DESSIN

DEMONSTRATE ECOSYSTEM SERVICES ENABLING INNOVATION IN THE WATER SECTOR

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D22.2 ICT PLATFORM FOR DISTRIBUTED SEWER MINING (TECHNOLOGY)

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The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement no. 619039

D22.2: ICT PLATFORM FOR DISTRIBUTED SEWER MINING (TECHNOLOGY)

SUMMARY

Deliverable D22.2 is part of Task 22.1.2 and T22.1.3 of the DESSIN Project which is related to the Athens Demonstration: "Sewer Mining for Urban Reuse enabled by Advanced Monitoring Infrastructure". More specifically D22.2 summarizes the results of T22.1.2 "Development of the sewer-mining software (s/w) and hardware (h/w) platform" and T22.1.3 "Development of the Communication Solutions".

The actual deliverable D22.2 is a prototype that can not be electronically submitted to the EC services. Hence, it is accompanied by this report which focuses on the development of the sewer mining software and hardware platform and the development of the communication solutions, for collecting, processing and visualizing data of the field sensors installed at the packaged plant in KEREFYT, Sanitary Engineering Research and Development Center of EYDAP. The platform incorporates OGC standards, which enables interoperable data representation and alert rules, while the User Interface enables real-time access and display of the sensor data and alerts. The communication solution implemented, supports the need of local and remote control and monitoring of the field sensors installed. The implemented platform follows a modular architecture, which is adaptable, scalable and interoperable and provides the operator of the sewer mining packaged plant a user-friendly, secure and efficient interface for monitoring and control.

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List of Acronyms and Abbreviations

ICT	Information and Communication Technology
OGC	Open Geospatial Consortium
Wi-Fi	Wireless Fidelity
TCP	Transmission Control Protocol
GSM	Global System for Mobile Communications
GPRS	General Packet Radio Service
LAN	Local Area Network
MLSS	Mixed Liquor Suspended Solids
USB	Universal Serial Bus
PLC	Programmable Logic Controller
HMI	Human Machine Interface
OS	Operating System
SOS	Sensor Observation Service
SES	Sensor Event Service
ORM	Object-Relational Mapping
sensorML	Sensor Model Language
O&M	Observations and Measurements
XML	Extensible Markup Language
UI	User Interface

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Executive summary

Deliverable D22.2 reports the outcomes of the activities of Task 22.1.2 "Development of the sewer-mining software (s/w) and hardware (h/w) platform" and T22.2.3 "Development of the Communication Solutions" of DESSIN Project which is related to Athens Demonstration: Sewer Mining for Urban Reuse enabled by Advanced Monitoring Infrastructure. Although the deliverable type is "prototype", it was decided not to limit this accompanying report to describing only the prototype but to focus additionally on the following topics:

- Design Considerations
- HW and SW architecture
- Prototype description

First the user and system requirements of the ICT platform under development have been defined. In section 2 the System architecture details have been presented including a description of the system components both hardware and software. The software platform components have been analysed, describing the standards incorporated for sensor data representation and web-connectivity for real-time accessing, monitoring and processing of field sensor. Finally, the ICT infrastructure, the web platform and its prototype development have been presented.

1 Introduction

1.1 Objectives

The objective of the ICT platform presented is to enable the collection, processing and visualization of data from the field sensors installed at the packaged plant in KEREFYT. It aims to enable the seamless integration of field sensors using known standards and enable local and remote real-time monitoring and control, of the system.

1.2 Design Aspects: User/System Requirements

To meet the objectives of the communication platform under development, the design process followed an iterative and incremental approach aiming to meet the user and system requirements, eliminating the design complexity while being flexible and adaptable to changes and modifications.

First the sensor devices and sensor controller specifications have been studied with respect to their communication capabilities, available interfaces and connectivity options. The ICT infrastructure to be used so as to enable remote connectivity was investigated, taking into account the topology of the pilot site and field sensor installation, the communication link requirements and the cost of the solution to be used.

For the software design of the platform, open source implementations were considered, while for the data representation of the sensor data well known and recognized standards were investigated in order to support interoperability of the platform under development.

Feedback from the operator of the packaged sewer mining plant was collected in order to make the User Interface and the web platform user friendly, easy to use and adaptable to extensions and changes.

The User/System Requirements for the design and development of the ICT and SW platform are summarized in Table 1.

Table 1: User/System Requirements

Code	Name	Description
USREQ01	Real-time Data	Platform should enable Real-time data retrieval and display
USREQ02	Event Detection	Platform should enable events of interest to be detected and displayed
USREQ03	Alerts	Platform should be able to raise alerts
USREQ04	Alert configuration	Platform should be able to configure alerts based on predefined Rules (e.g. thresholds)
USREQ05	Sensor Configuration	Platform should allow to configure sensor parameters (insert, delete, edit)

USREQ06	Sensor Metadata	Platform should enable to display sensor metadata (e.g. location, time etc.)
USREQ07	Interoperability	Platform should be based on known standards enabling interoperability (e.g. OGC)
USREQ08	Remote Sensing	Platform should enable local and remote access and control
USREQ09	Low cost	ICT platform should rely on low cost solutions
USREQ10	Historical Data retrieval	Platform should allow to retrieve historical data (e.g. based on predefined date and time period)
USREQ11	Visual Display	Platform should enable visualization of the sensor data (e.g. different colour schemes and charts)
USREQ12	Reporting	Platform should enable the operator to extract reports in various formats (e.g. text, xls etc.)
USREQ13	Security	Platform must be secure (authentication, secure protocols, etc.)
USREQ14	Easy to use/Friendly UI	Platform must have responsive design which must be easy to use

2 System Architecture

2.1 System Architecture

The system architecture of the ICT platform is presented in Figure 1 and is composed of the following components:

- Sensor Controller installed at the water treatment unit
- Single board computer (microcontroller)
- Wi-Fi Access point
- DESSIN server
- DESSIN Web Platform
- PLC - HMI

