BEMO-COFRA
Brazil-Europe Monitoring and Control Frameworks

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Issue #4 - Published by the BEMO-COFRA Project – February, 2014

The BEMO-COFRA project bids farewell

This 4th and final newsletter marks the end of the BEMO-COFRA project. It has been an exciting 30 months where for the first time European and Brazilian organisations worked together on a research project enabled by the first EU-Brazil call under the 7th Framework Programme.

BEMO-COFRA has brought universities, research institutions and private companies from Europe and Brazil together in a unique partnership. It has been challenging and very rewarding working together and sharing knowledge across large geographic distances and cultural borders. All partners agree that the project has been a success in many ways: its visions and aims have been achieved and new European-Brazilian partnerships and opportunities have been formed. While Telcos were used frequently as a tool to work closely together, several personal meetings and workshops were of course also held in both Brazil and Europe. These meetings gave partners another unique opportunity to gain an insight into cultural and professional ways; something which was enjoyed on both the professional and the social level.

A future with more cooperation across the Atlantic already looks promising for both academia and industry. The project consortium is committed to continuing the dissemination and exploitation of the results of BEMO-COFRA. Some of the partners from BEMO-COFRA have for instance already joined forces again by participating, along with new European and Brazilian partners, in a new research project called IMPRESS funded by the second EU-Brazil call.

The BEMO-COFRA project has worked steadily towards its aims and objectives throughout its 30 months lifetime. During the final months of the project, the results from each technical work package were brought together to present the final result: The BEMO-COFRA platform. Simultaneously, the non-technical development work packages, WP1, WP2, and WP8, were responsible for managing, disseminating and exploiting the project's progress and results as they came to reality. The following articles present an insight into the many activities and achievements of the project's research and development work.

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Large scale distributed system architecture

The overall aim of WP3 is to define the system architecture which would subsequently direct the design and implementation work undertaken in the other technical work packages.

As a first step in WP3, a study was made of the existing devices and standards adopted in the automotive industry and of the integration of robotics and sensor networks with wireless networks. This research allowed BEMO-COFRA partners to make an informed choice on the type of network to use in order to achieve the desired flexibility of the BEMO-COFRA solution. Also, having a precise description of existing devices and sensors was necessary in order to envision how BEMO-COFRA could develop the integration of robotics and sensor networks.

Research was also done on how to handle sensors controlled by embedded platforms such as Arduinos while accessed as Web Services through the LinkSmart platform. At the same time, based on the envisaged scenario, the requirements related to the architecture specification were defined and analysed. To further support this work, a visit was arranged to the FIAT Factory in Betim, Brazil. This visit proved very informative and inspired the BEMO-COFRA partners to visualise ways of improving the existing technologies used in a manufacturing plant. At the end of the first year, the preliminary architecture was defined and presented as part of the first year demo prototype.

In the second year of the project, several refinements were introduced to the preliminary architecture through careful analysis and discussion with other project partners. The key improvements included the

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Disseminination Events

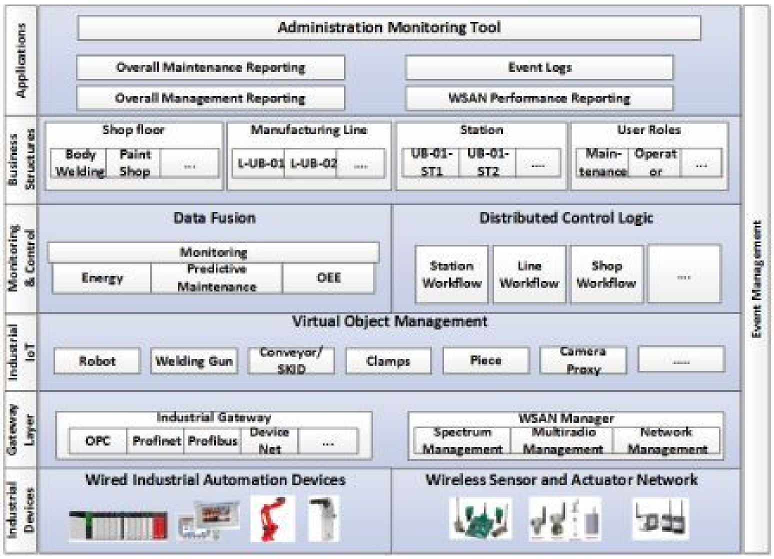
Cyber-Physical Systems: Uplifting Europe's innovation capacity
October 29-30, 2013, Brussels, Belgium.
The BEMO-COFRA project was presented at the event Cyber-Physical Systems: Uplifting Europe's innovation capacity. The objective of the event was to bring together key actors in EU research and innovation to discuss strategies and stimulate community building in the area of Cyber-Physical Systems. The event was organised by EC - DG CONNECT, ARTEMIS & Steinbeis-Europa-Zentrum.

