAM

3.3.4 Service Creation and Execution

Figure 20 the creation and the execution phase of a new service from an authenticated and authorized BigClouT user. The new service is developed by using the *Service Composition* component of the *City Service Composition* module and, in this example, it will use edge devices as computational device. The user defines the features of the new service and then defines the edge capabilities (in terms of processes and tasks to be executed ad edge level) and storage policies. The *Edge Composer* will deliver the configuration parameters to the proper component of the *Edge Storage & Computing* module. For the execution phase of the new service, the *Edge Computing Management* component will select the proper device applying the previously defined policies. The device will, then, process the data according to the policies defined by the user; as described in section 3.3.2, results coming from processed data are then dispatched to IoT Kernel.

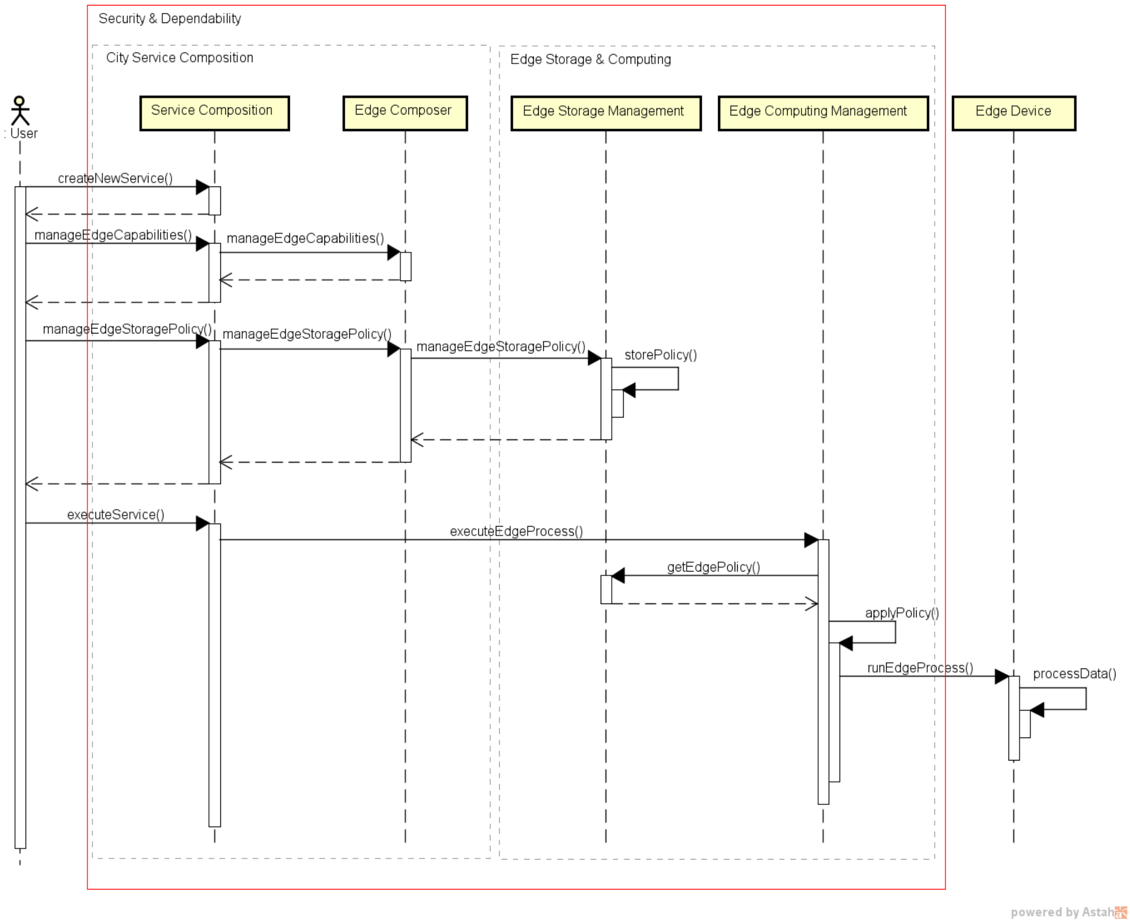

FIGURE 20: SERVICE CREATION AND EXECUTION SEQUENCE DIAGRAM

3.4 Modules and assets mapping

Starting from the first mapping identified in "D1.3 First BigClouT Architecture" and the consideration derived from "D2.1 Data collection tools and architecture" [2] and from "D3.1 Big Data Analytics Framework Architecture" [3], a new mapping among modules, their subcomponents and assets is reported in this section; an overview of this mapping is depicted in Figure 21. Specific component diagrams are also reported in order to clarify the specific role of each asset in BigClouT.

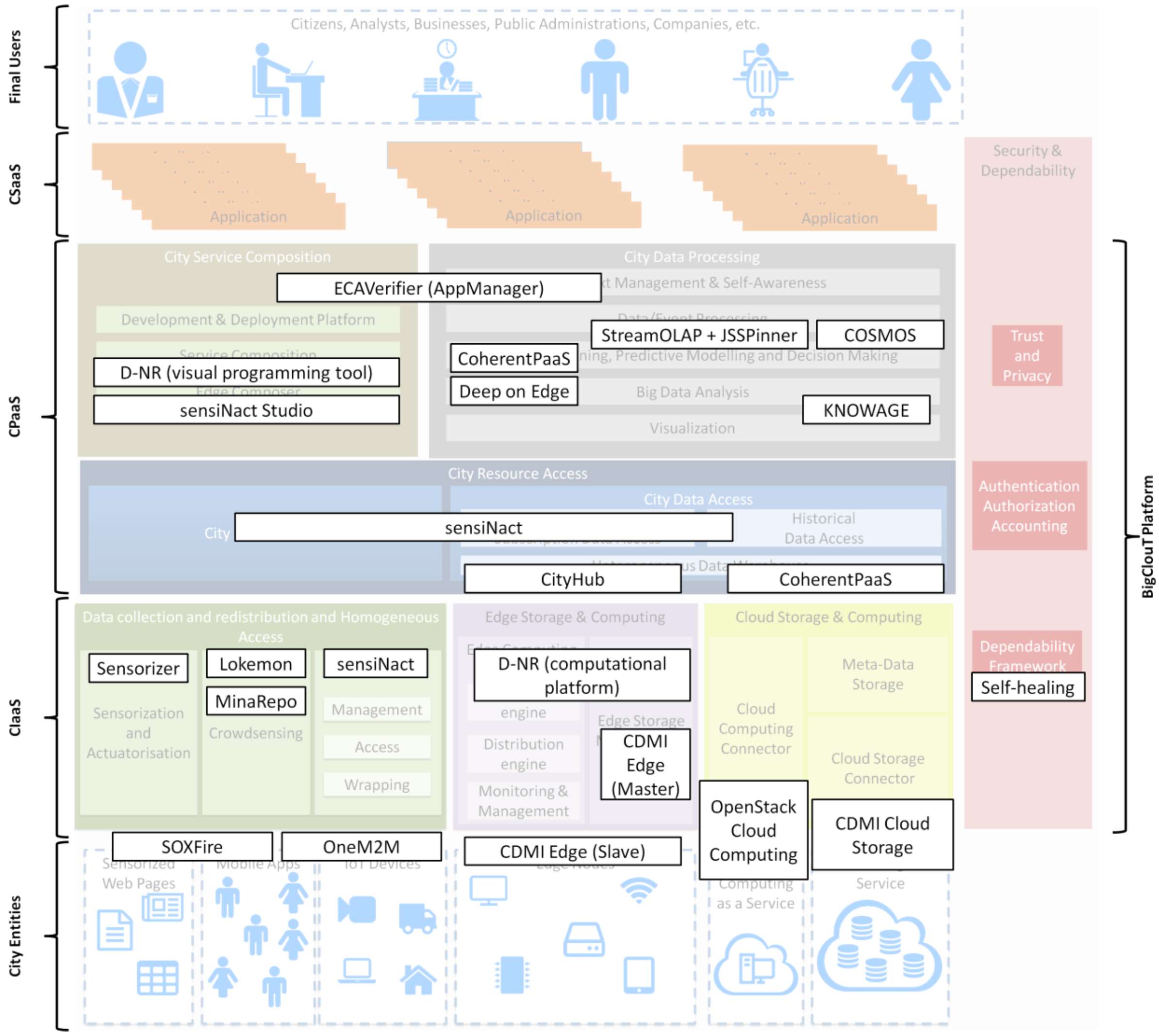

FIGURE 21: MODULE AND ASSET MAPPING OVERVIEW

Figure 22 depicts the BigClouT overall component diagram in order to report the main interactions among its logical modules. As depicted, all the heterogeneous data coming from the City Entities are acquired by the components of the CIaaS layer and then dispatched to the upper layers through the City Resource Access component of the CPaaS.

It is important to underline that Figure 22 do not report logical modules related to "Security and Dependability" layer because their interaction with the other components of the reference architecture is to be intended transparent; some technological solution that can be adopted for the implementation of this layer are reported in section 3.4.3.

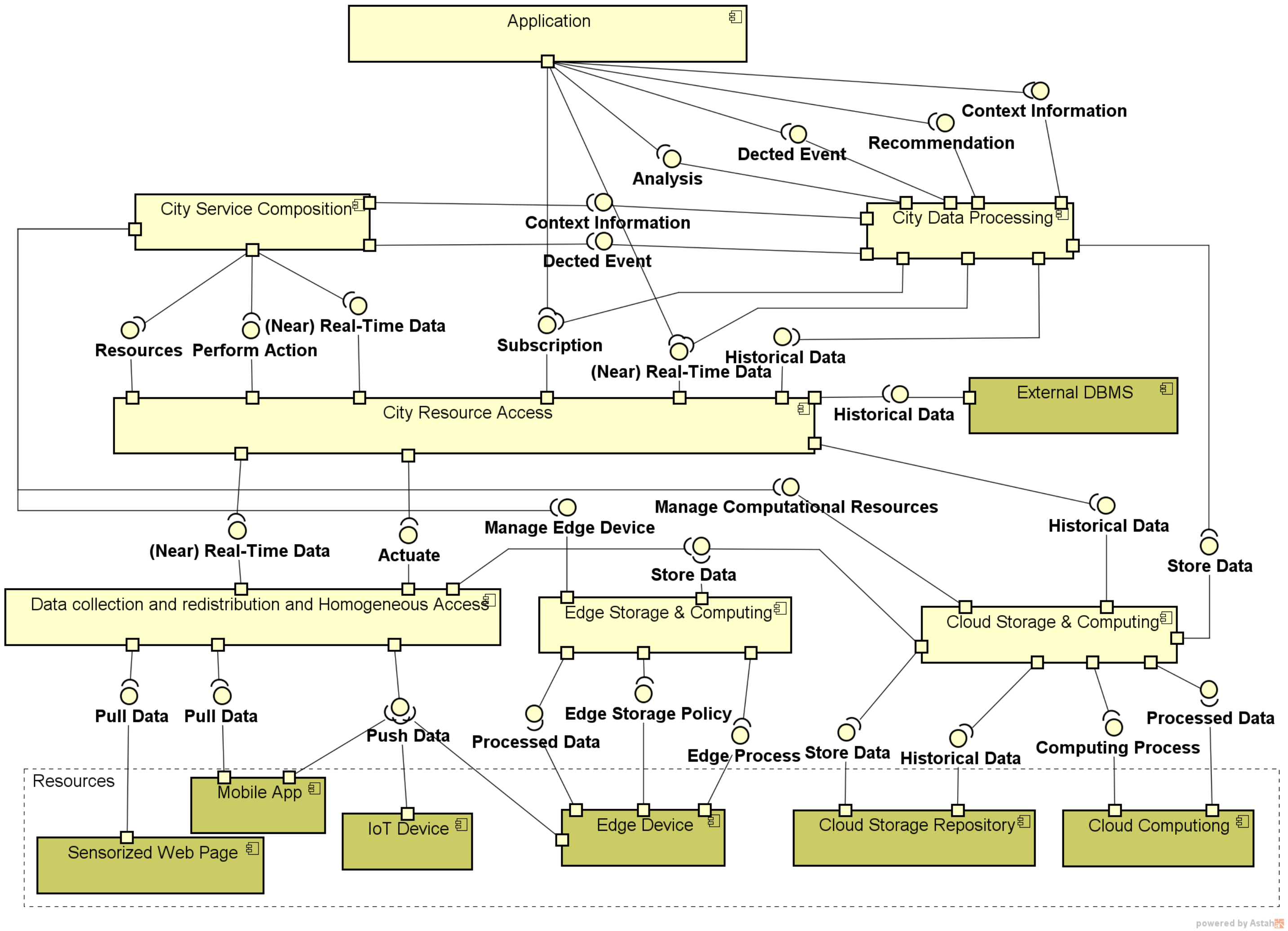

FIGURE 22 BIGCLOUT OVERALL COMPONENT DIAGRAM

3.4.1 BigClouT - CIaaS assets mapping

Figure 23 depicts the mapping among BigClouT CIaaS modules and technological assets. It reports also the main interaction points among them and the other modules of the platform. Modules (and technological assets) of CIaaS layer will interact mainly with:

- *City Entities* in order to retrieve and store data.
- *City Resource Access* module of the CPaaS layer in order to provide data to the upper layers of BigClouT platform.
- *City Service Composition* module in order to obtain the management configurations for both Edge Storage & Computing module and Cloud Storage & Computing module.
- *City Data Processing* in to store result of analysis.