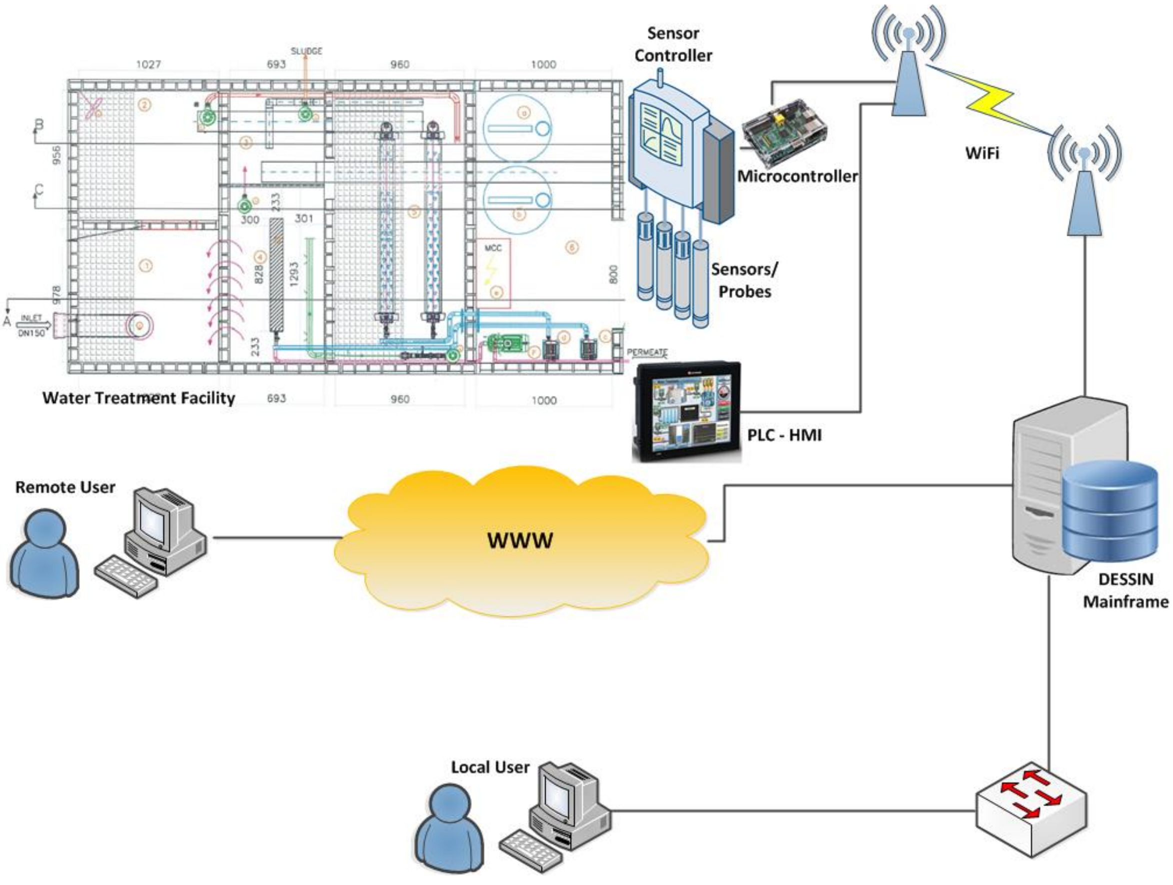

Figure 1: System Architecture

The following sections describe the different components of the system architecture.

As it will be described in section 2.1.5, the PLC – HMI is not part of the developed ICT platform and acts as a standalone system in the overall design framework.

2.1.1 Sensor Controller – Data Logger

The sensor controller sc1000 of Hach [1] consists of a Display Module and one or more Probe Modules. The sc1000 Display Module is intuitive, with an easy to use interface and large colour touch-screen display that can be used for any number of parameters. One Display Module controls one or several Probe Modules connected by a digital network. The Display Module is fully portable, and can be disconnected and moved anywhere within the network. The Display Module is also available with GSM/GPRS, Ethernet and TCP/IP capability.

The figure below illustrates Hach's SC1000 Controller.

Figure 2: Hach's SC1000 Display Module

Each sc1000 Probe Module provides power to the system and can accept up to 8 digital sensors/expansion boards. Probe Modules can be networked together to accommodate up to 32 digital sensors/expansion boards attached to the same network. The list of probes/sensors is presented in Table 2.

Table 2: List of probe modules/sensors

Sensor	Short Name	Location	Unit of Measurement	Hach Controller Device
DL0_S0	MLSS	Membrane Tank	mg/L	Solitax sc 1594970
DL0_S1	Turbidity	Permeate Tank – Inlet to RO	NTU	Solitax sc 1595089
DL0_S2_1	PH	RO Effluent	pH	PhD sc
DL0_S2_2	Temperature	RO Effluent	°C	PhD sc
DL0_S3_1	DO	Aeration Tank	mg/L	LDO 2

DL0_S3_2	Temperature	Aeration Tank	°C	LDO 2
DL0_S4	Conductivity	RO Effluent	mS/cm	Conductivity 34xx sc Prod RO
DL0_S5_1	Conductivity	Permeate Tank – Inlet to RO	mS/cm	Conductivity 3789-2 sc V2 Cond
DL0_S5_2	Temperature	Permeate Tank – Inlet to RO	°C	Conductivity 3789-2 sc V2 Cond
DL0_S6_1	Ammonium	Aeration Tank	mg/L	Anise
DL0_S6_2	Nitrate	Aeration Tank	mg/L	Anise
DL0_S6_3	Potassium	Aeration Tank	mg/L	Anise
DL0_S6_4	Chloride	Aeration Tank	mg/L	Anise
DL0_S6_5	Temperature	Aeration Tank	C	Anise
DL0_S7_1	Nitrate	Anoxic Tank	mg/L	Nise
DL0_S7_2	Chloride	Anoxic Tank	mg/L	Nise
DL0_S7_3	Temperature	Anoxic Tank	°C	Nise
DL0_S8_1	Conductivity	Inlet	mS/cm	Conductivity 34xx sc Prod UF
DL0_S8_2	Temperature	Inlet	°C	Conductivity 34xx sc Prod UF
DL0_S9_1	PH	Mebrane Tank	pH	pH sc PH RO
DL0_S9_1	Temperature	Mebrane Tank	°C	pH sc PH RO