ARTEMIS IA Co-summit 2013
December 4-5, 2013, Stockholm, Sweden
Exhibition and presentation of BEMO-COFRA at the ARTEMIS IA Co-summit 2013 exhibition in Stockholm, Sweden. The BEMO-COFRA stand attracted a lot of people interested in learning more about the project. The Co-summit – organised by ARTEMIS Joint Undertaking on embedded systems and ITEA, the EUREKA Cluster on software-intensive systems and services – was featuring international keynote speakers, a high level panel discussion and an inspiring project exhibition including speakers' corners fuelled by the project teams themselves. This year's theme for this high level event was: Software innovation: boosting high-tech employment and industry. The Co-summit had about 650-700 participants from industry, academia, public authorities and press from all over Europe.

Deliverables released:

introduction of a business intelligence layer to ensure the interoperability across different devices and ecosystems interacting with BEMO-COFRA Systems and refinements of the functional view that shows which functional components interact with each other.

The BEMO-COFRA platform is proposed as service-oriented, consisting of five loosely coupled core layers and their respective components. As shown in the figure below, each of the layers and their components are responsible for their respective part of the overall functionality.



The final activity in WP3 has focused on re-evaluating the results reported in the deliverable *D3.3 Traffic Modelling for the Floor* with a much bigger industrial trace, in order to characterize traffic models for the shop floor.

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Large Scale Wireless Sensors and Actuator

WP4 analyses dependability and scalability issues that still hinder wide adoption of WSANs for monitoring and control large scale complex systems.

The first activities in WP4 included an initial analysis related to the definition of dependability features in network-embedded systems such as WSANs. A list of dependability features to be addressed in single-radio WSANs was defined. These activities were followed by an investigation of the concept of multi-radio networks in order to be able to introduce multi-radio communication capability into the dependable WSAN which would ensure higher degree of availability, reliability, and robustness for manufacturing process monitoring applications. Another main achievement was the definition of the specifications of the network management protocol for the required set of WSAN parameters and resources.

At the beginning of the second year of the project, WP4 could demonstrate a pre-final stage of the dependable single-radio WSAN prototype, featuring context-awareness and dynamic channel allocation capabilities, where the WSAN demonstrated the ability to detect interference on the operating channel and reallocate the network to the best available channel. Moreover, the WSAN implements an initial set of network management features.

The next step focused on developing the dependable multi-radio WSAN prototype by first designing the overall multi-radio system architecture, and subsequently by defining all the enabling system functionalities, mechanisms, and interactions. During this development, dependability mechanisms from the single-radio WSAN were partially adapted to the multi-radio scenario, while other more sophisticated methods were introduced to enable multi-radio based operations.

Other results achieved during the beginning of the second year included enabling the management tool for WSANs to retrieve a subset of the WSAN nodes static parameters, and particularly information related to the node sensing application and reporting interval. The second year ended with work having been carried out to test, validate and implement the different components of the dependable multi-radio WSAN and preparing and planning for the integration with other partners' components.

Year 3 started off with an integration meeting in Germany. The integration of the dependable multi-radio WSAN prototype was performed which included:

• Integration of the multi-radio WSAN infrastructure with the WSAN Gateway that enables the context-awareness features. Communication was successfully established, then tests and validation activities of the different messages and functions were performed

• Finalising the multi-radio WSAN network management layout, based on SNMP, and initial integration between an SNMP Agent on the network side and the SNMP Manager on the Gateway side was accomplished

• Definition of the final layout for the large-scale multi-radio WSAN.