Data Collection and redistribution and Homogenous Access will collect data from Sensorized Web Pages, Mobile Apps, IoT Devices and Edge Devices. The *IoT Kernel* sub component will store these data through the *Cloud Storage & Computing* module. Moreover, (near) real-time data will be provided to the upper layers through the *City Resource Access* module. *Data Collection and redistribution and Homogenous Access* will also receive action to be executed on actuators. Table 22 reports the assets mapping of *Data Collection and redistribution and Homogenous Access*.

TABLE 22 DATA COLLECTION AND REDISTRIBUTION AND HOMOGENOUS ACCESS MODULE ASSETS MAPPING

Module Name	Data Collection and redistribution and homogenous access		
Assets Mapping	**Asset Name**	**BigClouT Subcomponent**	**Rationale**
	sensiNact	**IoT Kernel**	The sensiNact gateway will receive data from IoT devices or Edge devices and it will then dispatch the data to the upper layers; moreover it will store the data into the Cloud Storage Repository by using the interfaces provided CDMI Storage (Cloud Storage Connector). It will also receive in input actions to be executed on on IoT devices from the City Resource Access module.
	Sensorizer	**Sensorization and Actuatorisation**	Sensorizer will be used for gathering data from sensorized web pages; it will also perform actions over the sensorized web pages. The data will be then dispatched to the City Resource Access module.
	Lokemon	**Crowdsensing**	Lokemon will collect data provided by people and then will dispatch it, or part of it, to the upper layers through the City Resource Access module.
	MinaRepo	**Crowdsensing**	MinaRepo will collect city data through the participation of citizens. This data, or part of it, will be provided to the upper layer of the platform through the City Resource Access module.

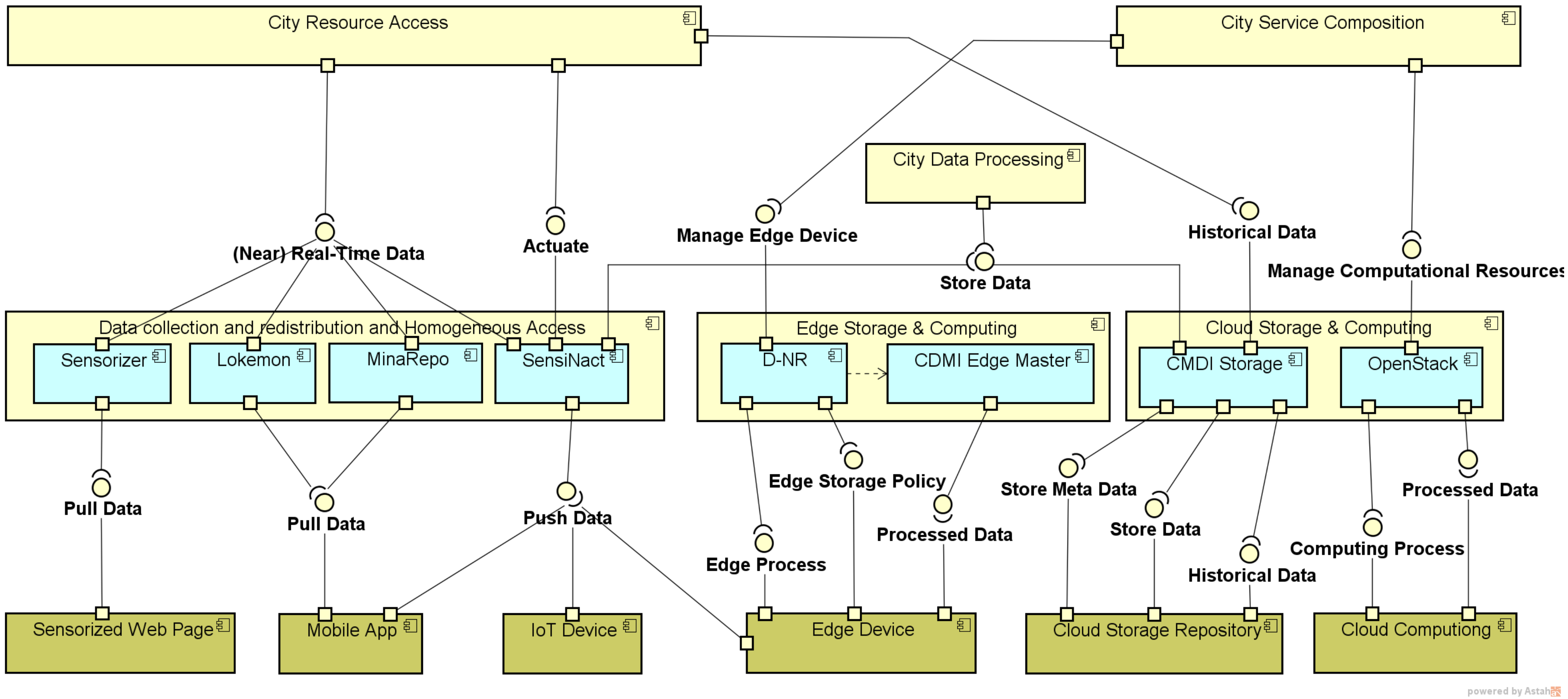

FIGURE 23: BIGCLOUT CIAAS COMPONENT DIAGRAM

Cloud Storage & Computing will interact with:

- City Resource Access: in order to provide historical data to the other modules of the platform.
- City Data Processing in order to store result of analysis.
- City Service Composition: in order to manage cloud resources.
- IoT Kernel: that will use Cloud Storage & Computing interfaces to store data.
- Cloud Storage as a Service: this City Entities will provide the cloud storage be used to write and read data and metadata coming from other modules of the platform.
- Cloud Computing as a Service: this City Entities will provide cloud computational resources for the applications of CSaaS layer developed on top of BigClouT.

Table 23reports the assets mapping of Cloud Storage & Computing.

TABLE 23 CLOUD STORAGE & COMPUTING MODULE ASSETS MAPPING

Module Name	Cloud Storage & Computing		
Assets Mapping	**Asset Name**	**BigClouT Subcomponent**	**Rationale**
	OpenStack Cloud computing	**Cloud Computing as a Service**	OpenStack Cloud Computing will be used to manage the virtual computational resources provided by the Cloud computing as a Service component at City Entity level. It will communicate with the City Service Composition module in order to receive the management instruction for the environment.
	CDMI Storage based on OpenStack Swift and Hypertable	**Cloud Storage Connector** **Meta-Data Storage**	CDMI Storage will be the northbound interface from which data or metadata would be written or read. It receives the data to be stored from IoT Kernel and will provide data to the Historical Data Access module of CPaaS component.

Edge Storage & Computing module will interact with:

- City Service Composition: in order to receive management instruction for edge devices.
- Edge Devices: in order to execute processes using the edge paradigm.

Table 24 reports the assets mapping of *Edge Storage & Computing*.

TABLE 24 EDGE STORAGE & COMPUTING MODULE ASSETS MAPPING

Module Name	Edge Storage & Computing		
Assets Mapping	**Asset Name**	**BigClouT Subcomponent**	**Rationale**
	Distributed Node-RED (computational platform)	**Edge Computing Management**	Distributed Node-RED will be used to configure edge devices and to manage the execution of edge processes. It will receive configuration of edge nodes (policies and tasks to be executed) from the City Service Composition module.
	CDMI Edge Storage	**Edge Storage Management**	CDMI Edge Storage will be the northbound interface from which edge devices would be managed. It receives the configuration from the Edge Composer component of the City Service Composition module.

3.4.2 BigClouT – CPaaS assets mapping

Figure 24 depicts the mapping among City Resource Access module of CPaaS layer of BigClouT and technological assets.

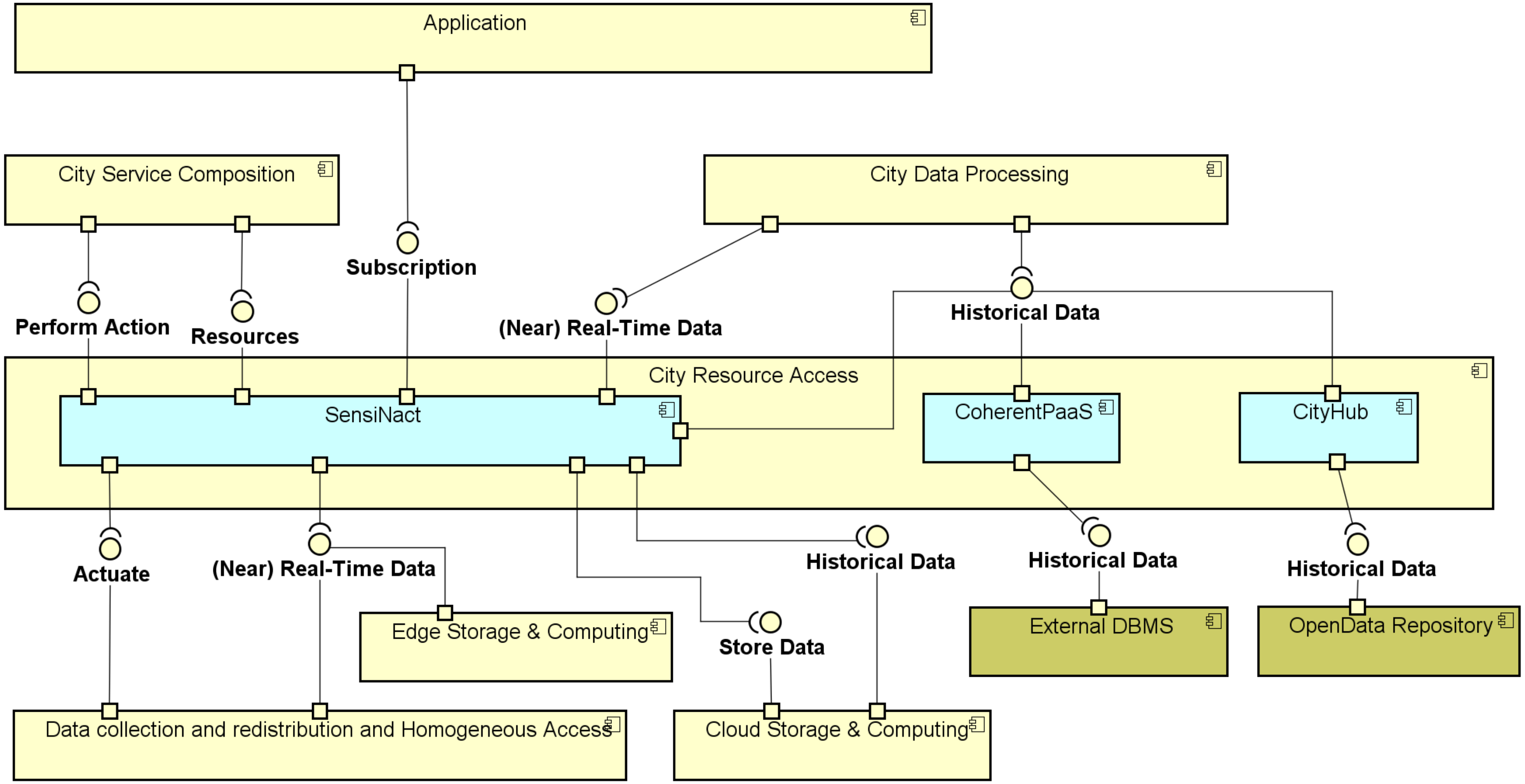

FIGURE 24: CITY RESOURCE ACCESS COMPONENT DIAGRAM

Assets composing *City Resource Access* will receive data from CIaaS components and will dispatch it to the upper layers of BigClouT. In particular, assets of City Resource Access will interact with:

- Data collection and redistribution and Homogenous Access: to gather real time or near real time data from devices and to perform action on actuators.
- Edge Storage & Computing: to receive data from edge devices.
- Cloud Storage & Computing: to access historical data.
- City Service Composition: to dispatch result of performed action on resources and to provide a list of the available resource in the platform.
- City Data Processing: to dispatch data to be used for analysis.
- Application (of CSaaS layer): to notify about existing subscriptions.
- External Data Sources: to access data from external and heterogeneous data sources.

Table 25 reports the assets mapping of *City Resource Access*.

TABLE 25 CITY RESOURCE ACCESS MODULE ASSETS MAPPING

Module Name	City Resource Access		
Assets Mapping	**Asset Name**	**BigClouT Subcomponent**	**Rationale**
	sensiNact	**City Action Access** **On demand & subscription data access** **Historical Data access**	sensiNact gateway covers different role into the City Resource Access module. It will receive the action to be performed on devices (actuators) and it will then execute those actions on them; it will dispatch to City Data Processing real time or near real time data coming from the Data collection and redistribution and Homogenous access component; moreover it is in charge of notify data consumers (application or user) about new data (in case of existing subscriptions).
	CoherentPaaS	**Heterogenous data warehouse**	CoherentPass will access to external heterogeneous databases in order to provide data to the City Data Processing module for further analysis.
	City Hub	**Heterogenous data warehouse**	City Hub will access to open data repositories, e.g. CKAN, in order to provide data to the City Data Processing module for further analysis.

Figure 25 depicts the interaction among assets composing *City Service Composition* and the other module of BigClouT. These assets will interact with:

- City Resource Access: to gather data, resources and results coming from the execution of action to the resources;
- Edge Storage & Computing: to manage edge device and to execute processes taking advantage of edge paradigm;
- Cloud Storage & Computing: to manage computational resources;
- City Data Processing: from which it will receive context information and detected events.

Table 26 reports the assets mapping of *City Service Composition*.

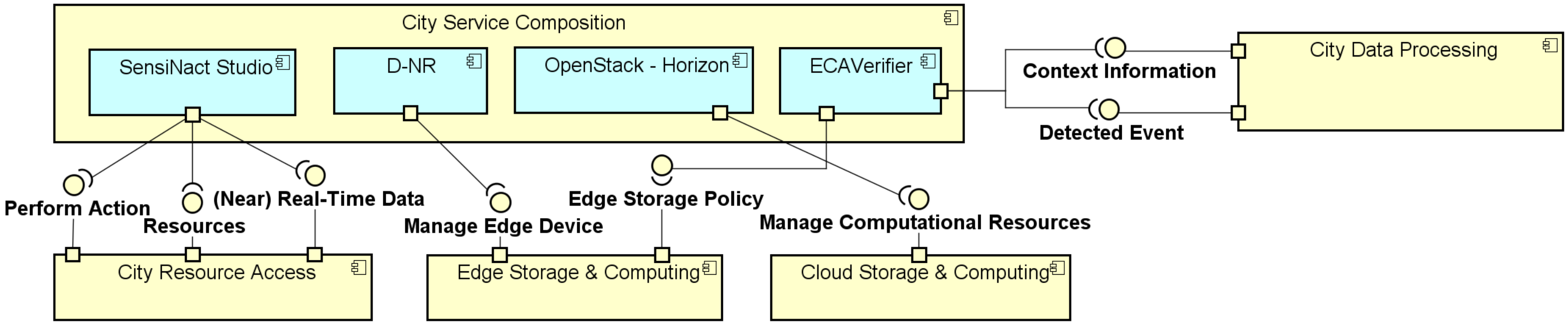

FIGURE 25: CITY SERVICE COMPOSITION COMPONENT DIAGRAM

TABLE 26 CITY SERVICE COMPOSITION MODULE ASSETS MAPPING

Module Name	City Service Composition		
Assets Mapping	**Asset name**	**BigClouT Subcomponent**	**Rationale**
	sensiNact Studio	**Service Composition**	SensiNact Studio offers a set of tools to monitor existing city entities and to easily create and deploy city applications built using those entities
	Distributed Node-RED - visual programming tool	**Edge Composer**	Distributed Node-RED provides support for the development and deployment of applications and for the edge composition component that guides the distribution of "edge" processing piece.
	ECAVerifier – AppManager	**Development & Deployment Platform**	ECAVerifier will receive context information and detected events from City Data Processing and will use this information to create policies and management information for other components of the platform, e.g. Edge Storage & Computing module.
	OpenStack Cloud Computing - Horizon	**Development & Deployment Platform**	OpenStack Cloud Computing asset and in particular Horizon, its graphical user interface of, will ease the management and the creation of new computational resources.

Figure 26 illustrates the main interactions among assets of the *City Data Processing* and the other modules of BigClouT. In particular City Data Processing interacts with:

- City Resource Access: to gather data to be used in analysis.
- Cloud Storage & Computing to store result of analysis (for readability reason internal relations among assets of City Data Processing and the interface "Store Data" are not reported, but each asset can leverage this functionality).
- City Service Composition: to provide context information and detected events.
- Applications (of CSaaS layer): to provide results of analysis to the end users.

Table 27 reports the assets mapping of *City Data Processing.*

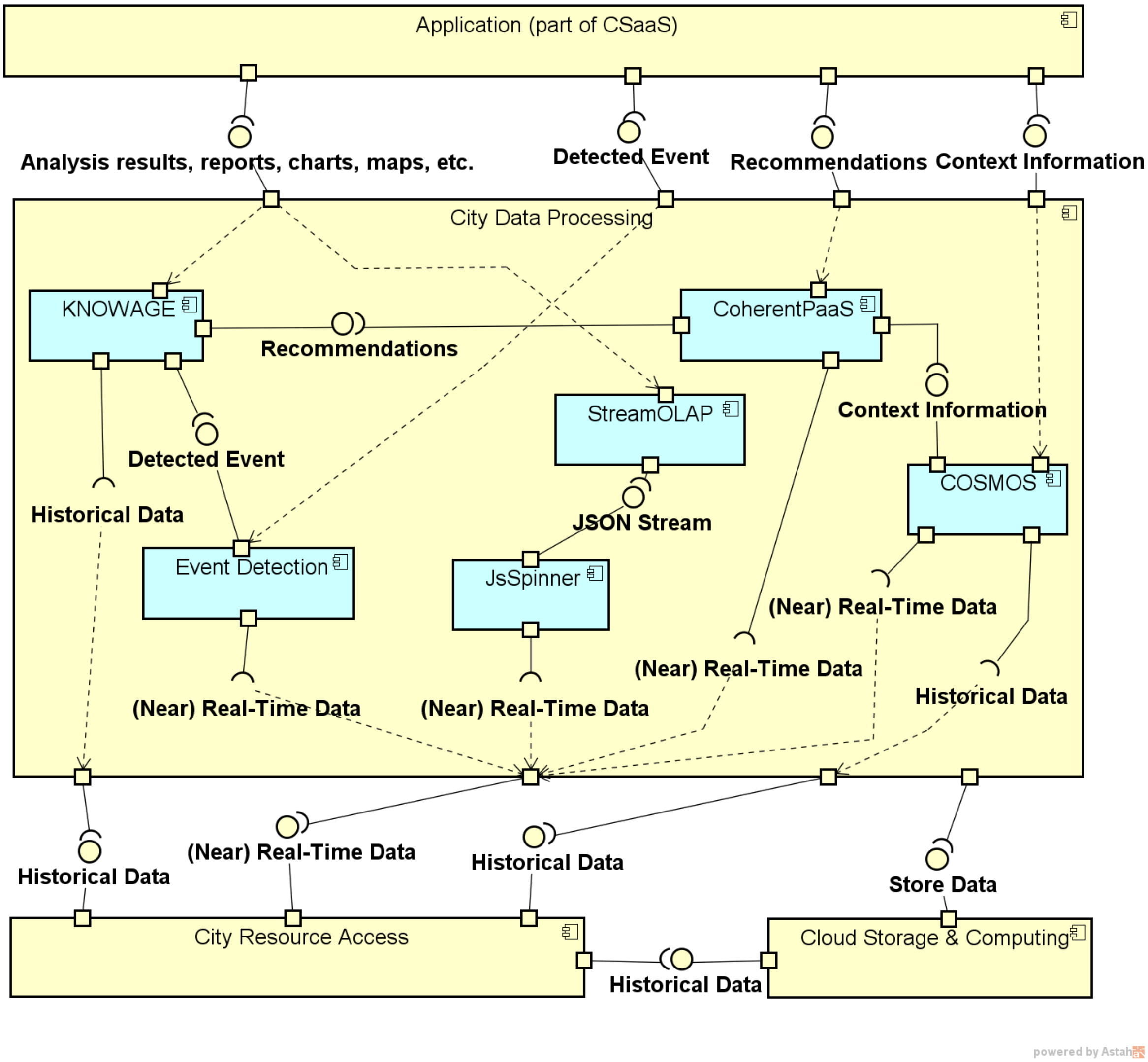

FIGURE 26: CITY DATA PROCESSING COMPONENT DIAGRAM

TABLE 27 CITY DATA PROCESSING MODULE ASSETS MAPPING

Module Name	City Data Processing		
Assets Mapping	**Asset Name**	**BigClouT Subcomponent**	**Rationale**
	COSMOS	**Data/Event processing** **Context Management & Self-Awareness**	COSMOS will extract context information from (near) real-time data and historical data coming from City Resource Access module. Context information will be then provided to CoherentPass or to applications of CSaaS layer.