2.1.2 Micro-controller Raspberry Pi

The Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer, monitor TV, electronic devices, industrial machines etc. and uses a standard keyboard and mouse. It's capable of doing everything you'd expect a desktop computer to do. It is a popular platform because it offers a complete Linux server in a tiny platform at very low cost and it enables developers to build systems and applications related to remote sensing and actuation, Internet of Things (IoT), monitoring, robotics etc. In our case it was the perfect solution for developing the remote sensing, monitoring and control capabilities of the platform.

The specifications of the Raspberry Pi used in our platform are summarized in Table 3

Table 3: Raspberry Pi Specifications

Components	Description
Chipset	Broadcom BCM2835.
Processor	ARM Cortex-A7 CPU
Graphic card	Broadcom Video Core IV. H GPU
Memory	1GB SDRAM
Maximum transfer speed USB2.0	60 MB/s
LAN	SMSC LAN9512
Memory Support	Micro-SD
Connectivity	4x USB 2.0, 1x HDMI (rev 1.3 & 1.4), 1x 10/100 BaseT Ethernet, 1x 3.5mm audio out jack, Composite video
Power supply	5V
OS support	GNU / Linux (Debian, Bodhi Linux, Fedora, Arch Linux), RISC OS, Plan 9
Dimensions	85,60 x 56 x 21mm

There are two interfaces used by the raspberry Pi:

- USB Wi-Fi adapter in order to enable connectivity to the local wireless LAN of EYDAP.
- RS485 USB adapter in order to enable connectivity to the sensor controller through Modbus Protocol. The communication with the controller and the access and retrieval of sensor data is achieved through this interface.

Fehler! Verweisquelle konnte nicht gefunden werden. Figure 3 illustrates the layout of single board computer, Raspberry Pi.

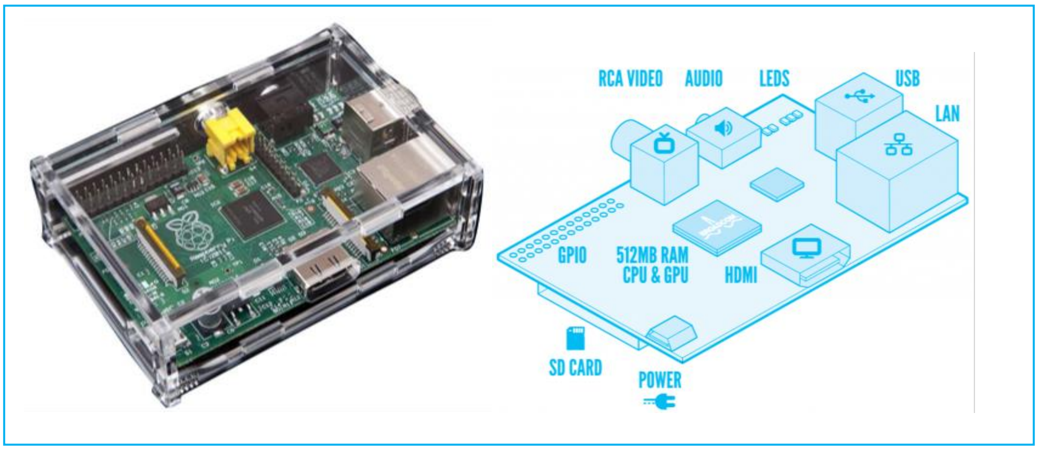

Figure 3 Raspberry Pi layout

2.1.3 Wi-Fi Access Point and Remote Access

The Wi-Fi access point is installed at EYDAP control room, which is at a distance of about 50m from the sewer mining packaged plant site. The Raspberry Pi is equipped with a Wi-Fi interface and is configured so as to connect to the wireless LAN of EYDAP. In addition, the router of EYDAP has been configured to port forward the IP of the Raspberry Pi so that it can be accessed remotely with Secure Shell (SSH) tunnelling or remote desktop.

Secure Shell, or SSH, is a cryptographic (encrypted) network protocol to allow remote login and other network services to operate securely over an unsecured network.

2.1.4 DESSIN Server

The DESSIN server is a desktop PC that hosts the DESSIN web platform and can be installed at any location since as it can be accessed either locally or remotely. The DESSIN server will be installed at EYDAP control center.

2.1.5 PLC System: HMI and Software

For completeness of the report and as part of the overall system of the packaged treatment unit, the Programmable Logic Controller (PLC) module and its Human Machine Interface (HMI) is presented. The details of the various treatment processes and their configuration have been presented in Deliverable D34.1 “An Optimal Configuration Small Packaged Plant for Urban Sewer Mining”.

It has to be noted that the industrial PLC and the system of valves, flow meters and pumps are not part of the implemented and presented ICT platform. For better usability of the packaged plant unit, the PLC controlled system has been implemented as a standalone system. Nevertheless, due to the open interfaces employed, the modularity and interoperability features of the communication and software architecture of the ICT platform, it can be seamless integrated with any industrial system such as the PLC.

The Unitronics V1210 PLC comprise a built-in operating panel containing a 12.1” Color Touchscreen [2].

