

LOW-COST INNOVATIVE TECHNOLOGY FOR WATER QUALITY MONITORING AND WATER RESOURCES MANAGEMENT FOR URBAN AND RURAL WATER SYSTEMS IN INDIA

# **Deliverable D 5.1**

# Conceptual design and architecture of the platform, first version



Lead: UNEXE

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Abstract		
This document captures the first version of the global system architecture, outlining all the components, their inputs and outputs and how they integrate with each other. It also identifies areas where existing technology will make up part of the solution and provides the foundations for designing a highly flexible, modular and		





expandable platform that will be suitable for the conditions in India and take advantage of the specific capabilities of the LOTUS sensor.

#### Keywords

global system architecture, water management, water quality, platform, IT

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# **The LOTUS Project**

LOTUS is a project funded by DG Environment under the European Union Horizon 2020 Research and Innovation Programme and by the Indian Government. It brings together EU and prominent Indian organisations with the aim to co-create, co-design and co-develop innovative, robust, affordable lowcost sensing solutions for enhancing India's water and sanitation challenges in both rural and urban area.

The LOTUS solution is based on an innovative sensor and includes tailor-made decision support to exploit the capabilities of the sensor as well as a specific approach to co-creation. LOTUS aims to be co-designed and co-produced in India, and have a wide, diverse and lasting impact for the water sector in India due to intense collaborations with commercial and academic partners in India.

Based on the low-cost sensor platform, solutions for the early detection of water quality problems, decision support for countermeasures and optimal management of drinking and irrigation water systems, tailored on the functionalities of the new sensor, will be developed and integrated with the existing monitoring and control systems.

This sensor will be deployed in five different use cases: in a water-network, on ground-water, in irrigation, in an algae-based wastewater treatment plant and water tankers. The packaging of the sensor, as well as the online and offline software tools, will be tailored for each of the use cases. These last will enable us to test the sensors and improve them iteratively.

The project is based on co-creation, co-design and co-production between the different partners. Therefore, an important stakeholder engagement process will be implemented during the project lifetime and involve relevant stakeholders, including local authorities, water users and social communities, and will consider possible gender differences in the use and need of water. Broad outreach activities will take place both in India and in Europe, therefore contributing to LOTUS impact maximization.

The further development and exploitation (beyond the project) of the novel sensor platform will be done in cooperation with the Indian partners. This will create a level playing field for European and Indian industries and SMEs working in the water quality area.





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## **Acronyms and Definitions**

Acronyms	Defined as
API	Application programming interface
CRUD	Create, read, update and delete
DSS	Decision support system
EC	Electrical conductivity
GPS	Global positioning system
loT	Internet of things
JSON	JavaScript Object Notation
JSON-LD	JavaScript Object Notation for Linked Data
LoRaWAN	Long range wide area network
LWM2M	Lightweight Machine-to-Machine
MVC	Model, view and controller
NGSIv2	Next Generation Service Interface v2
ONA	Open network architecture
OPC	Open platform communication
OPC-UA	Open Platform Communications United Architecture
OWASP	Open Web Application Security Project
PDPA	Personal Data Protection Act
SCADA	Supervisory control and data acquisition
SQL	Structured query language
TDS	Total dissolved solids
WDN	Water distribution network
WP	Work package
XSS	Cross-site scripting
XXE	XML External Entity
XML	Extensible Mark-up Language



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# **1 Executive Summary**

This document forms the conceptual design and architecture for the LOTUS project, developing a conceptual architecture from use case requirements (Sections 3.3 & 3.4) whilst drawing on state-of-the-art architectural and operational practices (Section 4.1).

The document has been substantially redeveloped once it became apparent that four of the five use cases would develop their own bespoke architectures, leaving the LOTUS platform to be the sole use of Use Case 4, 'groundwater and river water monitoring', with the platform using FIWARE as its core data collection, management and processing solution (Section 5).

There is scope to use functional leak detection components for Use Case 1, 'water distribution network Guwahati', though this will be considered in depth in appropriate deliverables in WP4.

The resulting architecture is evaluated against use case requirements for fit (Section 4.5) and each use case is presented within the architecture platform (Section 4.6) to illustrate functionality platform fit.





# **2** Introduction

This document presents the first version of the conceptual design and high level architecture of the LOTUS platform, based on state of the art internet of things (IoT) and open network architecture (ONA), the sensor functionalities (WP2), the specific user requirements (WP1), the strategic analytical tools (WP3) and the real time functionalities (WP4), combined with the specifics of the case studies (WP6).

In the architecture design, all components are outlined, along with their inputs and outputs and how they integrate with each other. It also identifies areas where existing technology will make up part of the solution and provides the foundations for designing a highly flexible, modular and expandable platform that will be suitable for the conditions in India and take advantage of the specific capabilities of the LOTUS sensor.

The initial architecture proposed here will be updated later in the project as, and if, needed.

The key objective is to deliver an integrated framework to cope with the interoperability issues that arise in diverse environments and Use Cases (WP6, T6.1). It is expected that modules will communicate with the platform through an application programming interface (API) developed in T5.1 and protocols developed in T2.2. Interfaces will be specified with clear adherence to exchangeability and compliance with existing standards.

The conceptual design and high-level architecture of the LOTUS platform will also take into account the outcomes from the co-creation workshops organised in WP1 (T1.2) in order to facilitate an enduser and pilot-driven approach. The integrated system will, therefore, be developed in strong collaboration with the demonstration use cases and the individual participants and actors.