	CoherentPaaS	**Data/Event processing** **Machine Learning, Predictive Modelling and Decision Making**	CoherentPass will produce recommendations from context information and (near) real time data. Produced recommendations will be provided to KNOWAGE and to applications of CSaaS layer.
	KNOWAGE	**Big Data Analysis** **Visualization**	KNOWAGE will gather data from different assets of the platform. It will use historical data provided by City Resource Access module, detected events, recommendations provided by CoherentPass. This data will be combined in order to produce analysis or reports that will be accessed by applications of the CSaaS layer or by user through its GUI.
	JsSpinner and StreamOLAP	**Big Data Analysis** **Data/Event processing**	StreamOLAP and JsSpinner will work together to perform OLAP analysis over stream of data; in particular JsSpinner will access (near) real-time data in order to detect events that will be provided to StreamOLAP as a JSON stream in order to enable it to perform analysis. Output data of StreamOLAP will be accessible by applications of the CSaaS layer through its APIs and by end users through its GUI.
	Event Detection	**Data/Event processing**	Event Detection will consume (near) real-time data in order to detect events of interest; detected events will be provided to KNOWAGE, in order to enable it to perform analysis and to produce reports, and to application of CSaaS layer through its APIs.
	DeepOnEdge	**Machine Learning, Predictive Modelling and Decision Making** **Big Data**	DeepOnEdge will combine edge computing and deep neural networks. The data produced using this asset will be stored into cloud repository through *Cloud Storage & Computing* module. Output of this asset will be used as input for further analysis. It is important to underline that even if DeepOnEdge it is formally a

		Analysis	technological asset of the City Data Processing, it is not reported in the diagram of Figure 26 because it is designed to be executed on edge nodes; results of its analysis will be accessed by the other assets through exposed Historical Data and (Near) Real Time interfaces (e.g. through Cloud Storage Connector, IoT Kernel, etc.)

It is important to underline that, even if document "D3.1 Big Data Analytics Framework Architecture" [3] reports also other three technological assets, (OLIM, IncMNod & SCAN++ and OMNI-Prop) they are not reported here because they provide very specific functionalities for specific application fields; indeed OMNI-Prop estimates attributes such as age, sex, preferences of users, OLIM infers user locations in real-time from social streams and IncMod & SCAN++ detects users community structure. In any case, as demonstrated in the same document "D3.1 Big Data Analytics Framework Architecture", it is possible to integrate these and other technological assets in the general architecture of BigClouT, in order to address specific needs.

3.4.3 BigClouT – Security and Dependability - suggested implementation solutions

This section reports a set of technological solutions that can be adopted for the implementation of the Security & Dependability layer of BigClouT reference architecture; Security & Dependability layer provides necessary functionalities to check and authorize the access to the modules of the platform in a secure way for the end users and for the applications of CSaaS layer.

Reported technological solutions are not binding or mandatory; they represent recommendation for the implementation of the Security & Dependability layer. Indeed it is important to underline that in many cases, security aspect are faced taking into account very specific and different requirements, which are strictly related to the context.

Because BigClouT is the evolution of ClouT, a first suggested approach for the implementation of security aspects is the one proposed in ClouT[10]: in order to assure a secure access to the exposed services, users identities could be managed in a single Identity and Access Management System; the proposed solution is called *Service Oriented Authentication, Authorisation and Accounting* (SOA3) and provides also a *User Management Service* for creating, modifying and deleting users.

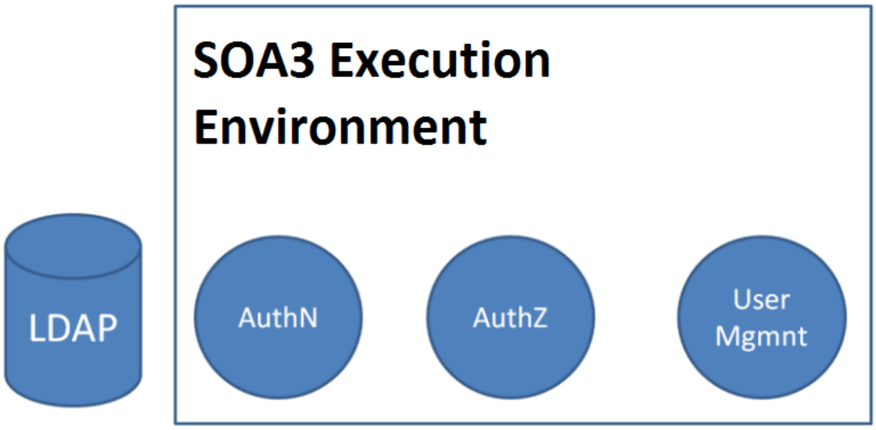

FIGURE 27: SOA3 SERVICES

SOA3 Services are taken into account for the proposed solution are reported in Figure 27; in particular:

- *Authentication Service* provides authentication functionalities based on both Username/Password and X509 Certificates; it also supports SAML Identity Federation providing SSO (Single-Sign-On) functionalities.
- *Authorisation Service* allows to define attribute-based access policies and to enforce them
- User Management Service provides CRUD APIs to manage ClouT user identities and their access credentials

With this solution, identities of users are stored in a LDAP Directory, whereas the *Authorisation Service* includes also a *Policy Administration Point* to store access policies.

SOA3 can be integrated in different way, for instance applications could forward user credential to Authentication and Authorisation Services using a secure channel to communicate with SOA3 or applications could be run in the same execution environment of SOA3.

A second approach could be represented by the adoption of OAuth2[11] to grant access to exposed functionalities only to registered and authenticated users; an example of tools that provide these functionalities are Keyrock IdM [12] and Wilma PEP Proxy [13].

Keyrock provides capabilities for management of users, such as account creation, user registration, user profile management and modification of user accounts. Wilma PEP Proxy is in charge of intercepting all the requests to the backend APIs and to verify if they are made by an authenticated user or application, through the use of token included in the requests that is validated against Keyrock; if the token is valid, Wilma PEP Proxy forwards the request to the requested API.

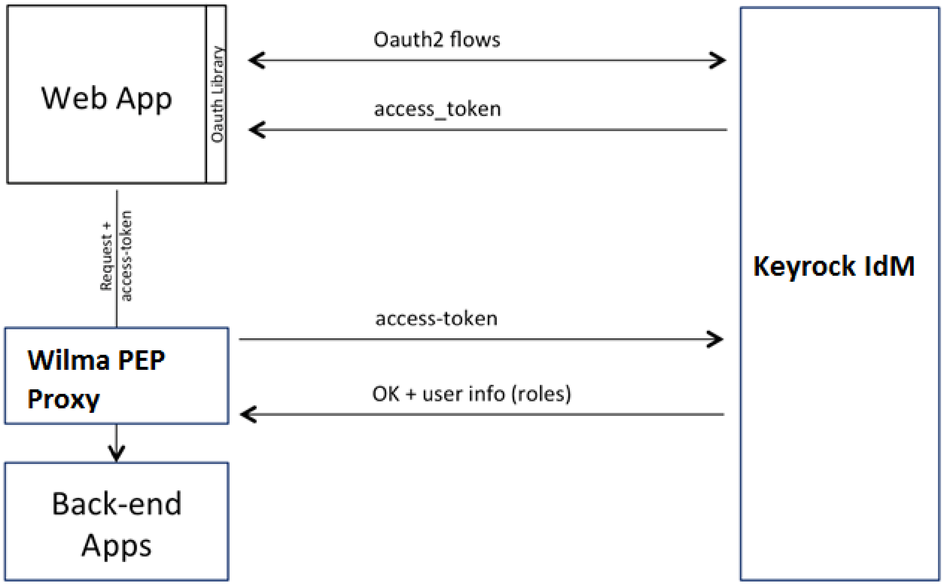

FIGURE 28: RELATIONS BETWEEN KEYROCK AND WILMA

In addition to these generic solutions, BigClouT offers a specific asset as reference implementation of the *Dependability Framework*, a sub component of the *Security and Dependability* module: it is Self-healing; Self-healing provides a functionalities and capabilities to identify and to correct the sensory faults, that could be generated for instance by malfunctions.

3.5 Data flows

This section of the document provides an overview of the data flow among the inner components of BigClouT, from the City Entities to the data consumers (end users and applications of CSaaS layer) and going through the modules of the platform.

Furthermore, starting from the updated use cases described in Section 1, specific data flow diagrams are reported, in order to depict the expected data flow of each use case.

3.5.1 BigClouT Data Flow overview

Figure 29 depicts the general overview of the overall data flow in BigClouT (different colours of lines are used only to clearer the different paths those may cross).

Data Collection and Redistribution and Homogenous Access module collects data from the underlying City Entities. Data are then dispatched to the *City Resource Access* module and to the *Cloud Storage & Computing* module.

City Resource Access module accesses (near) real-time data coming from the City Entities through its sub component *On demand & Subscription data access;* if subscriptions exist, this sub component notifies the data consumers that are interested. Moreover, through the sub components *Historical Data Access* and *Heterogeneous Data Warehouse*, historical data and data coming from external sources will be provided to the *City Data Processing* module.

Taking advantage of accessed data, different analysis would be performed; for instance. data consumers could perform data analysis creating reports (e.g. charts) visualized using functionalities of the *Visualization* module. Moreover, context information and detected events are extracted from the data and then dispatched to the subcomponents of the *City Service Composition* module.

Edge Composer, Service Composition and *Development & Deployment Platform* subcomponents will use this updated context information and these detected events to manage and modify, if needed, the edge policies or the cloud computing configurations dispatching the updated configuration to the *Edge Storage & Computing* and *Cloud Storage & Computing* modules. Moreover, *City Service Composition* subcomponents will be in charge of performing actions, if needed, to the *City Entities* taking advantage of the *City Action Access* subcomponent of the *City Resource Access* module.