Figure 4: Unitronics PLC+HMI Vision1210

The Vision1210 can support 24 auto-tuned PID loops to control temperature, level, and pressure. It has onboard I/O and expansion modules. It can support digital I/O types (including shaft-encoder inputs & PWM outputs) and analogue I/O. Communication options include TCP/IP Ethernet, cellular, and industrial protocols such as MODBUS through RS232/RS485 interface card.

The Unitronics offers free software that enables the operator to use a PC and work with a remote controller's (PLC) HMI panel. The SW connects remotely to the PLC's HMI through EYDAP's Wi-Fi networks. A screenshot of the actual HMI is depicted in Figure 5. The PLC can work in "Auto Mode" and "Manual Mode".

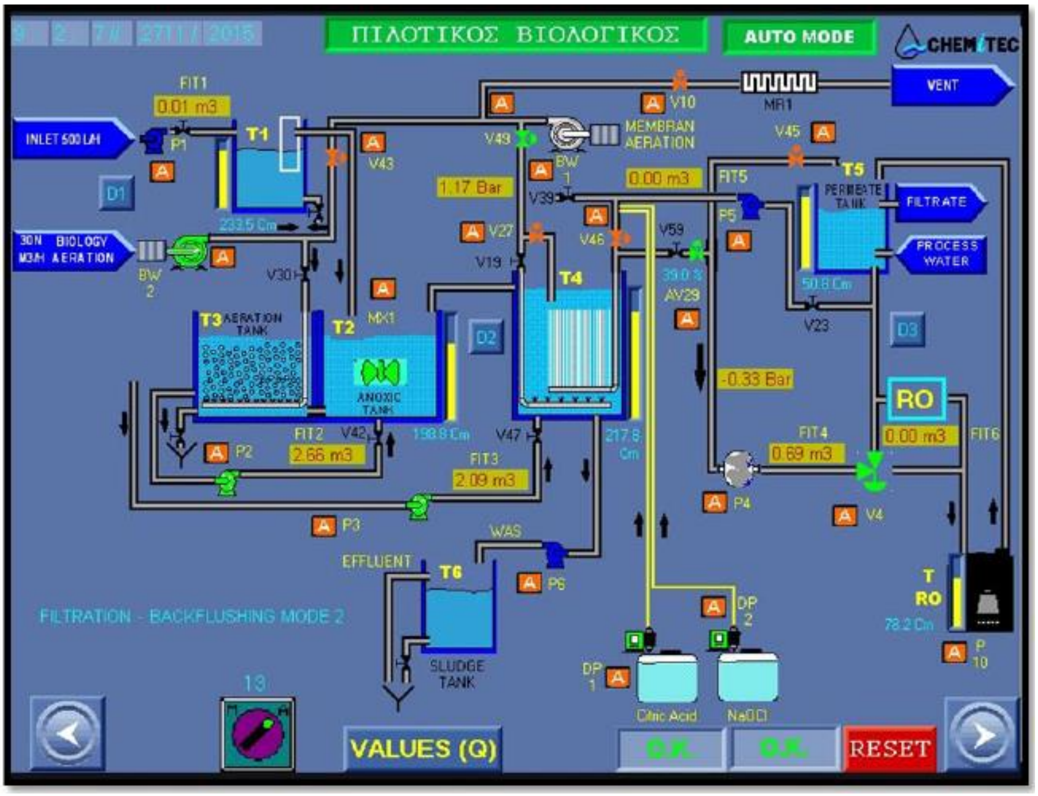

Figure 5: PLC/HMI Remote Access Screen

The basic functions of the PLC are listed below:

- Change from "Manual Mode" to "Auto Mode"
- Control and modification of supplies (VALUES Q) by setting minimum and maximum flow transmitter values
- Monitoring of alarms/alerts generated by the PLC
- Monitoring of tank level
- Monitoring of mixers and blowers and control of timers
- Monitoring and control of pumps, valves and flow meters
- Monitoring and control of pressure transmitters
- Control of "Cleaning in Place" function

2.2 Software Platform Architecture

The functional architecture of the software platform is depicted in Figure 6.

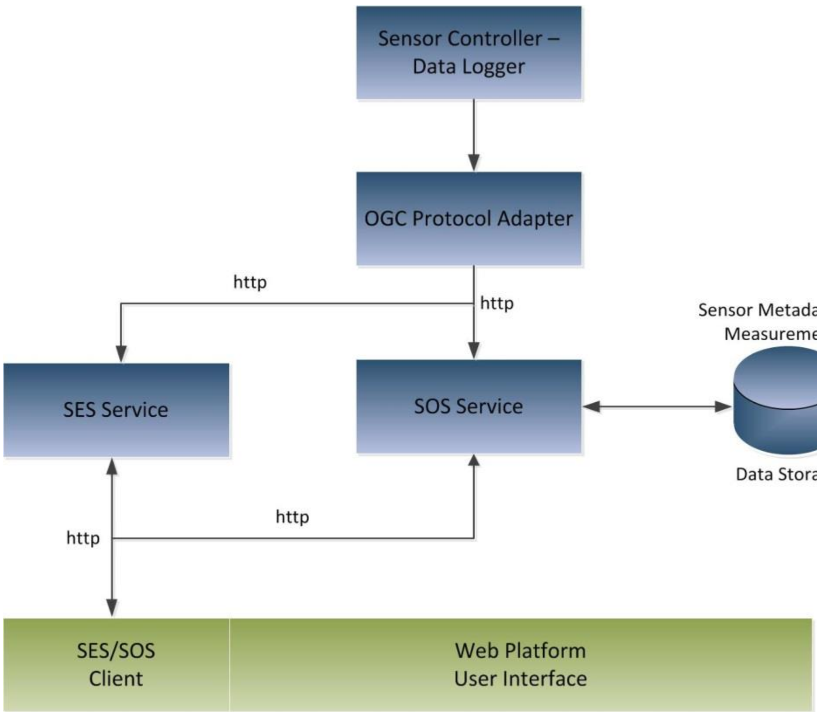

Figure 6: Software Platform Architecture

The architecture has been elaborated and modified throughout the development process in order to incorporate interoperability features, real-time monitoring capabilities, remote access, web-connectivity and a user friendly interface. After several iterations and design approaches the final software platform architecture and its components were defined.