# **3 Requirements and dependencies**

WP5 provides a platform for integrated (real-time and offline) operational management of water systems. Broadly speaking, this is required to provide processing, real-time display and monitoring of system information, and an interface to strategic analytical tools developed for each use case. Specific requirements and dependencies that must be considered in the design and architecture of the platform are discussed in this section.

# **3.1 Sensor functionalities**

The design of the platform needs to be tailored to the functionalities and capabilities of the LOTUS sensor. The LOTUS sensor will be tuneable to various water use cases, but in all instances will provide measurements of multiple parameters for chemical monitoring of water. Sensing capabilities will initially cover temperature, conductivity, pH and chlorine, and later pesticides and heavy metals. Bacterial contamination is also intended to be measured via indirect detection methods. Additionally, operational information on the status of each sensor (relating to, for example, communication, energy and global positioning system (GPS) location) will be available. The conceptual design and architecture of the platform must, therefore, facilitate the processing, display and monitoring of multiple measurements from each sensor and provide information on their operational status. Management of identifier information (IDs) for the sensors must also be considered. While the precise nature of the data processing, display and monitoring is varies by use case, the processing is expected to transform sensor (and other) data quantitatively and qualitatively into formats that meet the needs of the respective stakeholders. Specific requirements related to the handling of data from the LOTUS sensor in each use case are further detailed in Sections 3.3 and 3.4.

# **3.2 Strategic analytical tools and real time functionalities**

The platform needs to implement the strategic analytical tools developed in WP3, as required for each case study. These tools will provide functionality for the following; however, note that where the case study/studies implementing them do not require the conceptual architecture

some are use case specific, and may not be relevant to the conceptual architecture presented in this document if the use case implements an alternative solution.

- Creating historical time series data and outlining specific operational targets and chemical species to be monitored (T3.1)
- System modelling and simulation, including water quality demand, leakage and pressure management (T3.2). This includes modules for:
  - Optimizing intermittent operation of water distribution network (WDN) and transition towards 24x7 service delivery (T3.2.1)



- Optimizing demand and asset management techniques and practices for effective and efficient operations and management of water distribution systems (T3.2.2)
- Modelling and optimization of tanker-based water distribution system (T3.2.3)
- Groundwater and river water system modelling and simulation (T3.2.4)
- Adaptation to the use cases, deployment and evaluation (T3.3)

Note, however, some of these tools are case study specific and if a case study will not utilise the conceptual architecture presented in this document (as discussed in Section 3.4), they need not be considered further.

The platform also needs to implement the real time functionalities developed in WP4 for Use Case 4. These include real time software tools with geo tagging for water system management (T4.2) and will be adapted to the use cases, deployment and evaluation (T4.3).

Specific requirements from each use case relating to the implementation of strategic analytical tools and real time functionalities in the conceptual design and architecture of the platform are covered in Sections 3.3 and 3.4.

# **3.3 End-user-specific requirements**

The specific requirements from the stakeholders in India should be addressed in the design of the platform. This includes not only the system operators or administrators, whose requirements are captured in Section 3.4, but also the end users of the platform (e.g. members of the general population). This section specifically addresses the requirements of the end users.

Under WP1, co-creation workshops involving the final (end) users of the LOTUS uses cases and addressing user interaction and system functionality were held (as reported in D1.2). Taking into account the outcomes from these workshops in the development of the platform conceptual design and architecture will help to facilitate an end-user and pilot driven approach.

The workshops for Use Case 1 (WDN in Guwahati), Use Case 2 (tanker based WDN) and Use Case 4 (groundwater and river monitoring) involved members of the general population as final users. For Use Case 3 (irrigation WDN), farmers participated in the workshop, and for Use Case 5 (wastewater treatment), no workshop was held.

Commonly requested features included SMS notifications (use cases 1-5), information on water quality status (use cases 1, 2 and 4) and advice for safe water use (use cases 1 and 4). Specific parameters of interest were also identified by the users, along with requirements relating to monitoring frequency, data management and system maintenance.

An overview of all system functionalities and user interactions that the participants of the workshops expressed an interest in (as reported in D1.2) is given in Table 1. The section in D1.2 in which each is originally specified is indicated in brackets.







# Table 1. Summary of desired system functionality and user interaction expressed by end users inthe WP1 workshops

Use Case	System functionality	User interaction
1	<ul> <li>Turbidity and bacterial contamination are 'must have' parameters (D1.2, Section 2.7)</li> <li>The sensor should be used to increase trust in piped water supply (D1.2, Section 2.6.2.3)</li> </ul>	<ul> <li>SMS alert when groundwater does not meet safety standards (D1.2, Section 2.6.2.3)</li> <li>App with information on water quality status (e.g. using a colour coded system from 'good' to 'bad') and instructions for safe water use (e.g. a statement such as 'safe to drink after boiling/filtering/treatment') (D1.2, Section 2.6.2.3)</li> <li>Public display of groundwater quality (D1.2, Section 2.6.2.3)</li> </ul>
2	<ul> <li>Information on water quality, the quantity delivered by tankers and the time of filling the source should be provided (D1.2, Section 4.6.1.3)</li> </ul>	<ul> <li>SMS notification providing information on water delivered (D1.2, Section 4.6.2.3)</li> </ul>
3	<ul> <li>pH, and electrical conductivity (EC) are 'must have' parameters (D1.2, Section 5.6.1.4)</li> <li>Sodium is a highly desirable parameter (D1.2, Section 5.6.1.4)</li> <li>High temporal resolution of monitoring (D1.2, Section 5.6.1.4)</li> <li>Data should be transferred to a system for storage and analysis (D1.2, Section 5.6.1.4)</li> </ul>	<ul> <li>An advisory system for fertigation (D1.2, Section 5.6.1.4)</li> <li>Two data displays (D1.2, Section 5.6.2.3)</li> <li>SMS alerts (D1.2, Section 5.6.2.3)</li> <li>The system must require little maintenance (specifically, less than once a year) (D1.2, Section 5.6.2.3)</li> </ul>
4	<ul> <li>Fluoride, arsenic and iron are 'must have' parameters (D1.2, Section 3.7)</li> <li>Sensor should be used to encourage people to sign up to the government water supply (D1.2, Section 3.6.3)</li> </ul>	<ul> <li>App that enables users to access water quality status and receive advice for safe water use (D1.2, Section 3.6.2.3)</li> <li>SMS alerts when groundwater does not meet safety standards (D1.2, Section 3.6.2.3)</li> <li>Public display (D1.2, Section 3.6.2.3)</li> </ul>