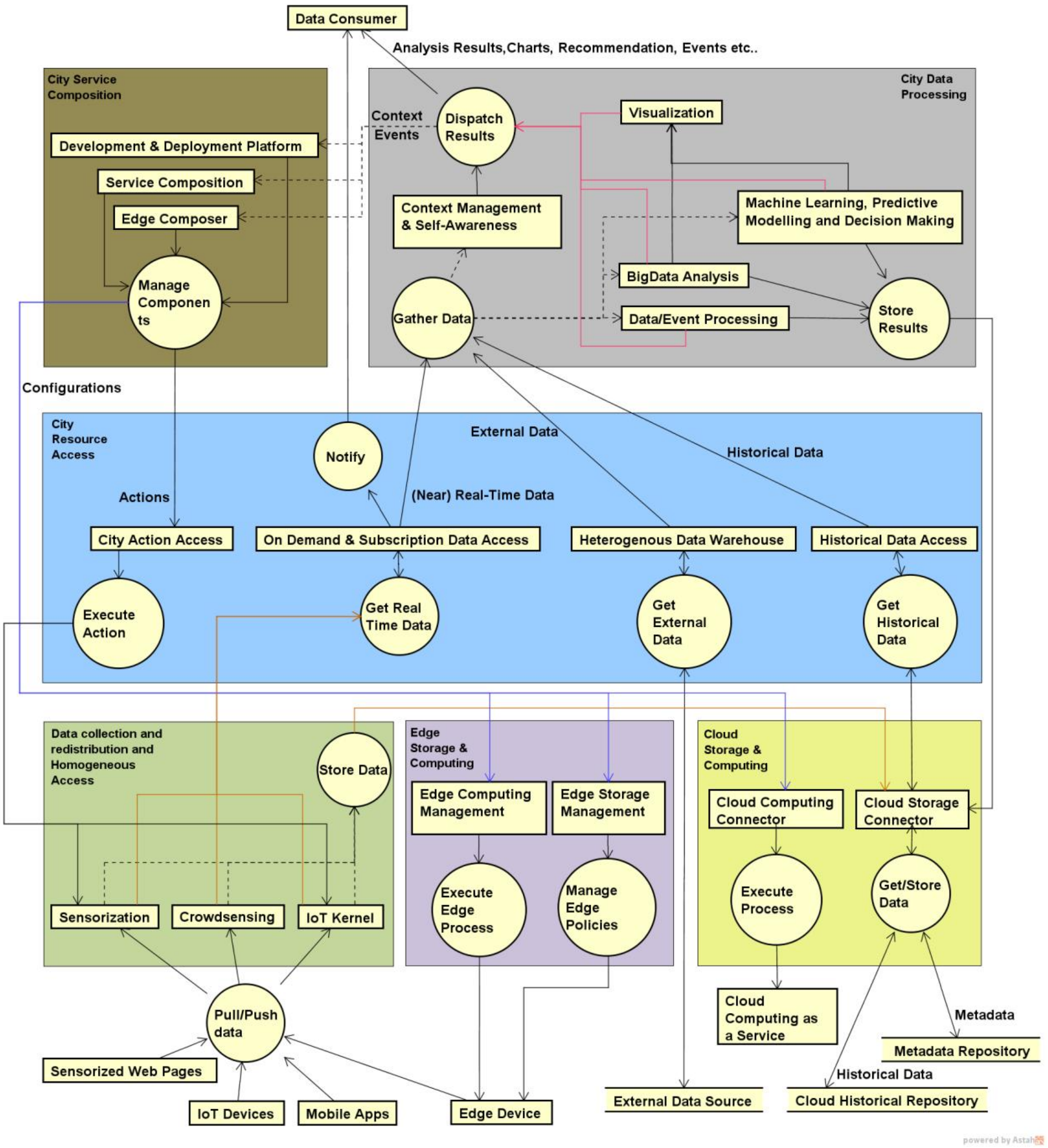

FIGURE 29 BIGCLOUT DATA FLOW OVERVIEW

3.5.2 Bristol - Smart Energy

Electric consumption data collected through the sensors deployed in a subset of Bristol's houses will be stored in a CKAN repository taking advantage of FIWARE Orion Context Broker. These data will be accessed using the *Heterogenous Data Warehouse* component of the *City Resource Access* module and then provided to the *City Data Processing* module. Then predictive analysis over this data will be performed in order to highlight the "phantom load" phenomena. This flow of data will be created taking advantage of BigClouT's *City Service Composition* module, in particular through the use of Distributed Node-RED. Figure 30 data flow of Smart Energy use case of Bristol.

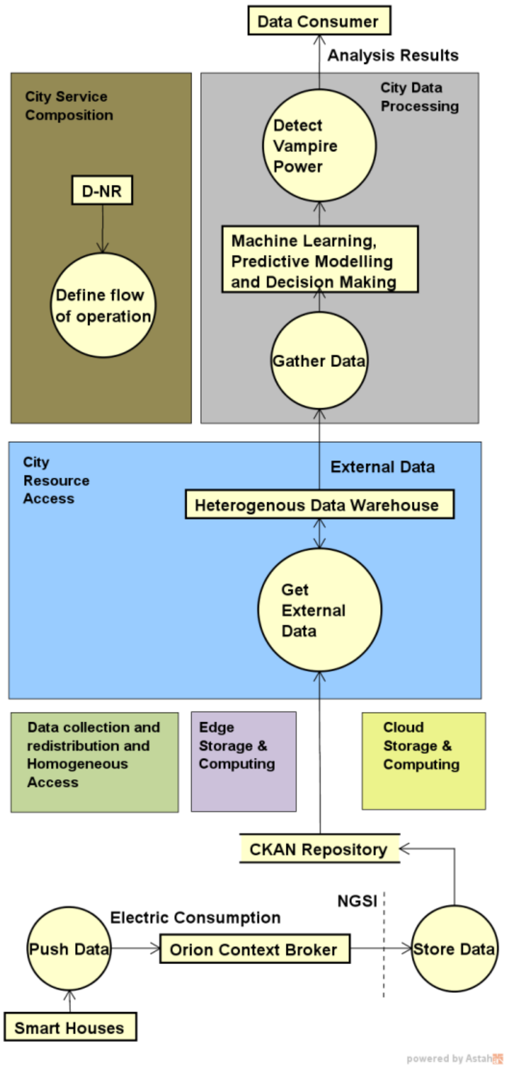

FIGURE 30: BRISTOL - "SMART ENERGY - PREDICTIVE ANALYSIS OF USERS' POWER CONSUMPTION" DATAFLOW

3.5.3 Bristol - Smart Mobility

By using air quality sensors deployed around the buildings of the University of Bristol, the goal of this use case is to offer to pedestrians a service which will identify the healthiest path within the city. The PM2.5/10, CO_2 or NOx measurements will be stored into in a CKAN repository through FIWARE Orion Context Broker. Feedbacks about air quality together with the location will be gathered from citizens through a dedicated application. These feedbacks will be stored in a cloud repository for further analysis, using the interfaces of the *Cloud Storage Connector* component of the *Cloud Storage & Computing* module. Feedbacks and sensors data will be combined and analysed using the *Data/Event Processing* and *Machine Learning, Predictive Modelling and Decision Making* components of the *City Data Processing* module. *Data/Event Processing* will be in charge of provide pedestrians with recommendations about the greener paths to follow. *Machine Learning, Predictive Modelling and Decision Makin* will be in charge of the prediction of future citizens' mobility patterns. Analysis results will be displayed to data consumers in a map created with the *Visualization* component of the *City Data Processing* module. Its components will access the data through the *Heterogeneous Data Warehouse* and *Historical Data Access* components of the *City Resource Access* module. As the previous use case, this flow of data will be created through BigClouT's *City Service Composition* module, in particular using Distributed Node-RED. Figure 31 depicts data flow of Smart Mobility use case of Bristol.

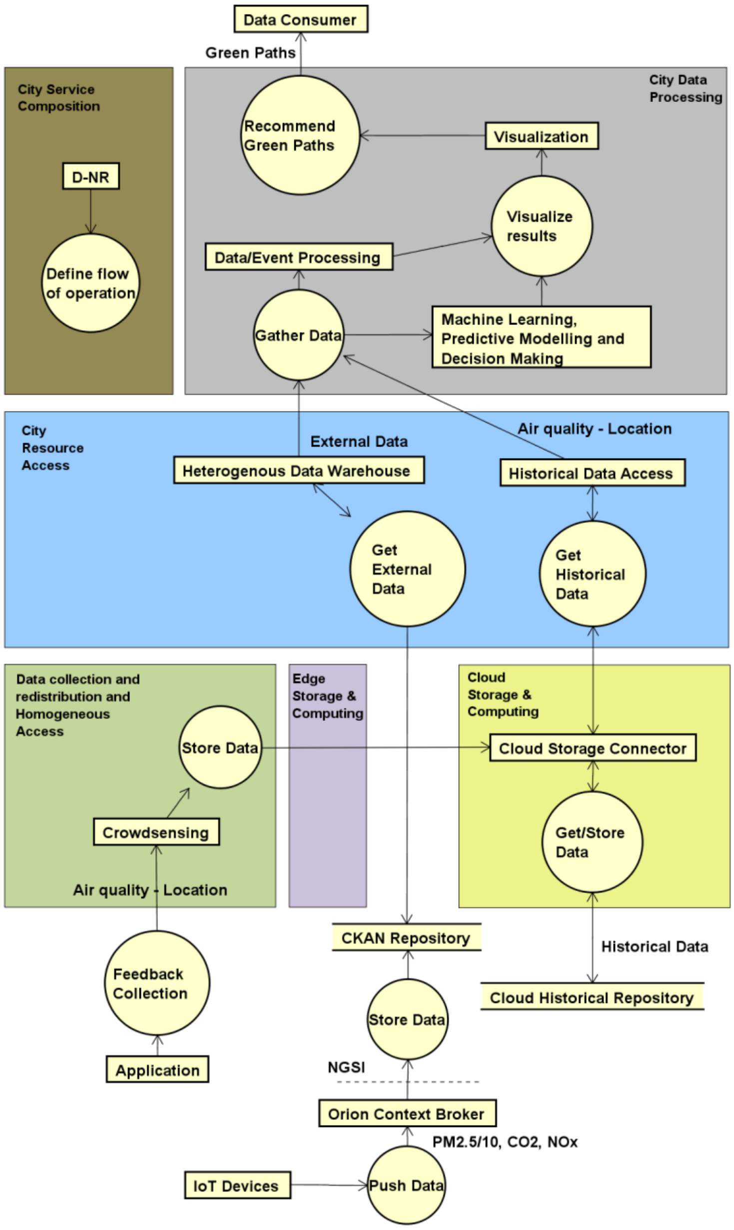

FIGURE 31 BRISTOL – "SMART MOBILITY" DATA FLOW

3.5.4 *Fujisawa - Participatory Sensing*

Data collected using Lokemon and MinaRepo will be stored in a dedicated Cloud repository. SOXFire will be used to disseminate these data to the *Data collection and redistribution and Homogeneous Access* module. Historical data will be accessed using the *Historical Data Access* component of the *City Resource Access* module. Data will be provided to KNOWAGE in order to perform analysis, whose results data and metadata will be stored into cloud repositories using *Cloud Storage Connector*. Figure 32 depicts data flow of Participatory Sensing use case of Fujisawa.

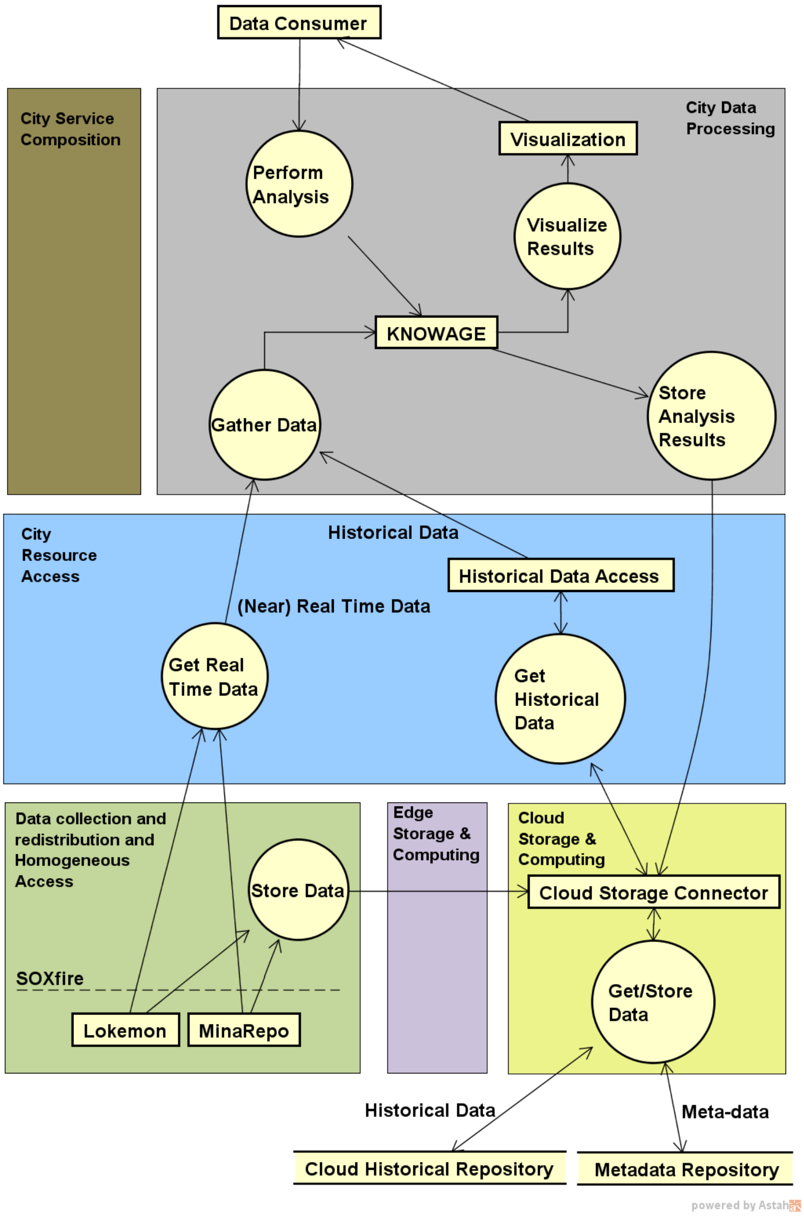

FIGURE 32 FUJISAWA - "OPTIMIZING THE INCIDENCE ON LOCAL ECONOMY OF FUJISAWA" DATA FLOW

3.5.5 Fujisawa - Infrastructure Sensing

The goal of this use case is to extract road conditions information by using edge approach. Road conditions is provided to data consumers using *Deep On Edge*. For this particular use case, the system is composed by an edge computer and a camera attached to Fujisawa's garbage trucks. *Deep On Edge* is deployed on the edge node and will analyses the collected images in order to extract road conditions. These data will be stored into cloud repository using *Cloud Storage Connector* for further analysis and will be provided to data consumers through the *On Demand & Subscription Data Access* subcomponent of the *City Resource Access* module. *Edge Composer* subcomponent of the *City Service Composition* module will be in charge of the management of edge devices policies and configurations.