The functional blocks of the SW architecture are summarized below:

- Open Geospatial Consortium (OGC) protocol adapter

- Sensor Event Service (SES)
- Sensor Observation Service (SOS)
- Data Storage
- SES/SOS Client
- Web Platform User Interface

OGC, the Open Geospatial Consortium is an international not for profit organization committed to making quality open standards for the global geospatial community [3]. The OGC's Sensor Web Enablement (SWE) standards enable developers to make all types of sensors, transducers and sensor data repositories discoverable, accessible and useable via the Web [4]. The SWE standards that have been incorporated in the SW platform design are the following:

- Observations & Measurements (O&M) –The general models and XML encodings for observations and measurements.
- Sensor Model Language (SensorML) – Standard models and XML Schema for describing the processes within sensor and observation processing systems.
- Sensor Observation Service (SOS) – Open interface for a web service to obtain observations and sensor and platform descriptions from one or more sensors.
- Sensor Event Service (SES), which is an enhancement of the Sensor Alert Service (SAS); currently available as an OGC discussion paper

Modbus interface card is available at the Sensor Controller/Data Logger. Modbus is a serial request/reply communication protocol mainly used for industrial applications and devices. It serves as an application layer messaging protocol for client/server communication between devices connected on different types of buses or networks [5].

The conformance of the designed software architecture to the aforementioned OGC SWE standards, provide reusability, scalability and extensibility. It furthermore enables the seamless integration with additional sensors and sensor system that might be of interest (e.g. meteorological sensors, actuators, alarm systems etc.). Therefore, the proposed software framework supports information interoperability of different sensors (independent of the type and the measurements they provide), hides the complexity of the physical layer communication protocols that may be custom or vendor specific, and stimulates the development of new and novel web based remote sensing applications. This is achieved by representing sensor data in a standard format (sensorML standard), by modelling the sensor data (observations and measurements) in a standard way (O&M standard), and by making the sensor data/events (SOS standard) and sensor alerts (SES standard) accessible in a standardized way over the web.

In the following sections the components of the SW platform are described.

2.2.1 OGC Protocol Adapter

OGC Protocol Adapter is responsible for the communication with the Data Logger through the serial MODBUS Protocol and gets the measurements for each available sensor on the system. In addition, the adapter has to translate the measurements to the O&M standard and sent it to the SOS service. Moreover, the adapter has to filter the measurements and if they exceeded the minimum or the maximum threshold given from the end-user, has to generate an alarm and sent it to the SES service.

The OGC protocol adapter communicates over HTTP with the SOS service and SES service described below.

2.2.2 SOS service

Sensor Observation Service (SOS) [6] Module is an aggregator service module that allows any authorized client to access (read/write) live sensor data, historical data as well as sensor metadata through a web service call. It is, in other words, a web service that allows the querying from / inserting to the database of real time or time-series sensor observations. Data can be selected based on time range, sensor type, geographical and network topological location.

2.2.3 SES service

Sensor Event Service (SES) [7] module provides a publish/subscribe based access to alerts within the sensor network. The goal of the Sensor Event Service is to deliver notifications that match the filter criteria defined by subscribers to the notification endpoints defined for a subscription. Since it is a publish/subscribe service, it creates different topics so the consumer does not have to receive unwanted alerts.

2.2.4 Data Storage

Hibernate open source persistent framework is an Object-Relational Mapping (ORM) solution for JAVA [8]. It is concerned with data persistence as it applies to relational databases (RDBMS), allowing application's data to outlive the applications process. It provides RDBMS vendor independence and transparent solution by hiding underlying tables from Java classes using XML files to map classes with tables. Hibernate frame-work decouples SOS service module from a specific RDBMS solution, providing excellent stability and quality, allowing the usage of SOS service module using the existing database infrastructure.

2.2.5 Sensor Data Representation Layer

2.2.5.1 OGC Standards

Open Geospatial Consortium (OGC) standards represent an evolutionary, standards-based framework that enables seamless integration of a variety of online geo-processing and location services. They provide a vendor-neutral, interoperable framework for web-based discovery, access, integration, analysis, exploitation and visualization of multiple online geodata sources, sensor-derived information, and geo-processing capabilities.

2.2.5.2 SensorML

The primary focus of the Sensor Model Language (SensorML) is to provide a robust and semantically-tied means of defining processes and processing components associated with the measurement and post-measurement transformation of observations [9]. This includes sensors and actuators as well as computational processes applied pre- and post-measurement. The main objective is to enable interoperability, first at the syntactic level and later at the semantic level (by using ontologies and semantic mediation), so that sensors and processes can be better understood by machines, utilized automatically in complex workflows, and easily shared between intelligent sensor web nodes.

2.2.5.3 O&M

This standard specifies an XML implementation for the OGC and ISO Observations and Measurements (O&M) conceptual model, including a schema for Sampling Features [10]. This encoding is an essential dependency for the OGC Sensor Observation Service (SOS) Interface Standard. More specifically, this standard defines XML schemas for observations, and for features involved in sampling when making observations. These provide document models for the exchange of information describing observation acts and their results, both within and between different scientific and technical communities.

2.2.6 SOS/SES client

Clients interfaces with functions that can communicate with SOS/SES services and able parse the OGC XML messages. In the below diagram (Figure 7) it is described the overview of the SOS/SES Client system. The system communicates over HTTP with the SOS and SES service interfaces. The Data Fusion Engine receives data from SOS/SES Interfaces in SensorML format, analyse and transform them to web format (JSON) and send the data through SOS/SES Web interfaces to the Web Platform/Dashboard.