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The platform design must consider the specific requirements of each individual case study (WP6), and its functionalities should be adjusted for the tools needed in each case (WP3 and WP4).

Requirement relating to each case study are detailed in the following sections, 3.4.1 to 3.4.5. Where applicable, this includes a summary of pertinent information from D6.1 [1], which includes information on the dashboards and interfaces, software / hardware component connectivity and software components required for each use case.

## 3.4.1 Use Case 1: Water distribution network Guwahati

This use case will be delivered by ABB and will not be considered further in the conceptual architecture.

The use case will provide the following run-time functionality:

- 1. Water quantity (pressure, flow) monitoring and anomaly detection in urban water distribution systems
- 2. Water quality monitoring and anomaly detection
- 3. Real time mitigation measures for water quantity and quality alerts
- 4. Real-time alerts to the public

These will be considered further in WP4.

## 3.4.2 Use Case 2: Tanker-based water distribution network

This use case will be delivered by Suyati and will not be considered further in the conceptual architecture.

## **3.4.3 Use Case 3: Irrigation water distribution network**

This use case will be delivered by JAIN / TU-Dortmund and will not be considered further in the conceptual architecture.

#### 3.4.4 Use Case 4: Groundwater and river water monitoring

Use Case 4 will monitor groundwater quality in the cities of Guwahati, and Bangalore, and both groundwater quality and river water quality for the city of Varanasi.

Dashboard requirements identified for Use Case 4 in D6.1 are as follows:

- 1) An administrator dashboard should be provided (D6.1, Section 5.6).
- 2) The administrator dashboard should include:
  - Display of the concentration of different substances (including EC, total dissolved solids (TDS), temperature, pH, total Hardness, chlorine, iron, arsenic, fluoride, nitrate





and microbiological indicators) in the groundwater and the observed groundwater table (for Guwahati and Bangalore) (D6.1, Sections 5.4.1 and 5.6).

- Display of different river water quality parameters (for Varanasi).
- A DSS displaying possible mitigation strategies for Guwahati, removal technologies for Bangalore, and removal methods or treatments for Varanasi (D6.1, Section 5.6).
- 3) The collected data to be represented with the graphical display (heat mapping type) with reference to the Indian water quality standards IS10500:2012
- 4) Seasonal variations interlinking the external environmental parameters and its influence on ground water quality

Additional features specified in D6.1 include:

1) A numerical transient state contaminant model for Guwahati will provide identification of an arsenic-safe aquifer or region for groundwater usage (D6.1, Section 5.1.1).

2) The river water quality monitoring in Varanasi will indicate the extent of water pollution and the presence of different pollutants to enable monitoring of the effectiveness of pollution control measures and assessment of the suitability of water for different uses (D6.1, Section 5.1.3).

3) Data will be collected from LOTUS sensors, both on-site and in lab, with an on-site storage capacity of at least 1000 entries and associated GPS data. Data will be stored in the cloud via the LOTUS box (D6.1, Sections 5.4.3 and 5.5).

4) GPS location data must be integrated to capture the location of the sampling site for strategic planning and preparation of contaminant map (D6.1, Section 5.4.3).

#### 3.4.5 Use Case 5: Wastewater treatment

This use case will be delivered by TU-Dortmund and will not be considered further in the conceptual architecture.

# **3.5 Other considerations**

The platform must have the capacity to be exploited as a product, alongside the sensor, following the INSPIRE (2007/2/EC) directive for data interoperability [2]. It should also be modular, adaptable (to the specific requirements for each Use Case), expandable and interoperable with other existing systems at the utilities/users.

# 3.6 Summary of requirements

This section aims to provide a clear summary of the requirements identified in Sections 3.1-0 that will inform the conceptual design and architecture. Each requirement is given a unique ID so that it may later be referred to when checking that the conceptual design and architecture developed enables every requirement to be met.





Requirements identified in Sections 3.1, 3.2 and 3.3 can be considered general, as they are not specific to any individual use case. These requirements are summarised in Table 2.

# Table 2. General requirements relating to the conceptual design and architecture of the LOTUSplatform

ID	Description
RG1	Measurements of multiple parameters from each LOTUS sensor must be handled
RG2	Strategic analytical tools developed in WP3 for creating historical time series, outlining specific operational targets and monitoring chemical species must be implemented
RG3	Strategic analytical tools developed in WP3 for system modelling and simulation must be integrated.
RG4	The platform must integrate strategic analytical tools that are adapted to the specific use cases
RG5	The platform must integrate real time functionalities developed in WP4
RG6	The platform must have the capacity to be exploited as a product, following the INSPIRE (2007/2/EC) directive for data interoperability [2].
RG7	The platform should be modular, adaptable (to the specific requirements for each Use Case), expandable and interoperable with other existing systems at the utilities/users.

