# INTEGRATION OF WSN USED IN LIFE SCIENCE AUTOMATION

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***Abstract.*** **Over the last years Wireless Sensor Networks (WSN) became more and more applicable for real world scenarios and now production ready solutions are available. In the same period the upcoming combination of Service-oriented Architectures and Web Service technology demonstrated a way to realize open standardized, flexible, service component based, loosely coupled and interoperable cross domain Enterprise Software solutions. But those solutions have been too heavy weighted to be suitable for limited devices like wireless sensor nodes and embedded systems. Thus, more and more research investigations have been launched to bring the aspect of cross domain interoperability to the field of embedded battery powered devices. Now it is time to show the potential of integrating Web Services enabled WSN solutions in Enterprise systems. The proposed laboratory assistance solution in this paper demonstrates the benefits of Web Service enabled WSNs for process monitoring and disaster management by extending an existing system in the Life Science Automation domain.**

***Keywords*****: Devices Profile for Web Services, Disaster Management, Laboratory Information Management System, Life Science Automation, Sensor Web Enablement, Sensor Observation Service, Service-oriented Architecture, Web Services**

## I. INTRODUCTION

In the domain of Life Science Automation (LSA) the experimental setups, laboratories and appliances, needed for complex automated chemical and/or biological screening analysis typically consists of closed proprietary and highly specialized solutions. These solutions are mainly configured to obtain a high throughput and satisfy the required environmental constraints for the experiments. Such closed process chains are especially designed to solve characteristic classes of analysis problems with high efficiency. The available integrated sensors/actors are wired and have fixed positions at the laboratory appliances. This makes it a hard challenge to extend or adapt them dynamically without high efforts. Using wireless sensors instead offers the needed flexibility. However, today´s wireless sensor nodes are not equipped with sensors needed in life sciences, e.g. CO and $H_2$. In this paper we introduce wireless sensor nodes addressing the needs of life sciences.

Another important challenge relies on the handling and usability of those appliances for non-technical employees. The typical scientist, who utilizes the laboratory for the experiments, is not skilled enough on the technical domain to setup, reconfigure, maintain or extend the existing workflow.

The integration of Wireless Sensor Networks (WSNs) in enterprise systems will be the right way for the future to realize a flexible and extendable system to overcome these above mentioned deficiencies. Web Service technology has a great potential to support a seamless integration of wireless sensor networks and to achieve an advanced applicability. Moreover, especially the benefits for usability and abstraction of a technical system providing services will be focused by our presented work.

An existing web based Laboratory Information Management System (LIMS) at the CELISCA laboratories and the corresponding appliances are extended with the WSN. The extension points to the LIMS are illustrated in Figure I-1. The LIMS controls the workflow (control logic) of an existing analysis process chain and supports the evaluation of data measured. We will show, that the WSN based service infrastructure, developed in this work, increases the flexibility, extensibility and usability of a given wired laboratory setup. Furthermore, we provide new interaction concepts for system control, setup and configuration.

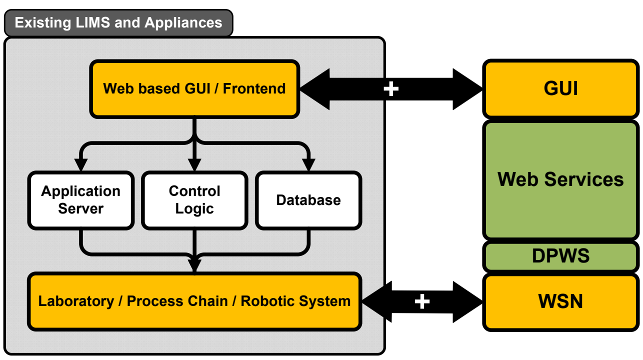


**Figure I-1: WSN extension for the existing LIMS**

This paper is organized as follows. In section II we briefly review WSN technology, service-infrastructures, and technologies for disaster management. In section III we give an overview of the developed system, based on DPWS and SWE middleware, to realize disaster prevention system for LSA. In Section IV we describe user interaction with wireless sensor network. We emphasize our Laboratory Assistance WSN and its innovations, at different levels of abstraction with a detailed overview, due to our integration and deployment concepts and details about the hardware of WSN. Finally the article ends with a conclusion.

## II. State of the Art

In this work, different components were combined to a new flexible WSN system including data capturing, storage, presentation and use of domain specific data in LSA. Therefore, this section shortly reviews the most important related work concerning wireless sensor networks (WSN), Service oriented Architectures and management of disasters or incidences.

