Autonomous Control of Large-scale Water Treatment Plants based on Self-Organized Wireless BioMEM Sensor and Actuator Networks

HYDROBIONETS is developing the world's first real-time, wireless micro-biological control system for water treatment and desalination plants, providing the fundamental design principles, signal processing and communication algorithms, and the implementation of a Wireless BioMEM Network (WBN) with distributed multi-sensing and multi-actuation capabilities, demonstrating the ability to detect and avoid bacteria biofilm formation in membranes, as well as the increased productivity and energy efficiency of these industrial plants.

Key Innovation

The HYDROBIONETS project focuses on the research and development of Self-Organized Wireless BioMEM Networks (WBNs) and their integration in a global system to monitor the complete water cycle in large-scale water treatment and desalination plants. The key feature is the integration of BioMEM sensors and actuators in motes and the adaptation of the network function to the specific requirements that this type of application imposes. The WBNs will achieve the distributed monitoring of critical parameters, representing a novel instrument that can be successfully applied in the short-term to the challenge of dense wireless networked control of microbiological parameters of water in the different stages of process in these plants. A demonstration system will be installed and tested in a pilot-scale desalination plant. A world-class interdisciplinary team formed by materials, sensors, microsystems, communications, signal processing, control and networking experts, as well as end-users, has been assembled to investigate, develop and validate the WBNs. This is a novel and ambitious approach in the field of microbiological water monitoring and control where several different disciplines converge.

Measurable Goals

- Prediction and avoidance of membrane bio-fouling
- Increased productivity of the plant and reduction in operating costs
- Improved management of the industrial plant in general
- Improved data access and visualization of the various plant processes

Sensing Motes

Three-dimensional interdigitated sensors integrated in silicon have been developed that are able to monitor the presence and growth of bacteria in different locations of a desalination plant. The sensors are mounted in a custom-designed flow cell specifically tailored for the plant conditions in terms of pressure, temperature, flow, etc.

The sensor and flow cell combination is mounted on a platform (mote) which includes the sensor readout electronics, calibrant solution, fluidic control valves and wireless communication. These sensor motes have been placed at various important locations within the pilot plant.

At A Glance

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EC contribution:

2,350,000 Euro

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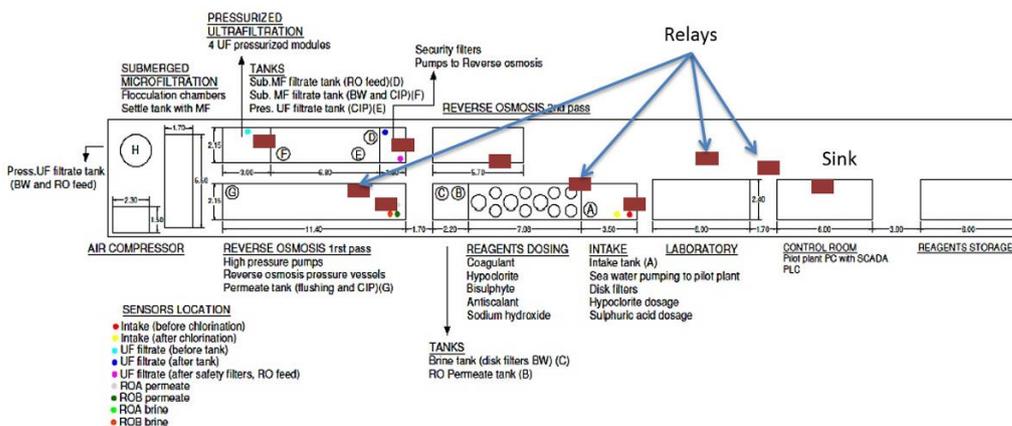1st October 2011

Duration:

39 months

Wireless BioMEM Network (WBN)

The work that has been completed on the WBN includes the following:

- Design and development of the HYDROBIONETS network platform, a 3-tier network for biofilm data acquisition and remote configuration of the BioMEM sensor nodes, including energy efficient and resilient medium access and routing protocols
- Extensive field studies for capturing and analysing the performance of multi-hop WBN topologies in RF-harsh environments (rural, industrial), totalling more than 750,000 instances of end-to-end network traffic
- Synthesis and evaluation of feature selection techniques for characterizing the holistic performance of WBN multi-hop topologies in both rural and industrial environments
- Formulation and testing of WBN Distributed Data Collection protocols capable of reconstructing smooth spatio-temporal fields from a limited number of randomly collected measurements
- Design and validation of efficient WBN Distributed Data Storage mechanisms that minimize storage and communications requirements without limiting the data retrieval capabilities
- Development of Distributed Link Quality Estimation architectures, offering critical and up-to-date information for the efficient multi-hop aggregation of the sensed measurements to centralized processing units
- Design and validation of cross-layer protocols for efficient distributed in-network estimation and detection tasks
- Design of an integrated uncertainty-aware high-level data management and analysis (U-HDMA) system
- Development of an uncertainty-aware early warning engine supporting fast pairwise sensor correlation monitoring
- Integration of sensor data with metadata and static information from the plant for improving the early warning and early response to certain events in the industrial plants, as well as for modelling the behaviour of the various parameters
- Design of a flexible and versatile visualization platform for monitoring the HYDROBIONETS infrastructure

Project Partners

Universidad de Valencia (Spain)

CSIC-CNM (Spain)

FORTH-ICS (Greece)

KTH (Sweden)

ATEKNEA (Hungary)

Acciona Agua (Spain)

iXscient (UK)

Demonstration and Use

HYDROBIONETS has performed a practical deployment and demonstration of the HYDROBIONETS system working under real conditions in one of Acciona's pilot-scale desalination plants at La Tordera, Spain. The aim is to provide several tangible improvements in the functioning of the plant such as: an increase in reverse osmosis (RO) membrane lifetime due to early detection of bio-fouling; improved optimization of biocide and cleaning agent doses for RO membrane cleaning and recovery; more efficient disinfection stages in the process and an improvement in the assessment of the efficiency of pre-treatment stages before the membranes. Overall, this will lead to increased productivity and lower operating costs. The WBN will monitor the bio-fouling potential of the seawater at the inlet, as well as at the different pre-treatments steps, and most importantly, before the RO membranes. Moreover, the dosing of biocides, such as chlorine, used for disinfection, will be also controlled in a dynamic and proactive way. The schematic and photo below show the positioning of the sensor motes in the pilot plant.