More detailed, tailored requirements can be identified for the individual use cases. As only Use Case 4 needs to be considered in the conceptual architecture (as discussed in Sections 3.4.1 to 3.4.5), the following requirements relate specifically to this use case. Firstly, the user requirements and case study requirements presented in Sections 3.3 and 3.4 identify a variety of sources from which the LOTUS platform needs to be able to collect data. Table 3, therefore, collates all the data sources that the conceptual design and architecture must consider for Use Case 4.

#### Table 3. Summary of data collection requirements for Use Case 4

ID	Description
RDC1	Collect data from LOTUS sensors (in bulk)

Secondly, multiple requirements related to the management, processing and use of this data can be identified from Sections 3.3 and 3.4. These include storage of data in meaningful, accessible and long-term repositories, processing of data pre/post storage, and use of data to create new insights





(e.g. with analytical and decision support tools). Specific requirements applicable to Use Case 4 are summarised in Table 4.

ID	Description
RDM1	A data logging system is required to store data collected from sources in Table 3
RDM2	Data collected needs to be processed for and used in advisory / decision support tools
RDM3	Data collected needs to be processed for and used in a contaminant transport model

#### Table 4. Summary of data management, processing and use requirements for Use Case 4

Thirdly, the user requirements and case study requirements presented in Section 3.4 indicate that Use Case 4 requires an administrator dashboard. Table 5, summarises the requirements for this.

ID	Description
RD1	A dashboard for administrators is required
RD2	The observed groundwater table and concentration of different substances in the groundwater should be displayed
RD3	River water quality parameter concentrations should be displayed
RD4	A contaminant map should be provided, indicating the presence and extent of pollutants
RD5	A DSS displaying possible mitigation strategies and removal method(s) or treatment(s) should be included

#### Table 5. Summary of administrator dashboard requirements for Use Case 4





# **4 Conceptual design and architecture**

# 4.1 State of the art

State of the art areas of consideration include IoT architecture, ONA, the INSPIRE (2007/2/EC) directive for data interoperability [2], application technology stacks and cybersecurity. Further detail is given on each of these in the following sections, 4.1.1 to 4.1.5.

#### 4.1.1 IoT architecture

The IoT architectural stack is considered to be comprised of the following components; sensing, network, data processing and application layers. This architectural stack allows fairly dumb sensing components to become part of complex applications, regardless of their location in the world relative to the application and user.

From Use Case 4, it can be seen that in some instances LOTUS sensors (sensing) are bundled with mobile phones (network) to create the lower core of an IoT stack. It is therefore expected that the platform architecture will provide the rest of the IoT stack (data processing & application layers) and will use a network layer to communicate with the LOTUS / mobile bundles.

## 4.1.2 Open Network Architecture

Although ONA is normally considered as a feature of mobile telephony, it can be considered in more general terms as connectivity between networked systems. There is a role for ONA in Use Case 4 such that arbitrary (and undefined) components can be connected using open interfaces, typical based on networking protocols.

## 4.1.3 INSPIRE (2007/2/EC) directive for data interoperability

The INSPIRE (2007/2/EC) directive [2] is concerned with the use of open data formats for interoperability between users and systems. Given the need for Use Case 1 to use external run-time components (WP4), it makes sense to define these interfaces using a format that provides interoperability.

Currently, FIWARE [3] is being extended to provide a data interoperability platform for water systems under the FIWARE4Water project [4], and this should be strongly considered given the INPIRE directive.



## 4.1.4 Application technology stacks

The conceptual architecture presented in this report is a client/server, which presents many technology choices.

#### 4.1.4.1 Server-side

From the server-side, there is an assumption that the server will run Linux as this would appear to be an industry-standard and cost-effective approach, giving a wide choice of back-end development languages and frameworks, with technology interoperability allowing solutions to be developed using multiple languages and frameworks.

#### 4.1.4.2 Client-side

Client-side development is largely concerned with the development of 'dashboard' applications that many of the case studies require, the assumption being that these would either be mobile native apps or web-based applications. This creates a wide range of technology stacks that could be employed.

For Use Case 4, suitable technology stack(s) can be chosen once there are clear requirements for runtime and visualisation / dashboard application in D4.1.

### 4.1.5 Personal Data Protection

The recent Personal Data Protection Act (PDPA) 2019 [5] enshrines personal data protection into Indian law and it should be noted that the act is largely geared around businesses collecting data rather than technology providers. It is also centred on data management for individuals and, given that case study 4 is centred on collecting, processing and storing river and ground water data, it should be exempt from the personal aspects of the PDPA, unless it becomes a requirement to store personal data for dashboard use, but this should be discouraged.

## 4.1.6 Cybersecurity

The Open Web Application Security Project (OWASP) Foundation maintain a 'top 10' of security risks for web applications [6]. These should be considered for a defensive architecture and are outlined below along with good practice that should be adopted for the LOTUS platform.

#### a. Injection

Injection flaws are concerned with injecting malware into commands sent from client to server, typically SQL queries. Within the LOTUS platform environment, this risk can occur whenever data is received by the server from a client, such as the platform dashboard clients and other services. This issue can be minimised by following a design pattern of not sending SQL, or any other plain text queries, to the server and sanitising inputs prior to executing plain text commands.