It is important to underline that data flow reported in this section is a peculiar, because it makes use of Deep on Edge; from a logical point of view is part of the *City Data Processing* module, but from a physical point of view it is deployed on edge nodes. Figure 33 illustrates data flow of Infrastructure Sensing use case of Fujisawa.

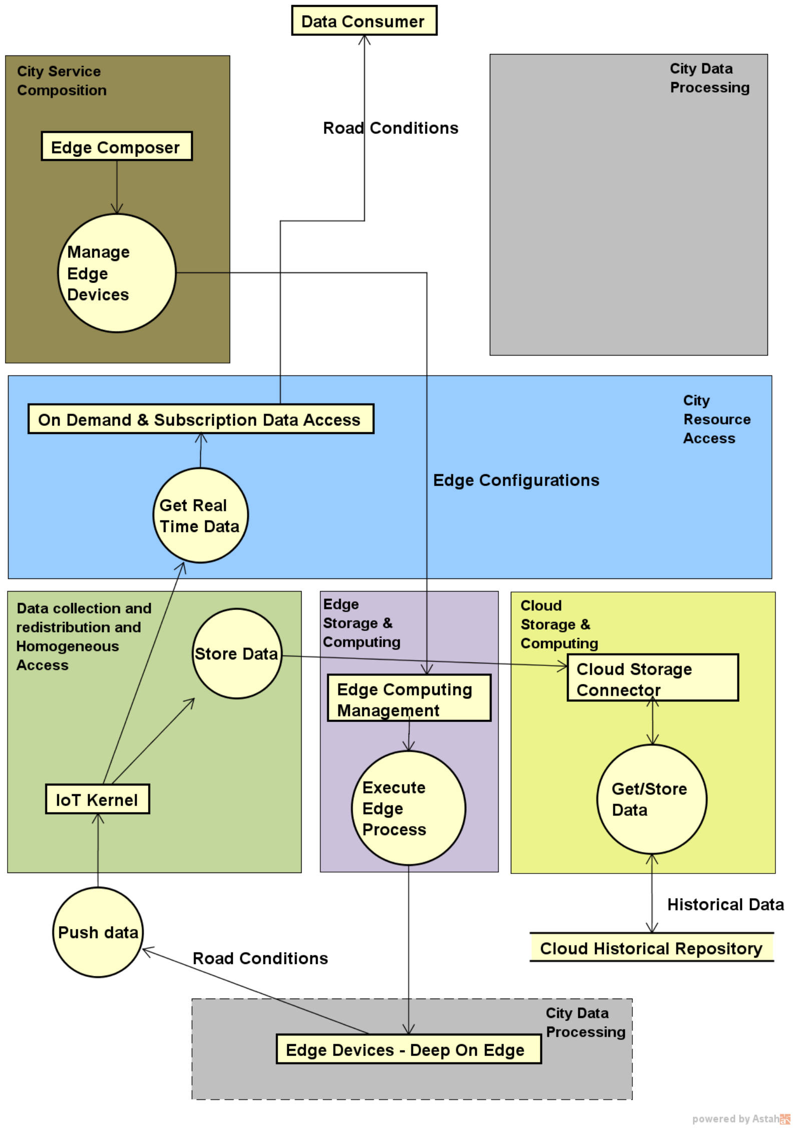

FIGURE 33 FUJISAWA - "FINE-GRAINED CITY INFRASTRUCTURE MANAGEMENT" DATA FLOW

3.5.6 Grenoble Common

Figure 34 depicts the general data flow of both use cases of Grenoble. Business applications will be defined using sensiNact Studio, part of the *City Service Composition* module. Live data will be provided to analytical tools using sensiNact, external repositories will be accessed through *CityHub*, part of the *Heterogenous Data Warehouse*, and historical data will be accessed through *Historical Data Access* subcomponents. Anonymized data collected from the IoT devices or from the Web applications and analysis results will be stored into cloud repositories through the *Cloud Storage Connector*.

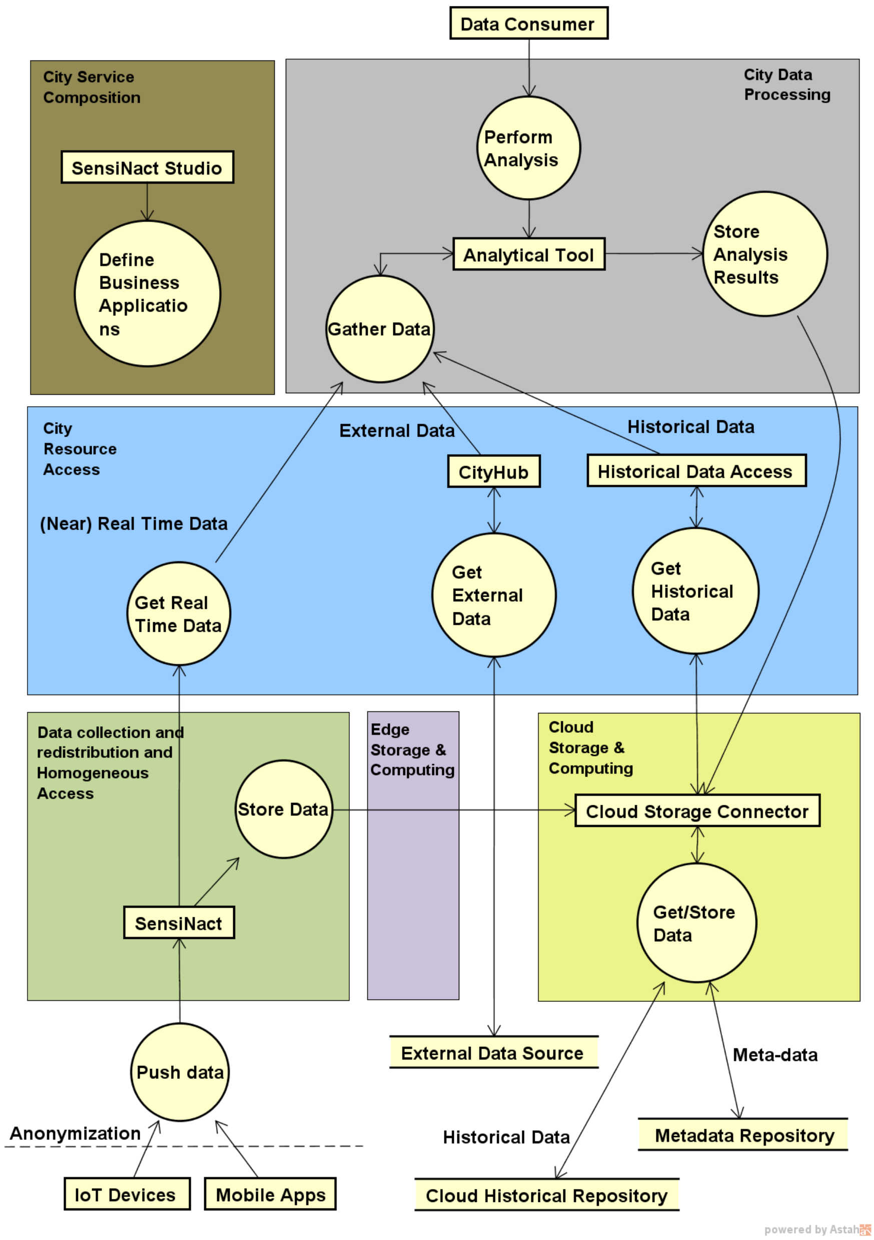

FIGURE 34 GRENOBLE - "MONITORING OF ECONOMIC IMPACTS OF EVENTS" AND "MONITORING OF INDUSTRIAL ESTATES" DATA FLOW

3.5.7 Tsukuba - Provide tourism, traffic and environmental information in real time to visitors

Anonymized data gathered from Mobile Apps and web pages will be stored into cloud repositories through *Cloud Storage Connector*; this data, live twitter data stream and historical data will be used to perform analysis in order to extract context information and to provide useful information to Tsukuba tourists. Twitter data stream is accessed using *Heterogenous Data Warehouse* subcomponent and historical data is accessed using *Historical Data Access* subcomponent. Figure 35 illustrates data flow of Tourist App use case of Tsukuba.

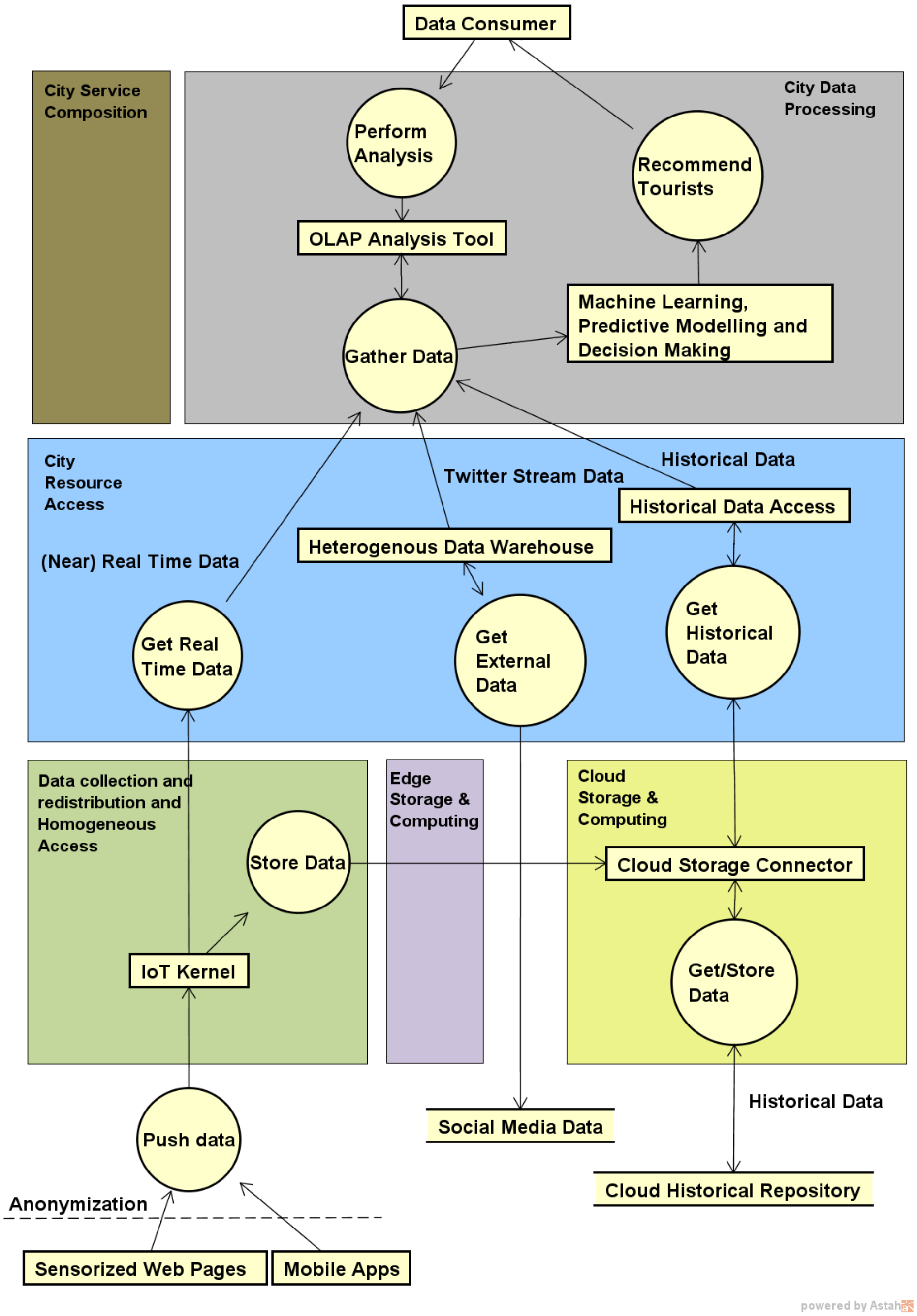

FIGURE 35 TSUKUBA - "PROVIDE TOURISM, TRAFFIC AND ENVIRONMENTAL INFORMATION IN REAL TIME TO VISITORS" DATA FLOW

3.5.8 *Tsukuba - Grasp status about foreign visitors to Tsukuba and provide concierge service to them*

Tsukuba city problems are notified by foreign visitors using mobile applications. These data will be historicized into cloud repositories through *Data Collection and Redistribution And Homogenous Access* and *Cloud Storage and Computing* modules and then provided to *City Data Processing* module and analyzed in order to provide tourists with useful information during their staying in Tsukuba. Figure 36 depicts data flow of Participatory Sensing App for Foreign Visitors use case of Tsukuba.