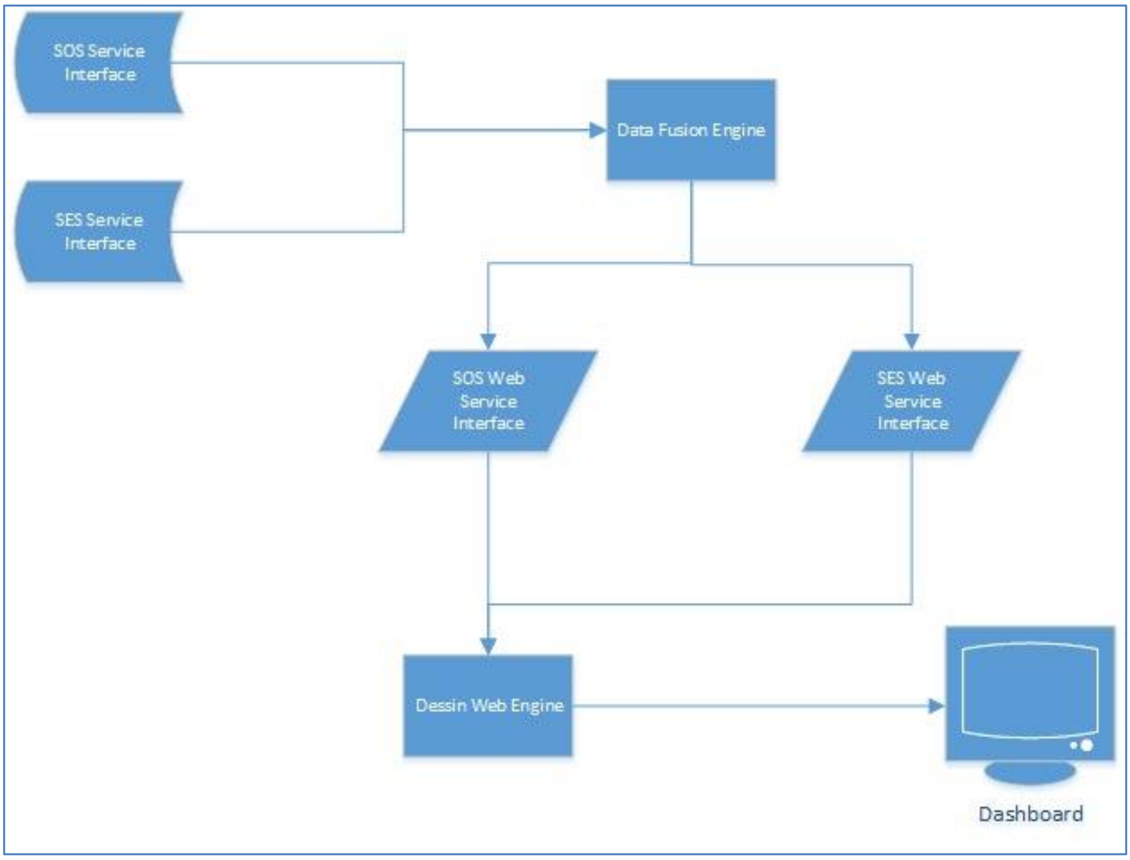

Figure 7: SOS/SES Client System Overview

2.2.7 Web platform (Dashboard)

The DESSIN Web Platform is a user friendly, responsive platform for monitoring and administering of small packaged plants for urban sewer mining. It is a secured platform, using OAuth2 authentication mechanisms [11], allowing user control, i.e. access to advanced platform functionality (adding/deleting/configuring sensors) to authorized personnel, while providing monitoring functionality to other users.

It collects the data (dummy data were initially used) from the SOS Web Interface offering real-time and historical monitoring of the water features/characteristics provided by the sensors (i.e. turbidity, pH, temperature, conductivity, BOD, etc.).

The platform allows the operator to select particular points/locations from the various locations of the tank, which embody specific sensors measuring specific water qualities. Measurements are displayed in the form of gauges and graphs through a Graphical User Interface.

The selected data can be exported in various data formats/files. By using the integrated historical functionality (date and time options) of the platform, operators can compose comparisons and reach important conclusions, regarding the cleaning cycles of the sewer mining system.

In Figure 8, the User workflow of the Dashboard is provided, showing the aforementioned description.