#### b. Broken Authentication

Application functions related to authentication and session management are often implemented incorrectly, allowing attackers to compromise passwords, keys, or session tokens, or to exploit other implementation flaws to assume other users' identities temporarily or permanently.

For Use Case 4, there is no consideration given to user authentication as there are no user or security requirements currently defined within the use case. This will be addressed in D5.2.

#### c. Sensitive Data Exposure

Many applications have been 'hacked', revealing sensitive data (user accounts and passwords, communication records, transactions and so on), due to application developers and operators under-estimating the importance of sensitive data and failing to secure it appropriately.

It is unlikely that Use Case 4 will contain sensitive data, but consideration will be given to protecting both short and long-term data.

#### d. XML External Entities (XXE)

XML External Entities relates to security issues with older XML parsers that can lead to unauthorised system access.

The LOTUS platform will use up-to-date XML parsers that do not suffer from XXE issues and will evaluate 3<sup>rd</sup> party software for Use Case 4 against this consideration.

#### e. Broken Access Control

Broken access control describes situations where users can access data that they shouldn't due to issues with access control (rather than authentication issues as described previously).

#### f. Security Misconfiguration

Security misconfiguration is regarded as the most commonly seen security issue and describes multiple issues based around poor security, particularly running services with 'default' security, ignoring patch requests and avoiding system hardening.

#### g. Cross-Site Scripting (XSS)

XSS is a web-based hack that redirects a user's browser to an untrusted site. For Use Case 4, this is can be an issue for any clients that are realised through web services, rather than as bespoke apps.

#### h. Insecure Deserialization

Insecure deserialization describes transport level hacks where data is spoofed between client and server leading to many different issues. For the LOTUS platform, consideration will need to be given to robust client/server communication for the dashboard apps.





#### i. Using Components with Known Vulnerabilities

Many software components have, or have had, vulnerabilities that create attack vectors for hackers. Typically, as these weaknesses are discovered, they are fixed, or the components replaced for more secure components.

Within the LOTUS platform, care will need to be taken to keep the core platform up to date.

#### j. Insufficient Logging & Monitoring

The inabilities to log and monitor atypical behaviour is a core issue behind most cybersecurity issues, as they enable atypical behaviours to occur undetected, often for a long period of time. A logging component will be a core part of the LOTUS platform, all components should use it and operators should monitor its output.





# 4.2 Platform components

## 4.2.1 Conceptual platform

Section 3 details each use case and requirements for the LOTUS case study and is the source for the architectural activities within this report. Whilst the case studies are not identical there is a fair amount of functional overlap and commonality between them allowing for the creation of a re-usable core platform that can be customised by each use case to tailor required functionality.

Given the broad data collection, processing and presentation requirements of use case, it worth considering the model-view-controller (MVC) architecture for the conceptual platform, Figure 1. This architecture defines clear boundaries between data (as model), data processing (as controller) as user interaction (as view).



Figure 1. Prototypical MVC architecture

However, given the requirement in most case studies for concurrent user activity and, in some cases, different types of user to be able to interact with the systems developed, it makes sense to use a client/server architecture, with the assumption of multiple clients sharing data and functionality provided by a bespoke server. Figure 2 details the model-view-controller architecture implemented as client-server, with the server responsible for data storage (model) and data processing (controller) whilst the client, as dashboard(s), is responsible for presenting data (view) to the user and taking user input to be processed on the server.





D5.1 Conceptual design and architecture of the platform, first version



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Figure 3 details the final iteration of conceptual platform with the introduction of IoT concepts, from Section 4.1 and the differentiation of external data types into LOTUS-sourced data (from the LOTUS sensor) and other data sources.



Figure 3. Conceptual architecture

Within these conceptual architecture components, there are the following roles and responsibilities:



#### LOTUS sensor

These are devices as defined in Section 3.1 and are multi-function data collection devices. Their responsibility is to collect data which can be collected by the platform.

#### • 'Other' sensor

These are any other kind of sensor that are not explicitly LOTUS sensors, typically GPS sensors. This data is collected alongside LOTUS sensor data and may be combined with LOTUS data in situations where it makes sense to.

#### Data collection

The role of the data collection component is to collect sensor data and to prepare it for packaging into managed repositories. In Use Case 4, bulk LOTUS data will be presented for collection. It will be a responsibility of this component to log issues during the collection of data and to validate and verify incoming data where possible.

#### Data management

The role of data management is the storage and manipulation of data. It is assumed that data will be managed in some form of repository in which data can be created, retrieved, updated and deleted within system policies.

Data management will also be responsible for the system-wide logging to record important incidents during platform operation.

#### Data processing

This component is responsible for transforming data to provide some form of insight that can be shared with users via the presentation server and client components or sent to other systems via the other data component.

#### Presentation server & client

These two components provide client / server communications such that client applications running on remote h/w can communicate with the server-based data and processing stack.





Architectural Component	Use Case 1 Water Distribution Network Guwahati	Use Case 2 Tanker-based water distribution	Use Case 3 Irrigation water distribution network	Use Case 4 Groundwater and river water monitoring	Use Case 5 Wastewater treatment
Data collection	Data collected by SCADA	Data collected by tanker platform	Data collected by JAIN platform	Collect data from LOTUS boxes	Data collected by SCADA
Data management	Data managed by SCADA	Data managed by tanker platform	Data managed by JAIN platform	Manage sensor data Long-term data storage	Data managed by SCADA
Data processing	Water quantity monitoring and anomaly detection in urban water distribution systems Water quality monitoring and anomaly detection Real time mitigation measures for water quantity and quality alerts	Data processed by tanker platform	Data processed by JAIN platform	Decision support for mitigation, removal & concentration	Data processed by SCADA
Application Dashboard(s)	Real-time alerts to the public	Dashboard by tanker platform	Dashboard by JAIN platform	Dashboard for end user and CWC admins	Data visualised by SCADA

Table 6. Table of case studies and relevant architectural components

# 4.3 Platform requirements & assumptions

This section of the report examines the components of the platform in more detail in order to realise their requirements and assumptions.