### A. *Wireless Sensor Networks*

Recent technological advances enabled the development of tiny wireless devices which are referred to as Wireless Sensor Nodes. Those devices usually consist of a number of physical sensors, gathering environmental data like temperature or light, a microcontroller, processing the data, and a radio interface to communicate with other nodes. These devices are typically battery driven to allow autonomous work and wireless deployment. Figure II-1 shows a schematic illustration of a sensor node. The included sensors for $H_2$ and CO are not a typical part of such devices and represent our extensions to fit the need of the LSA domain.

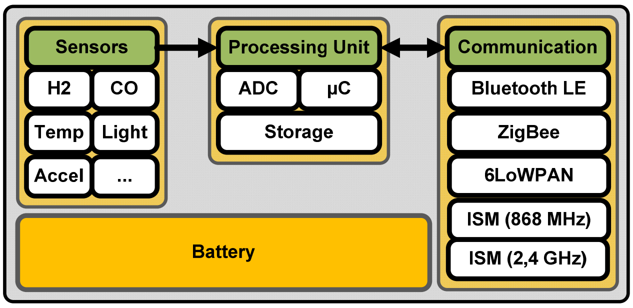


**Figure II-1: Schematic of a typical WSN node**

Wireless Sensor Networks are interconnected assemblies of such devices [1]. In recent years, much work has been done on the various aspects of the wireless sensor networks, especially on the communication level and has result in standardized communication interfaces, like ZigBee, Bluetooth Low Energy, 6LoWPAN, Wireless HART, and SP100. However, developing wireless sensor nodes with low powered sensors measuring typical gazes which are used in life sciences has been left out. We have developed wireless sensor nodes which can measure carbon monoxide (CO) and hydrogen ($H_2$), two very dangerous gazes. In the industrial domains WSNs become more and more attractive due to its flexibility, sizing dimensions and ease of use [2,3,4,5,6,7,8]. The main focus relies on process control and monitoring applications. In contrast to traditional wired sensors, WSN nodes can be easily placed, as close as possible to the process, without costly wiring and in combining those with actuators, reactions to measurement events can be initiated immediately. This work especially covers the benefits of WSN applications for the industrial domain of LSA.

### B. *Service oriented Architecture*

Over the last years Service-oriented Architectures (SOA) tried to renew Enterprise Software Systems in a flexible, open standardized, interoperable and component based manner. The preferred implementation technology for SOA is the Web Service approach [9].

But the heavy weighted first generation of upcoming standard technologies were not suitable for mobile and limited embedded devices like wireless sensor nodes. Thus, more and more research investigations were launched to bring the aspect of cross domain interoperability to the field of embedded battery powered devices [10,11,12]. The results were combined in the Devices Profile for Web Services (DPWS) [13], which represents the official OASIS standard for the seamless integration of embedded mobile systems into the Web Service concepts. In the domain of sensor applications the Open Geospatial Consortium (OGC) founded the initiative for Sensor Web Enablement (SWE) and released a collection of open standards [14]. These standards realize the high level management of sensor data and networks, accessible via Web Service technologies. Especially the Sensor Observation Service (SOS) is highly relevant for our research investigations [15].

Our solution builds up on the above mentioned standards to realize the interoperable device connectivity and the management of sensor data.

### C. *Managing Disasters and Incidences*

Most commonly disaster management is used as a synonym for emergency management. It deals with natural and human based disasters, like earth quakes or explosions. The four phases of emergency management are mitigation, preparedness, response and recovery [16]. The aim of mitigation is to prevent hazards from developing into disasters. Preparedness is to develop plans how to react on disasters. The response phase includes mobilization and coordination of emergency services, e.g. police and ambulance. Recovery treats restoring of affected areas and infrastructures. An actual example of an emergency management system (EMS) is SAHANA [17]. It impressively shows that a main purpose of EMS is to deal with a kind of resource management, planning and coordination in the case of present disasters. Another project, dealing with that topic, called SoKNOS, is further described in [18].

In contrast to the above mentioned description for disaster management, the solution of this paper focuses on the mitigation phase. The goal is to detect incidences and hazards as soon as possible to prevent disasters in observed LSA environment to ensure a correct analysis procedure. Therefore an observation service has been implemented, which analyses actual sensor readings to initiate alarm chains and react on abnormal environmental parameters.