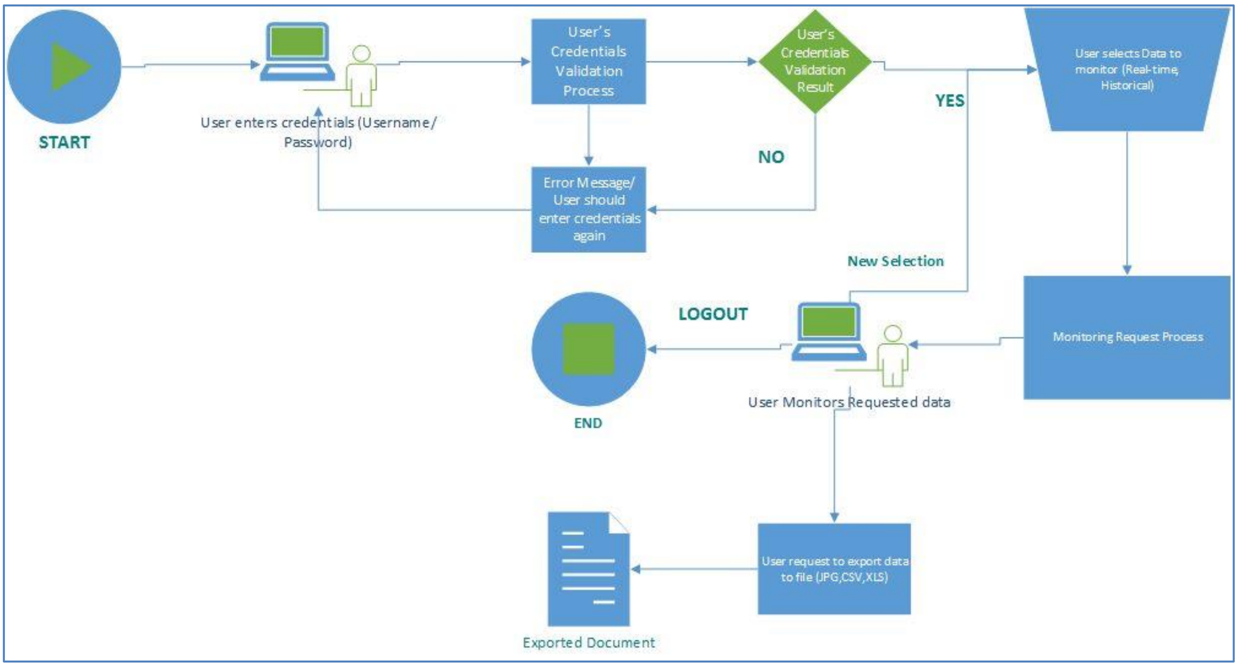

Figure 8: User Workflow

An embedded real-time alerting capability allows for the configuration of operator-defined event alerts and notifications. When the Data Fusion Engine receives (in real-time) a new event/alert from the SES Interface, it sends the web-transformed event to the Web Engine, showing to the Operator of the Dashboard the message of the alert/event (time, sensor name, description/action).

3 Prototype

The following pictures and figures illustrate the pilot site of the water treatment unit at KEREFYT (EYDAP premises in Athens), the hardware components and interfaces of the ICT platform as well as screenshots from the prototype monitoring web platform.

Figure 9 and Figure 10 illustrate the Athens KEREFYT pilot site where the water treatment unit and the control centre are located.

Figure 9: Athens KEREFYT Pilot Site - 1

Figure 10: Athens KEREFYT Pilot Site – 2 (Overview)

Figure 11 depicts the interior of the sensor controller including the Modbus RS485 card.

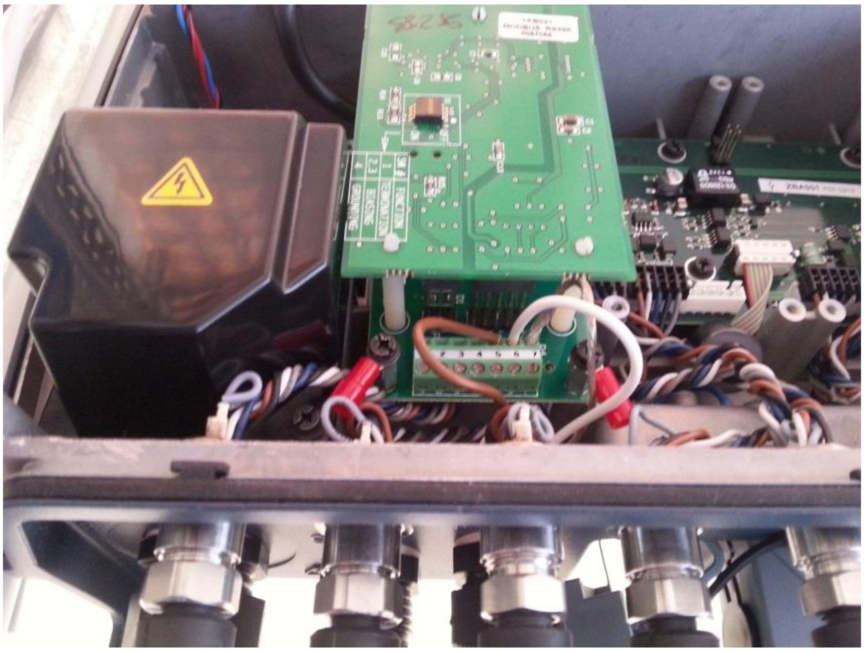

Figure 11: Sensor Controller/Data Logger

In Figure 12 the USB to RS485 adapter is shown, that connects the Modbus RS485 card with the Raspberry Pi.

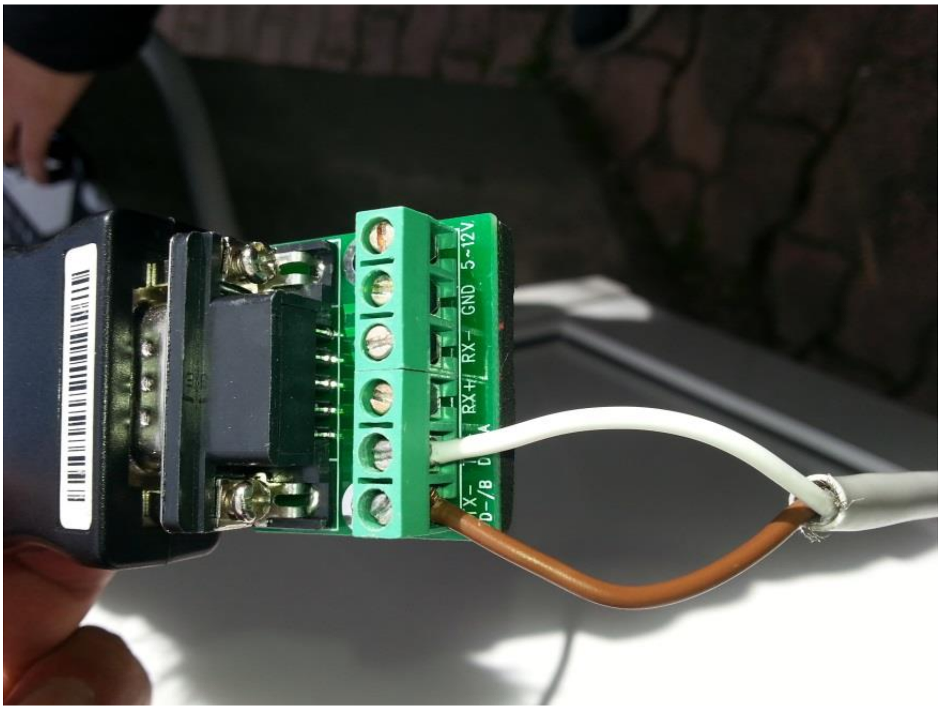

Figure 12: RS485 to USB Adapter

Figure 13 shows the overall connectivity of the Raspberry Pi through the USB to RS485 adapter with the Modbus RS485 card of the sensor controller.