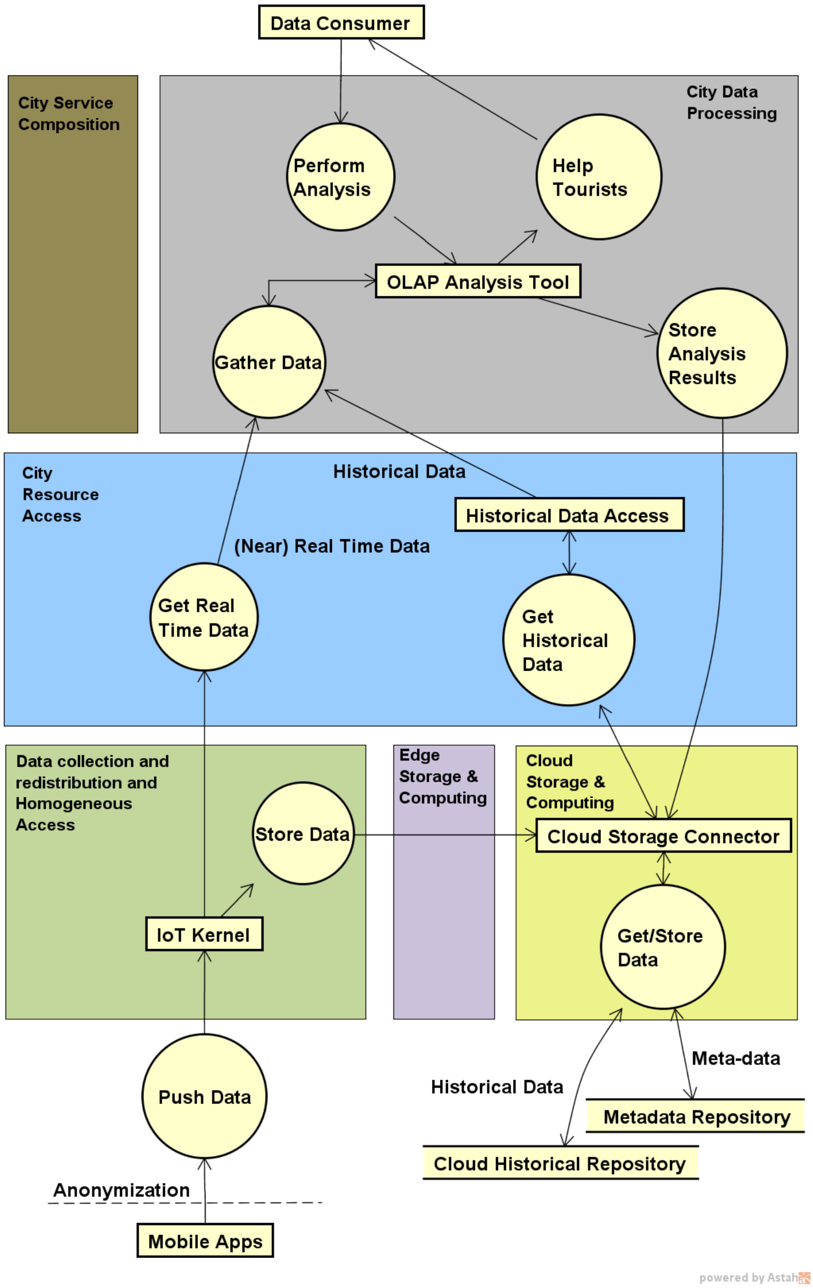

FIGURE 36: TSUKUBA - "GRASP STATUS ABOUT FOREIGN VISITORS TO TSUKUBA AND PROVIDE CONCIERGE SERVICE TO THEM" DATA FLOW

4 CONCLUSION

This document is the final one of WP1 of BigClouT; it describes the final version of BigClouT logical reference architecture that comes from its previous version described in [5] and evolves the ClouT architecture including specific modules in order to support new functionalities expected for BigClouT: big data analysis, self-awareness, real time intelligence and edge computing. Architecture reported here takes into account input provided by other two documents (“D2.1 Data collection tools and architecture” [2] and “D3.1 Big Data Analytics Framework Architecture” [3]) that investigate and detail CIaaS and CPaaS layer of BigClouT architecture.

Reported reference architecture is also derived from updated reference use cases and from the resulting final requirements, that are the inputs for the specification of the reference architecture itself; furthermore they play an important role for the validation of the final system and its evaluation against to the desired functionality. Functional and non-functional final requirements of BigClouT are also reported.

This document and the reference architecture here reported represent the basis on top of which point activities of WP2 "Programmable Smart City" and of WP3 "Extracting city knowledge for intelligent services" will continue and BigClouT use cases will be built.

5 ANNEX A - REUSABLE ASSETS

This section reports a brief description of technological assets involved in BigClouT reference architecture; for each of them the current TRL (Technology Readiness Level) level and the expected one.

For more information about them please refer to document "D1.1 Analysis of existing reusable European and Japanese assets" [14]

Asset Name	Rationale	Current TRL	Expected TRL
CDMI Storage	In ClouT project, ENG developed a cloud storage platform implementing CDMI specification and providing query queues to perform queries for retrieving historical sensor data. During the project the platform will be extended and integrated with modules to provide edge storage capabilities. In other words the new platform will decide, according to data requirements, if storage will happen at sensor level, at intermediate level or at storage level. The provided functionalities will be demonstrated in real and relevant use cases. CDMI Storage will provides an elastic storage specialized for sensor data and metadata (Hypertable) and object data, such as images and videos (Openstack Swift). The RESTful interface is compliant with CDMI Standard. The physical storage is composed by several instances of Swift and Hypertable, deployed on different nodes. According to the load, the number of active nodes can dynamically change modifying the overall capacity.	4	5
City Hub	LANC has prototyped a cloud based platform for Smart Cities: CityHub. Combining an IoT platform with an open-data repository, it offers a common set of APIs for smart city data management and application development. During the project, components from CityHub will be adapted to work with the BigClouT platform and where appropriate used within field trials. CityHub combines a real-time data sensing platform with an open data system called CKAN designed to support static data and metadata storage.	4	6
CoherentPaaS	ICCS has developed a scalable architecture enabling transactional semantics over a document oriented data store, that allows the execution of OLAP analytics under simultaneously OLTP workloads. The transactional document-store will be extended to support other data stores and cross-datastores queries. CoherentPaaS will provide capabilities to perform data modelling from various data sources and for analytics on top of data (e.g. recommendation services etc.). Moreover, it will provide capabilities for predictive analytics on IoT resource consumption.	4	6
COSMOS	ICCS has developed in FP7 COSMOS project a Trust and Reputation model for preventing erroneous results in virtualized communities of IoTs; during the project it will be	4	6

	tested in the real-life smart cities scenarios. COSMOS provides the following capabilities: • Sensor Data Collection & Process • Data Process & connection of components • Workflows definition and enactment • Special IoT services such as (IoT scheduling/planner, location "fuzzy-fication", etc.)		
DeepOnEdge	The goal of DeepOnEdge (DoE) is to explore lightweight and high accurate data analysis method on edge-side where only limited computing resource is available. In order to achieve this goal, DeepOnEdge (DoE) integrates edge computing and deep neural networks.	3	4
Distributed Node-RED - visual programming tool and Distributed Node-RED - computational platform	LANC has developed a prototype of a distributed dataflow programming tool for Smart Cities, built using the IBM open source technology (Node-RED). It provides a visual programming tool for rapid application development. LANC is extending this tool to support the new functionality and APIs developed in BigClouT in particular the distributed edge processing and adaptive mechanisms. This tool, Distributed Node-RED (D-NR) is composed of two parts: • Distributed Node-RED - visual programming tool tool provides support for the development and deployment of city applications and for the edge composition component that guides the distribution and edge processing piece. • Distributed Node-RED - computational platform provides the core components of the distributed edge processing module including the constraint engine, distribution and management. It uses constraints and other information provided in the city service modules to drive policy and mechanisms.	2	4
ECAVerifier	ECA Verifier provides awareness mechanism. It supports the model checking technique for verification of ECA (Event-Condition-Action) rules.	4	6
KNOWAGE	KNOWAGE is the evolution of SpagoBI, a free and open source business intelligence suite optimized to extract knowledge from large volumes of heterogeneous data. KNOWAGE supports a wide range of data sources from analytical databases and appliances to NoSQL databases. KNOWAGE is developed and supported by ENG and by a large community of developers, and it has been adopted in several real operational environments and in different applicative domains. KNOWAGE will be involved in the development of the BigClouT Big data framework and its functionalities will be demonstrated in the specific project use cases. KNOWAGE provides functionalities for business analytics and business intelligence; KNOWAGE is able to perform analysis working with different is able to manage and to work with different data types and sources and provides capabilities for data	5	6

	visualization.		
Lokemon	In BigClouT project, Keio is proposing a new participatory sensing method called Lokemon, which associates avatars to locations/places that address the privacy concerns of the citizens and motivate them to participate. Lokemon will be completely designed and implemented in the context BigClouT project, and it will be tested in both laboratory-level and real field-level, in order to ensures to increase readiness level. Lokemon is a brand new way of motivating citizen to participate crowd sensing without any privacy issues. Lokemon ask users to pretend themselves to be cute monsters associated to location spots when communicating with various people. Any users currently located near the spot can be a Lokemon and answer questions from other remote users. Remote users can ask questions related to the location wherever they are. "How many people are lining at the bus stop now?" "What's the mood of the restaurant right now?" The "Lokemonized" user will answer to questions asked to the Lokemon by the remote users.	5	7
MinaRepo	MinaRepo is a prototype of participatory sensing system for city operation. MinaRepo is designed for enhancing efficiency of city workers' daily work. To naturally fit with their existing working scheme, MinaRepo has several practical functionalities such as providing various report types, setting emergency level, etc.	6	7
OpenStack Cloud computing	Provides elastic computation capabilities enabling to instantiate and remove Virtual Machines according to the amount of required resources.	9	9
Self-Healing	In ClouT project NII developed a self-healing framework, that provides functionalities to identify, classify, and correct data faults in sensor readings, through the analysis of spatial and/or temporal correlation between sensor readings. This framework is Self-Healing; it will be extended in order to support self-adaptiveness to balance tradeoff between non-functional requirements for data processing, such as accuracy, realtimeness, and privacy, and, it will be validated within testbeds in the BigClouT project. The self-healing tool provides a function to correct the sensory faults, that being of bias, drift, dysfunction or random.	4	6
sensiNact	In the context of the BUTLER and ClouT projects, CEA has developed sensiNact, an IoT platform, that provides support for various IoT protocols (e.g.: CoAP, Zigbee, enOcean, BLE, Smart TV APIs, etc.). It is has been demonstrated in different application domains in projects' proof of concept scenarios. The platform will be extended in order to support self-adaptivenes, and the BigClouT project will allow to validate it within the project's pilot testbeds, and to increase its readiness level. The sensiNact gateway provides a hierarchical service model easily extensible on which apply a set of access methods, standardizing the access to every connected counterparts whatever they are: physical	4	6