## III. SYSTEM OVERVIEW

The following section includes an overview of our WSN infrastructure, summarizes the basic architecture and gives detailed descriptions of the used hardware, service components, workflow and the WSN itself. The core components of the solution are illustrated in the architecture overview of Figure III-1.

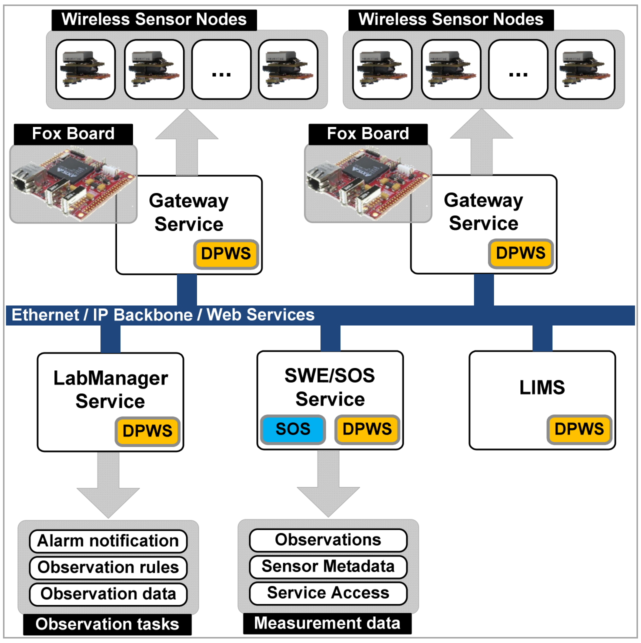


**Figure III-1: Schematic architectural overview**

### A. Hardware

The required hardware for our WSN infrastructure consists of the wireless sensor nodes itself and a gateway to enable service based interaction with the WSN. Both elements are optimized for energy aware processing.

***Wireless Sensor Nodes:*** The wireless sensor nodes have to fit requirements like high robustness, autonomous acting, small sizing dimensions and a long battery life. To meet these requirements we build up a WSN node based on the eZ430-RF2480 platform for wireless communication [19], via ZigBee technology, from Texas Instrument and extended this platform with the needed modules for additional measuring, communication and energy supply capabilities. To meet the special requirements in LSA, the needed sensor add-ons for measuring phenomena like temperature, gas concentrations (CO and $H_2$), light intensity, battery voltage and vibration were integrated. Thus, the WSN node can be integrated in typical data capturing scenarios of the LSA domain. The gas sensors are based on the electro-chemical measurement principal. This avoids the necessity for active heating and only a small current is needed, depending on the gas concentration. The following Figure III-2 shows the resulting WSN node in combination with different sensor modules.

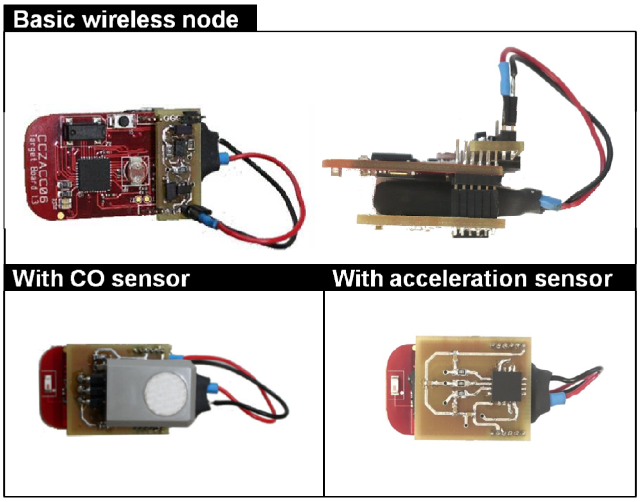


**Figure III-2: The customized WSN node**

This WSN node has a sizing dimension of 38 x 38 x 48 $mm^3$. The energy source of the node consists of an internal lithium-polymer accumulator. Through an integrated mini-USB connection this accumulator can be recharged. To configure or update the software of a wireless sensor node, the ZigBee or the mini-USB interface can be utilized.

***WSN Gateway:*** The Fox Board LX832 [20], produced by Acme Systems, is a compact embedded Linux server system and represents the service gateway for the WSN nodes in our solution. This board is suited with integrated interfaces for USB 1.1, Ethernet 10/100, IDE and RS232. For the WSN nodes this gateway represents the collector for their measured observation data. A sensor node registers at the gateway via ZigBee and this will make the measurement data available for the upper service instances by serving them through defined interfaces.