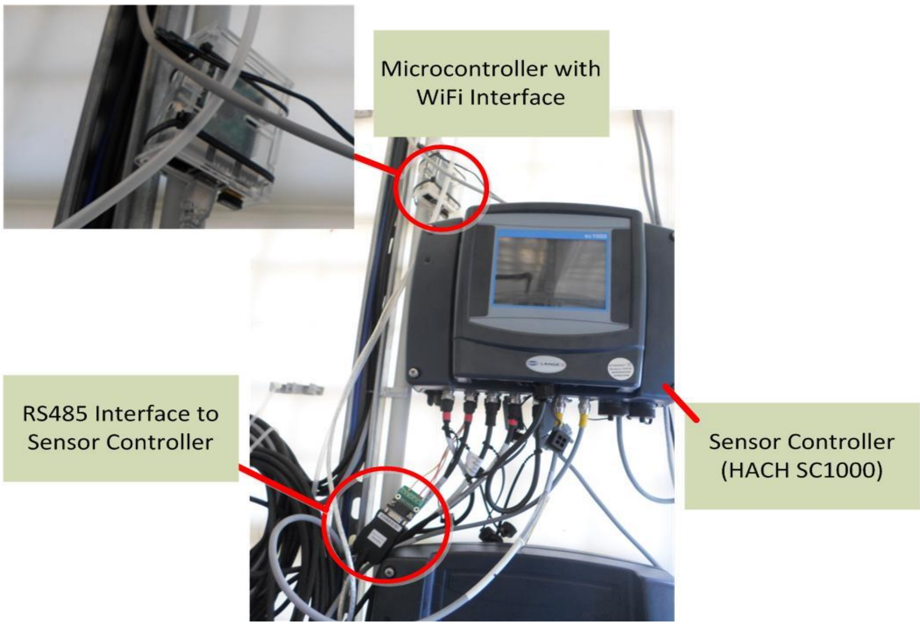

Figure 13: Sensor Controller Connectivity

In Figure 14 the installed PLC/HMI of the water treatment unit is illustrated.

Figure 14: PLC HMI Installation at KEREFYT Pilot Site

The login screen of the user interface of the developed platform is depicted in Figure 15.

Figure 15: Web Platform UI Login Screen

In Figure 16 the live data dashboard screen of the developed platform is depicted. The user can select the sensor data to be displayed, while the alarms and alerts (including an alert text) of the respective sensors are illustrated.

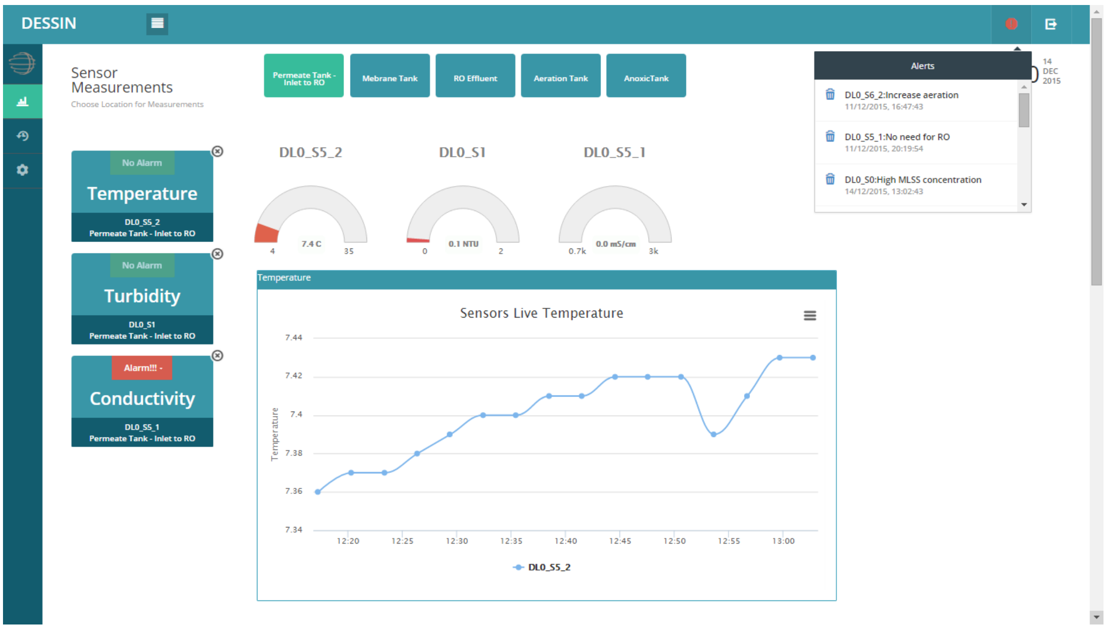

Figure 16: Web Platform UI Live Data Dashboard Screen

Figure 17 illustrates the historical data dashboard screen. The user can filter and select sensor data to be displayed for a specific time period (in the example from 12th to 18th of December).

Figure 17: Web Platform UI Historical Data Dashboard Screen

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[4] http://www.opengeospatial.org/ogc/markets-technologies/swe

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[8] http://hibernate.org/

[9] http://www.opengeospatial.org/standards/sensorml

[10] http://www.opengeospatial.org/standards/om

[11] http://oauth.net/2/

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