	apparatus, web services or applications, virtual entities.		
sensiNact Studio	In the ClouT project, CEA has developed sensiNact Studio, an IoT service development, deployment and management tool that is able connect to IoT platforms and to provide functionalities to build services and applications by mashing up services offered by IoT devices. During BigClouT project, sensiNact Studio will be evolved leveraging security and dependability properties, essential in the IoT context, in order to make IoT applications reliable and secure by design. The project's pilots will allow demonstrating the concept in relevant environments thus increase its TRL level. The sensiNact Studio offers a set of tools to monitor existing city entities, to easily create and deploy city applications built by using those entities	4	6
Sensorizer	In ClouT project, Keio has developed a tool for accessing static web site as active modern sensor stream. This tool is Sensoriser; it is composed of a client-side (browser plugin) and a server-side part. During the project, Sensoriser will be extended with new functionalities (e.g.: such as automatic sensorising mechanism, enhancing scalability, optimized web-access scheduling etc.), and it will be validated within field trials, in order to increase its readiness level. Sensorizer leverages crowd sourcing for accurate EWC (Entombed Web Content) discovery, periodic web scraping with a headless browser for excavation from dynamic web pages, and a standardized communication protocol (XMPP) for data streaming to wide variety of applications. Sensorizer is a set of: • an authoring tool with which arbitrary elements on a web page can be defined as an EWC container; • a probing tool running on the master/helper servers that periodically mines current value from the container web pages; • a data transmission middleware that uses XMPP over HTTP.	5	7
StreamOLAP	TSU has developed a system for OLAP (online analytical processing) to allow real-time decision making over streams of data. Thos tool is StreamOLAP; it is based on a stream processing engine and a conventional OLAP engine, in order to enable interactive multi-dimensional analysis over real-time information. During the project, StreamOLAP will be applied in real applications in order to allowing users to make decisions over real-time information; it will be also extended for more enhanced analysis and it will be validate in the pilots. StreamOLAP provides capabilities to perform online analytical processing (OLAP) over streams data. Moreover, StreamOLAP will be integrate with JSSpinner, in order to improve its capabilities.	2	4
JsSpinner	JsSpinner provides stream processing capabilities; it is able perform queries to continuously get filtered stream.	4	5

6 ANNEX B - AVAILABLE DATA SOURCES

This section reports a summary of available data sources that will be involved in the implementation of use cases of BigClouT.

Grenoble data sources

Table 28 reports data sources of both use cases of Grenobles, that are described in sections 1.1.1 and 0.

TABLE 28: AVAILABLE DATA SOURCE OF GRENOBLE USE CASES

Use case		Monitoring of Economic Impacts of Events Monitoring of Industrial Estates					
City		Grenoble					
Descriptio n	**Data Model**	**Frequency**	**Expected Amount**	**Data Provider**	**Repository**	**License**	**Available**
Zone Map	-	once	-	Innovalée Association	-	-	Not yet available
Transport agency: (category - line - time table - stop stations - plan - website link)	http://data.metropolegrenoble.fr/ckan/dataset - (JSON)	once	few kb/ day	OpenData Grenoble Metropole	-	-	Already available
	JSON	Daily	few kb/ day	Web/Mobile Application	-	-	Not yet available
Local shop: category - name - address - location - phone number - times	JSON – GeoJSON	once	few kb/ day	Innovalée Association	-	-	Already available
	JSON – GeoJSON	Daily	few kb/ day	Web/Mobile Application	-	-	Not yet available

Local restaurant: category - name - address – location - phone number - times	JSON - GeoJSON	once	few kb/ day	Innovalée Association	-	-	Already available
	JSON - GeoJSON	Daily	few kb/ day	Web/Mobil e Application	-	-	Not yet available
Company: category, name, address, phone number, email address, location,	JSON - GeoJSON	once	few kb/ day	Innovalée Association	-	-	Already available
	JSON - GeoJSON	Daily	few kb/ day	Web/Mobil e Application	-	-	Not yet available
Event: name - address - location - datetime - description - price - plan - website	JSON - GeoJSON	once	few kb/ day	Innovalée Association	-	-	Already available
	JSON - GeoJSON	Daily	few kb/ day	Web/Mobil e Application	-	-	Not yet available
Car-sharing web site link	-	once	few kb/ day	Innovalée Association	-	-	Already available
	-	Daily	few kb/ day	Web/Mobil e Application	-	-	Not yet available
Roadworks : location - scheduled begining of works - scheduled end of	http://data.metropolegrenoble.fr/ckan/dataset - (JSON - GeoJSON)	once	few kb/ day	OpenData Grenoble Metropole	-	-	Already available

works	GeoJSON	Daily	few kb/ day	Web/Mobil e Application	-	-	Not yet available
Sport activity: address - phone number - location – times - website link	JSON - GeoJSON	once	few kb/ day	Innovalée Association	-	-	Already available
	JSON - GeoJSON	Daily	few kb/ day	Web/Mobil e Application	-	-	Not yet available
Conciergeri e: address, phone number, location, website link, times	GeoJSON	once	few kb/ day	Innovalée Association	-	-	Not yet available
	GeoJSON	Daily	few kb/ day	Web/Mobil e Application	-	-	Not yet available
Tram arrival delay for a specific station	http://data.metromobilite.fr/api/dyn/{X}/json (JSON)	150/day	few kb/ day	OpenData Grenoble Metropole	-	-	Already available
	JSON	Daily	few kb/ day	Web/Mobil e Application	-	-	Not yet available
Route	https://data.metromobilite.fr/otp/ (JSON)	150/day	few kb/ day	OpenData Grenoble Metropole	-	-	Already available
	JSON	Daily	few kb/ day	Web/Mobil e Application	-	-	Not yet available

Bristol data sources

Table 29 reports data sources of the use case "Smart Energy - predictive analysis of users' power consumption" of Bristol that is described in section 1.2.1, whereas Table 30 reports data sources of the use case "Smart Mobility " that is described in section 1.2.2; it is important to underline that for both use cases, even if data sources have been identified, most of their related information (such as license, availability, frequency, etc.) is not yet decided.

TABLE 29: AVAILABLE DATA SOURCE OF BRISTOL USE CASE "SMART ENERGY - PREDICTIVE ANALYSIS OF USERS' POWER CONSUMPTION"

Use case		Smart Energy - predictive analysis of users' power consumption					
City		Bristol					
Description	**Data Model**	**Frequency**	**Expected Amount**	**Data Provider**	**Repository**	**License**	**Available**
Electricity – Gas - Water Consumption	REPLICATE output (JSON-NGSI)	To be defined	To be defined	To be defined	To be defined	To be defined	Not yet available
Temperature – Humidity – Pressure - Luminance	To be defined	To be defined	To be defined	To be defined	To be defined	To be defined	Not yet available

TABLE 30: AVAILABLE DATA SOURCE OF BRISTOL USE CASE "SMART MOBILITY"

Use case		Smart Mobility					
City		Bristol					
Description	**Data Model**	**Frequency**	**Expected Amount**	**Data Provider**	**Repository**	**License**	**Available**
Traffic Flow – GPS	To be defined	Suggesting 1 min to 1 hour	To be defined	Bristol Is Open IoT System	To be defined	To be defined	Not yet available
PM2.5/10 CO2 NO NO2 SO2 O3 Noise Level	To be defined	Suggesting 1 min to 1 hour	To be defined	To be defined	To be defined	To be defined	Not yet available

Weather static Temperature Humidity Pressure Luminance							

Tsukuba data sources

Table 31reports data sources of the use case "Provide tourism, traffic and environmental information in real time to visitors" of Tsukuba that is described in section1.3.1, whereas Table 32reports data sources of the use case "Grasp status about foreign visitors to Tsukuba and provide concierge service to them" that is described in section 1.3.2.

TABLE 31: AVAILABLE DATA SOURCE OF TSUKUBA USE CASE "PROVIDE TOURISM, TRAFFIC AND ENVIRONMENTAL INFORMATION IN REAL TIME TO VISITORS"

Use case		Provide tourism, traffic and environmental information in real time to visitors					
City		Tsukuba					
Description	**Data Model**	**Frequency**	**Expected Amount**	**Data Provider**	**Repository**	**License**	**Available**
Photos with location information	Image (JPEG), JSON	Several times per day	100 MB/day	Smartphone	-	-	Already available

TABLE 32: AVAILABLE DATA SOURCE OF TSUKUBA USE CASE "GRASP STATUS ABOUT FOREIGN VISITORS TO TSUKUBA AND PROVIDE CONCIERGE SERVICE TO THEM"

Use case		Grasp status about foreign visitors to Tsukuba and provide concierge service to them					
City		Tsukuba					
Description	**Data Model**	**Frequency**	**Expected Amount**	**Data Provider**	**Repository**	**License**	**Available**
Short text with location information of the image and the report (problem) provided by the user	JSON	Several times per day	1 MB/day	Smartphone	-	-	Already available

Fujisawa data sources

Table 33 reports data sources of the use case "Optimizing the incidence on local economy of Fujisawa" of Fujisawa that is described in section 1.4.1, whereas Table 34 reports data sources of the use case "Grasp status about foreign visitors to Tsukuba and provide concierge service to them" that is described in section 1.4.2.

TABLE 33: AVAILABLE DATA SOURCE OF TSUKUBA USE CASE "PROVIDE TOURISM, TRAFFIC AND ENVIRONMENTAL INFORMATION IN REAL TIME TO VISITORS"

Use case		Optimizing the incidence on local economy of Fujisawa					
City		Fujisawa					
Description	**Data Model**	**Frequency**	**Expected Amount**	**Data Provider**	**Repository**	**License**	**Available**
MinaRepo - Road, Park, Event, Disaster, Garbage, etc	Open311[15]	20 per day	5MB/day	Smartphone (Participatory report by people)	-	No license. Ask permission to Fujisawa City	Already available
Lokemon - chatting info (conversation), people movement	JSON	50 per day	10MB/day	Smartphone	-	No license. Ask permission to Fujisawa City	Already available

TABLE 34: AVAILABLE DATA SOURCE OF TSUKUBA USE CASE "PROVIDE TOURISM, TRAFFIC AND ENVIRONMENTAL INFORMATION IN REAL TIME TO VISITORS"

Use case		Fine-grained city infrastructure management					
City		Fujisawa					
Description	**Data Model**	**Frequency**	**Expected Amount**	**Data Provider**	**Repository**	**License**	**Available**
Road condition	Video (MPEG)	18FPS	20GB/day	drive recorder cam	-	No license. Ask permission to Fujisawa City	Expected data: April 2018

Analysis Results	-	-	-	-	-	No license. Ask permission to Fujisawa City	Expected data: April 2018
Garbage Truck sensor - GPS, gyro, PM2,5, light,UV, accelerometer	XML	100 per second	20GB/day	On board device		No license. Ask permission to Fujisawa City	Already available

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