### B. Service Components

The implemented service components of our WSN infrastructure represent the core concept for an easy self organized integration and deployment by abstracting the hardware and connection details through devices services.

***LabManager:*** This service component represents the core of the disaster prevention and the process monitoring. It includes a service for notification events, a rule engine for the process observation and the needed functionalities to interact with the other basic system service components. The LabManager runs observation tasks, which were configured via the LabAssistant component, and is able to perform several of those tasks in parallel. An observation task consists of the following configuration subset:

- A set of observations which represents the abstract WSN measurement data and delivers the input parameter for the observation rules.
- A set of observation rules which describes system reactions triggered by the input of the WSN observation data. Each rule contains threshold levels and regions, the input data has to meet.
- A set of notification events (SMS, Mail, Beep or combined alarm action) that will be triggered if a

violation of the corresponding observation rule takes place.

The behavior of the LabManager Service is comparable to a specialized workflow engine, which has multiple inputs and controls the firing of alarm events. The requests for sensor observations will be done via a combination of Service Discovery and Publish/Subsribe mechanism, included in the SWE/SOS Service and the Gateway Service. The realization of the Web Service connectivity was implemented using the AXIS2 engine of the Apache Software Foundation [21].

***SWE/SOS Service:*** This service component provides the sensor measurement data of the heterogeneous WSN combined with additional metadata through a standardized Web Service interface as WSN observation offerings. The used SOS server is based on a reference implementation of the 52°North initiative and to avoid the complicated generating/parsing of XML requests, the corresponding OX Framework is used to access and configure the SOS Services [22]. Figure III-3 illustrates exemplary for the SOS Assistant GUI the function of this OX Framework. The OX Framework offers a simplified access to SOS server via method calls. The input parameters for these methods will be send as JSON formatted set over HTTP. Defining new sensor observations and the SWE/SOS Service configuration will be realized via the SOS Assistant web frontend.

The SOS Service includes three core functionalities to request all metadata about the SOS Service and its offerings, the specified observation data and the corresponding metadata, and to get detailed information about the specified sensor, which provides the observation data. Additional transactional operations enable the registration of new sensors and insertion of new observations.

***Gateway Services:*** The Fox Board Gateway is abstracted through Web Services, implemented using the DPWS technology stack WS4D-gSOAP [23]. These services enable WSN nodes to dynamically discover and connect to the gateway, forward the WSN observation data to the SWE/SOS Service, discover sensors, register new sensor nodes, request locally stored sensor data and let other services subscribe for defined WSN observation events. Several Fox Board gateways and its services can run in parallel to provide a scalable and reliable access to the WSN, without concurrent behavior.

### *C. LabAssistent and SOS Assistant*

The LabAssistant is a web based frontend to configure the WSN, the Gateway and the LabManager Service. It is realized as fat client web application using the AJAX technology of the open source Google Web Toolkit (GWT) and its support for Remote Procedure Calls [24]. Additionally, the assistant guides a user through the integration and deployment process of the WSN.

The SOS Assistant is similar to the LabAssistant. It provides a web based frontend to configure the SWE/SOS Service of our solution. This includes the management of sensors, observations and the graphical illustration of observation requests/data.

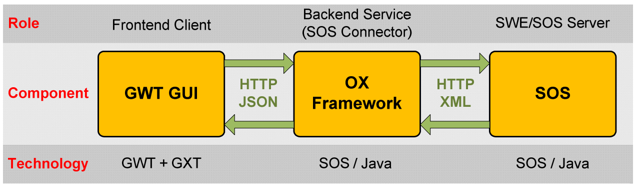


**Figure III-3: Components of Graphical User Interface**

### *D. Resume*

The above presented hardware and software components combined with the capabilities for defined service-oriented orchestration and collaboration of devices, fits best to create a flexible WSN infrastructure and provides an innovative way to extend existing wired systems with the beneficial features of WSNs. Especially the ease of use, interoperable service interaction and the self organizing discovery features make our solution very flexible. The architecture and implementation of the existing LIMS have been not affected by our WSN infrastructure. The next section emphasizes the deployment and integration aspects of our disaster prevention, with a concentrated focus on the interaction of the user with our solution.