## 4.3.1 Data collection

This component is responsible for the collection and validation of data from LOTUS and other sensors.

The assumptions being that:

- 1. The platform can request updates / data from sensors
- 2. Sensors can send data to the platform on demand
- 3. Sensors can send erroneous data which required validation
- 4. Sensors can be broken and send no data or data that is garbage
- 5. Sensors can send the same data multiple times
- 6. LOTUS sensors are not the only sensor input
- 7. Data from multiple sensors (LOTUS + GPS) may need to be combined for storage

#### 4.3.2 Data management

This component is responsible for the data lifecycle (create, read, update and delete, CRUD) within the platform. The assumptions being that:

- 1. The platform will realise its own storage solution
- Sensor data collected through the data collection component will be stored for a relatively 'long' duration, potentially years
- 3. Other components within the platform will require data through searching
- 4. Data can be accessed from other data providers that are external to the platform and data can be added to platform-based repositories
- 5. Users of the platform can add additional data repositories
- 6. Data can be modified and/or deleted from the platform repository
- 7. Platform-wide logging will be managed through the data management component
- 8. EPANET models will be stored as part of data management

#### 4.3.3 Data processing

This component is responsible for interpreting data from multiple sources; the data management component and external data sources and realises what is described as 'decision support' in several of the case studies.

The assumptions being that:



- 1. Data processing demands have the scope to be suitably unique to a particular use case and will be realised as bespoke components
- 2. Results from data processing may be stored in a platform repository.
- 3. Core use case functionality will be realised as interactions between data processing and data presentation.

## 4.3.4 Data presentation (client & server)

This component is responsible for realising functionality of the overall use case application and associated dashboard. The presentation component is realised in two parts: server and client.

The assumptions being that:

- 1. The presentation client will realise the dashboard component, or dashboard-like component of each use case.
- 2. The presentation client effectively forms the 'view' component of an MVC architecture and is responsible for taking user input and sending it to the server application and receiving server responses and presenting them back to the user.
- 3. The presentation server is effectively the 'control' component of an MVC architecture and will service user requests, leveraging the platform's data management and processing components.
- 4. The overall architecture can support multiple clients to give different dashboard functionality.
- 5. Presentation client & server functionality is likely to be largely bespoke for each use case, given the diverse range of functionality required and the choice of client-side technology stacks available.
- 6. The client/server component will provide core communication functionality between client and server.

## 4.3.5 Platform considerations

- 1. The platform is extendable, with support for each use case to develop bespoke functionality across all components of the platform to meet their needs
- 2. The platform will collect LOTUS and associated sensor data
- 3. Data stored in the platform can be used by other systems
- 4. Data stored in other systems can be used (if accessible) by the platform
- 5. Dashboard applications can be developed using suitable hardware & technology stacks
- 6. FIWARE-compatible JSON-LD will be used as data format where possible
- 7. Cybersecurity will be considered as a core part of the architecture and the platform will be designed around current OWASP guidelines.





# 4.4 Conceptual architecture

The architecture is presented as Figure 4 and its refinement is effectively the combination of the architecture, presented in Figure 3, and the requirements and assumptions, presented in Section 4.3. The conceptual architecture enumerates a refinement of component-based functionality that details how component functionality can be realised.

The architecture realises key conceptual affordances:

- 1. Dashboard functionality is deliberately minimal to allow use cases to use technology stacks that meet their needs
- 2. Data collection is open-ended to support different methods of collecting data, from both sensors (LOTUS and others) and other data sources.

Section 4.6 models each use case with the conceptual architecture for functional fit and use case implementation.







Figure 4. Conceptual architecture

# 4.5 Applying the Conceptual Architecture to use case requirements

This section of the report maps the conceptual architecture components and functions to the specific use case requirements identified in Section 3, to assess their fit. Table 7 addresses the data collection requirements (detailed in Table 3), Table 8 addresses the data management, processing and use requirements (detailed in Table 4), and Table 9 addresses the dashboard requirements (detailed in Table 5).

## **4.5.1 Data collection requirements**

ID	Description	Conceptual Architecture consideration
RDC1	Collect data from LOTUS sensors (in bulk)	LOTUS sensor data will be collected using the 'receive data from sensor' and/or 'poll sensor for data' functionality within the data collection component. It is assumed that sensors will either be polled for data or will automatically send data to the platform.

#### Table 7. Data collection requirements mapped to conceptual architecture components

## **4.5.2** Data management, processing and use requirements

# Table 8. Data management & processing requirements mapped to conceptual architecture components

ID	Description	Conceptual Architecture consideration
RDM1	A data logging system is required to store data collected from sources in Table 3	Data can be stored within the data management component, or externally through the 'write data to external source' functionality in the data processing component.
RDM2	Data collected needs to be processed for and used in advisory / decision support	Data (both internal and external) can be processed for decision support within the data processing component. Given the bespoke nature of each use cases advisory and support tools, it is expected that these components will be developed for each use case rather than solely relying on 'off-the-shelf' solutions, though there may be



	tools	scope for software re-use depending on use case needs.	
RDM3	Data collected needs to be processed for and used in a contaminant transport model	Data can be collected from the data collection and data processing components and accessed through the data management component, or externally.	

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## 4.5.3 Dashboard requirements

Table 9. Administrator dashboard requirements mapped to conceptual architecture components

ID	Description	Conceptual Architecture consideration
RD1	A dashboard for administrators is required Dashboard applications will be devusing server and client technologies t	
RD2	The observed groundwater table and concentration of different substances in the groundwater should be displayed	appropriate for the use requirements presented.
RD3	River water quality parameter concentrations should be displayed	
RD4	A contaminant map should be provided, indicating the presence and extent of pollutants	
RD5	A DSS displaying possible mitigation strategies and removal method(s) or treatment(s) should be included	





# **4.6 Applying the Conceptual Architecture to the** use cases

This section of the report models each of the use cases in the conceptual architecture to investigate how the platform can be used and extended to best meet the use cases requirements.

## 4.6.1 Use Case 1: Water Distribution network Guwahati

This use case will be implemented largely outside of the LOTUS platform. It is expected that the ABB solution will integrate with leak detection functionality; this is covered in WP4.

## 4.6.2 Use Case 2: Tanker-based water distribution network

This use case will be implemented independently of the LOTUS platform

## 4.6.3 Use Case 3: Irrigation water distribution network

This use case will be implemented independently of the LOTUS platform

## 4.6.4 Use Case 4: Groundwater and river water monitoring

This use case is concerned with groundwater monitoring at two sites and river water monitoring. Although these site-based applications are currently considered as a single implementation, it is expected that they will be implemented as stand-alone solitons with some technology / functionality sharing. The conceptual architecture is presented as Figure 5.

#### • Data Collection

From the requirements presented, data will be collected from LOTUS sensors and then uploaded into the platform in bulk. This suggests different functionality from other user cases where data is collected one reading at a time or in bulk.

#### • Data Management

It is assumed that historic data will be stored within the platform for long-term comparison (T3.1) and water and GPS data combined to create geographic data. Data will also be archived to long-term storage where necessary.

#### • Data Processing & Application Dashboard

From the requirements for this use case, there are several instances of decision support required, geared around water quality mitigation and water removal, and these functional components will be shared between the three site applications (Guwahati, Bangalore & Varanasi).



SMS functionality has been requested as part of the client dashboard. With this approach, additional data management will need to maintain a repository of user phone nos. and provide SMS on demand. This may be easier to achieve through mobile notifications that can be broadcast to all users. However, this does rely on having the app running.

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#### Figure 5. Conceptual architecture for groundwater and river water monitoring

#### 4.6.5 Use Case 5: Wastewater treatment

This use case will be implemented independently of the LOTUS platform



# **5** Realising the conceptual design

This section of the report takes the conceptual architecture developed in Section 4.4 and applies the real-world components outlined in Section 4.1 to propose a physical design. At the core of this design is the philosophy of the 'context broker', Figure 6, or a centralised data hub, which relies on data being passed between components (typically component to broker and broker to component) using flexible and extensible data formats (JSON/JSON-LD) which reduces the design-time reliance on fixed data structures.



Figure 6. Typical IoT-inspired context broker architecture

The key benefit of the context broker approach is that the only part of the architecture that needs to be explicitly defined is that of the message format between broker and clients of the broker. This approach typically uses open data transfer protocols (http requests) with platform-agnostic data formats, e.g. JSON and JSON derivatives. Whilst this approach is not necessarily efficient in terms of data packet size, modern network performance does not generally make this an issue, even with 'low performance' networks, whilst the flexibility of key-value pair data packets makes it relatively trivial to extend component interoperability as new data providers and consumers are added to a broker system.

# **5.1 FIWARE Context Information Broker**

FIWARE [3], as mentioned in Section 4.1.3, is being extended to provide a data interoperability platform for water systems under the FIWARE4Water project [4], and is currently being used as a context broker in multiple water system research programmes that UNEXE is part of, making it an ideal candidate for use in LOTUS.





## 5.1.1 FIWARE as a platform

As a platform, FIWARE [9] is a curated framework of open source platform components which can be assembled together and with other third-party platform components to accelerate the development of Smart Solutions. These components address the following areas of functionality: interfaces to IoT, core context management and, context processing, analysis and visualisation. This approach allows users of FIWARE to take a 'mix and match approach', with multiple components being provided for each area of functionality and allows users to engage with as much (or as little) of the FIWARE stack as required.

## **5.1.2 FIWARE as functionality**

FIWARE effectively provides three functional components that map to the conceptual platform's data collection, data management, data processing and presentation components. As a context broker architecture, the 'interfaces to IOT' component is responsible for packaging data from sensing devices and delivering them to the context broker ('core context management'). The 'core context management' component is responsible for the short, medium and long-term management of data and the 'data processing and presentation' components are responsible for interrogating and displaying data from the context broker.

#### 5.1.2.1 Interfaces to IOT

FIWARE provides a number of IOT Agents [10], supporting different data formats (JSON, LWM2M, Ultralight, LoRaWAN, OPC-UA and Sigfox) as well as a core agent library that is designed to be extended for custom data formats. The goal of these interfaces is to deliver data to the context manager using the NGSIv2 API [10] and associated data formats.

Given Use Case 4's requirement to collect sensor data in bulk (RDC1), LOTUS sensors could be configured to download bulk data through their USB interface with a PC implementing the IOT Agent. Conversely, the LOTUS sensor could be configured as an IOT Agent to communicate directly with the context broker.