## IV. INTEGRATION & DEPLOYMENT

The deployment and integration strategy of our laboratory assistance solution raises the functionality, flexibility and usability of the existing LIMS system to a new level, results in cost efficient workflow turnarounds and reduces setup times. Especially the usability advantage for non-technical skilled users is a real innovation of our solution. The user now handles services of the WSN and is able to place the sensors where he needs them for his experiment. Without our WSN infrastructure the user had to be or to call a specialist, if changes in the appliances of the experiment had to be made. Especially when changing the wired sensors in their positions or measurement services. They have to be rewired, tested or recalibrated, and their new services had to be implemented. With our solution the user is able to change the hardware, replace or relocate sensors, without the need to change the software or anything else, because the setup of an experiment is bound to services of the WSN and not to the sensor hardware itself. This makes it possible to work with components-of-the-shelf WSN nodes suited with defined sensors. Figure IV-1 shows the typical steps to deploy and integrate the WSN infrastructure.

Setting up a new WSN deployment for an experiment becomes a simple procedure. Before creating a new experiment, the sensors have to be placed/plugged at the laboratory appliances and the existing sensors must be checked out. The wireless sensor nodes register themselves and their observation offerings at the Gateway Service nearest to them (step 1 to 3).

The user initiates a new experiment via the LabAssistant and creates the needed observation tasks for the process monitoring. These tasks will be suited with the necessary observation rules and the corresponding input parameter from the previously installed sensor observations. Each rule violation will be bound to a specific notification. The available observation offerings of the WSN nodes will be discovered automatically by the LabManager and the user has to pick the right ones from a list to assign them to the observation rules. If different sensor data should be combined to new observations, the user is able to create those combinations through the SOS Assistant. Assigning sensor observations to an experiment includes an automated subscription of the LabManager for observation events at the SWE/SOS or Gateway Service (step 4 to 9).

After the successful deployment procedure the experiment will be started and runs now with our integrated disaster prevention. While the experiment runs external applications are able to request the corresponding observation time series via the Web Service interface of the SOS server. When the experiment ends the WSN nodes will be picked up by the user and recharged at a charge station. The complete observation data is stored in an SOS server database and will be served through a Web Service for the post data processing. The existing LIMS runs in parallel to our solution and is not affected (step 10 to 16).

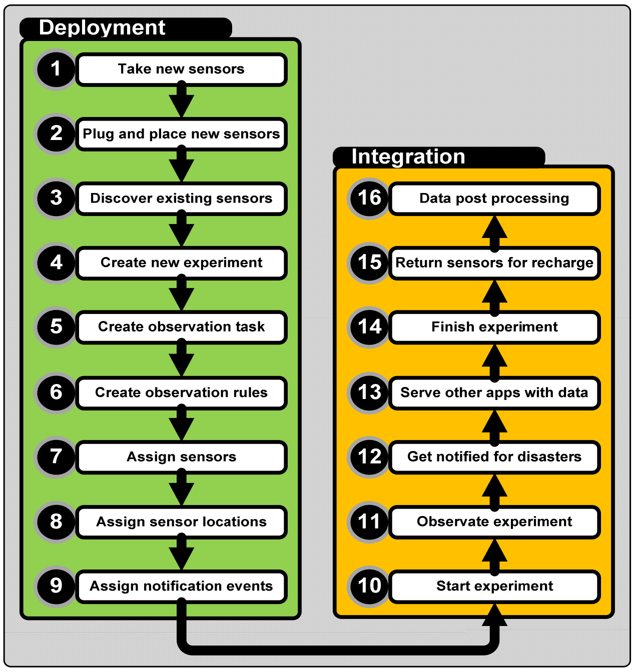


**Figure IV-1: Deployment and Integration flow**

## V. CONCLUSION AND FUTURE WORK

In this paper we have presented a SOA to integrate wireless sensor networks into an existing laboratory information management system (LIMS). The architecture uses DPWS based Web Services for the collaboration and orchestration of devices, abstracted as service instances. Thus, a decoupling of the hardware and higher functionalities were reached, with the additional benefit of a higher usability and flexibility. Furthermore, the functionality of SWE/SOS is now available to the Life Science Automation domain, which is very beneficial, because measurement data will be handled on a higher level and new combinations of different sensor data can be easily created. Using a WSN in the presented application ensures flexibility necessary to construct future Life Science Laboratories. Using information from WSN in an easy way inside today's application is very challenging and this will be supported by our services over different layers.

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