#### 5.1.2.2 Core context management

FIWARE provides a number of context brokerages [13] depending back-end databases and data lifetimes. Typically, the Orion-LD context broker [12] is used for the collection and short-term management of data with Cygnus, Comet and Quantum Leap context managers providing longer-term, time-sliced storage for a variety of SQL and non-SQL databases.

Given Use Case 4's requirement to store sensor data (RDM1 & RDM2) over a potentially long-time (given the need for seasonal data), it would make sense to pair an Orion-LD broker with Quantum Leap to provide long-term data storage.







#### 5.1.2.3 Context processing, analysis and visualisation

FIWARE provides a number of generic tools for analysis and visualisation [14], whilst the NGSIv2 API [10] and JSON data formats provide users with a flexible interface for building tools from scratch, which is something UNEXE has done on other projects.

Given Use Case 4's dashboard requirements (RD1-RD5) and requirement for heat mapping, it's likely that a combination of FIWARE's visualisation tools and bespoke tools with meet these requirements, depending on target platform(s).

## **5.1.3 FIWARE data structures / formats**

FIWARE's reference data structures are defined in a set of GitHub repositories [7]. For LOTUS sensors, datamodel.device [8] can be used as a data format that describes a physical device that can perform a particular activity, typically sensing some property from the environment (pressure, pH, salinity etc).

The flexible format of the device structure allows a device to define multiple 'controlled properties' that the device will capture, enabling this data structure to work with the LOTUS sensor's multiple sensing capabilities. Figure 7 details this with a device containing an array of 18 controlled properties in one sensor unit.

🔻 🗏 0 = Object {id: "urn:ngsi-ld:Sensor:dolni okol test sensor_1", type: "https://uri.etsi.org/ngsi-ld/default-context/Sensor",
🚾 id = "urn:ngsi-ld:Sensor:dolni okol test sensor_1"
type = "https://uri.etsi.org/ngsi-ld/default-context/Sensor"
🕨 🗏 https://uri.etsi.org/ngsi-ld/name = Object {type: "Property", value: "dolni okol test sensor:1", metadata: }
🔻 🗏 https://uri.fiware.org/ns/data-models#controlledProperty = Object {type: "Property", value: , metadata: }
type = "Property"
🔻 🔚 value = Array(18)
0 = "https://uri.etsi.org/ngsi-ld/default-context/"pressure transmitter""
1 = "https://uri.fiware.org/ns/data-models#temperature"
2 = "https://uri.etsi.org/ngsi-ld/default-context/ammonium"
3 = "https://uri.etsi.org/ngsi-ld/default-context/chlorine"
4 = "https://uri.fiware.org/ns/data-models#pressure"
5 = "https://uri.fiware.org/ns/data-models#flowrate"
6 = "https://uri.fiware.org/ns/data-models#conductivity"
7 = "https://uri.fiware.org/ns/data-models#free chlorine"
8 = "https://uri.fiware.org/ns/data-models#ph"
9 = "https://uri.fiware.org/ns/data-models#iron"
10 = "https://uri.fiware.org/ns/data-models#arsenic"
11 = "https://uri.fiware.org/ns/data-models#nitrates"
12 = "https://uri.fiware.org/ns/data-models#pesticide"
13 = "https://uri.fiware.org/ns/data-models#fluoride"
14 = "https://uri.fiware.org/ns/data-models#turbidity"
15 = "https://uri.fiware.org/ns/data-models#hardness"
16 = "https://uri.fiware.org/ns/data-models#carbonate"
IT = "https://uri.fiware.org/ns/data-models#bicarbonate"
Ingth = 18

#### Figure 7. FIWARE device data structure showing multiple sensor data

In comparison, Figure 8, shows a device with a single sensor that captures pressure data, (<u>https://uri.fiware.org/ns/data-models#pressure</u>). This demonstrates the flexibility of the key-value pair approach to FIWARE's data format. It should also be noted that 'controlled properties' will contain key-value pairs that relate to data (and keys) that are relevant to their properties (sensors).





- 0 = Object {id: "urn:ngsi-ld:Device:003", type: "https://uri.fiware.org/ns/data-models#Device", https://uri.etsi.org/ngsi-ld/name: , https://uri.fiware.org/ns/data 

   id = "urn:ngsi-ld:Device:003"
  - type = "https://uri.fiware.org/ns/data-models#Device"
  - Https://uri.etsi.org/ngsi-ld/name = Object {type: "Property", value: "Isonzo Bridge sensor", metadata: }
  - ttps://uri.fiware.org/ns/data-models#controlledProperty = Object {type: "Property", value: "https://uri.fiware.org/ns/data-models#pressure", metadata: }

value = "https://uri.fiware.org/ns/data-models#pressure"

#### Figure 8. FIWARE device data structure showing single sensor data

This is particularly attractive for the LOTUS platform as it effectively builds the context broker around a single data structure, in that the interfaces to IoT will create data using this structure, context management will store is and context processing & visualisation will process and visualise using this structure.





# **6** Conclusions

This document has taken use case requirements (WP1 and WP6) and required tools (WP3 and WP4), detailed in Section 3, to create a conceptual architecture that follows the state-of-the-art (Section 4.1) guidelines.

Given that the majority of use cases are being realised through bespoke solutions, there is a limited role for the LOTUS platform. However, it will be realised for Use Case 4.

There is scope to use functional leak detection components for Use Case 1, 'water distribution network Guwahati', though this will be considered in depth in appropriate deliverables in WP4.





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