A selection of deliverables recently completed:

- D2.5 Final Validation Report of the Platform (Public)
- D4.3 WSAN Network Management (Public)
- D5.2.2 Final administration too (Public)
- D5.3.2 Final LinkSmart-enabled environment (Public)
- D6.4 Software interfaces for controlling production devices/equipment (Confidential)
- D6.5 Production Monitoring and Control Platform (Restricted)
- D7.1 Report on application development (Public)
- D7.2 Final Industrial Test Site Assessment (Restricted)
- WD7.2 Final Industrial Test Site Assessment (Restricted)
- D8.2.2 Dissemination Report II (Public)
- D8.3 Report on Innovation Transfer Activities (Public)

Public deliverables can be downloaded from the project website after they have been reviewed and approved by the EC:
www.bemo-cofra.eu

SEVENTH FRAMEWORK PROGRAMME

CNPq
Conselho Nacional de Desenvolvimento Científico e Tecnológico

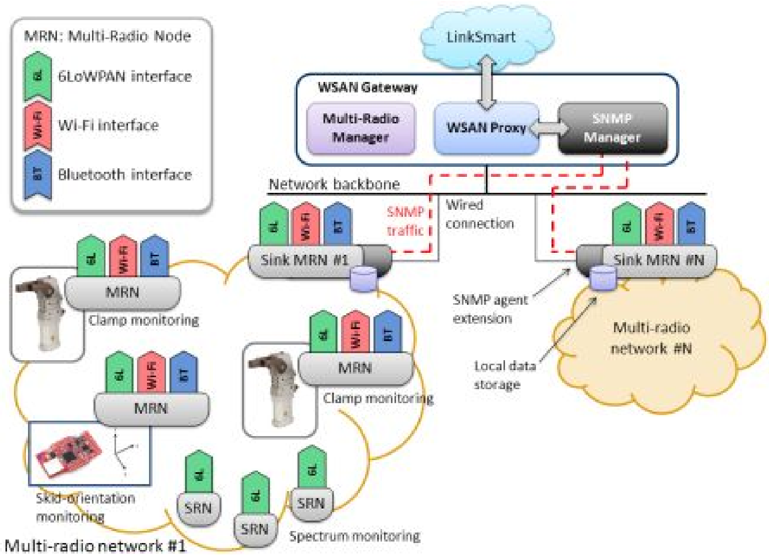
The BEMO-COFRA project is a 30-months EU-Brazil cooperative research project which started in 2011. The project is partly funded by the European Commission under the 7th Framework Programme in the area of EU-Brazil Research and Development cooperation under Grant Agreement no. 288133. The Brazilian funding is provided by CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico.

Read more at:
www.bemo-cofra.eu

Later on, ISMB and VTT finalised the development of the network management tool and integrated the different components. Moreover, GUIs were developed to allow the user to perform control actions on WSAN resources and display network topology, spectrum occupancy, real-time and long-term monitoring, and WSAN packet losses and delays.

The final activities in WP4 were focused on the expansion of the dependability and network management features to support operations in large-scale networks.

The final prototype demonstrates a large-scale multi-radio WSAN, providing dependable monitoring of manufacturing processes, and providing the user with monitoring and control capabilities as depicted in the figure below:



Multi-radio WSAN architecture for manufacturing, integrated into LinkSmart environment.

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Distributed Control Logic and Enabling Features

WP5 is concerned with the distributed control logic and enabling features, i.e., with developing the monitoring and control tool for WSANs and the LinkSmart-enabled monitoring and control infrastructure.

The activities in WP5 during the first year focused on analysing the current control logic of the framing station in the car manufacturing plant. The analysis was used to define the design of the LinkSmart application that will be the high-level representation of the complete control logic orchestrating the WSN and PLC resources of the framing station. In addition, two surveys were produced: one on available tools for network monitoring of 6LowPAN and another on potential implementation platforms for the tool. Based on these surveys it was decided to utilize SNMP where possible and to create a web-based and Android version of the tool. Another task undertaken in the first year was an investigation of the interfacing with existing resources of the framing station. As a result, we discovered that it was possible to use an OPC server to communicate with the PLC environment, even though this would require the implementation of support for the OPC 2.0.5 currently used in the framing station.

During the first quarter of the project's second year work in WP5 concentrated on integrating all the components from WP5. The control logic for the demo was designed, implemented and tested before it was integrated into the local PLC. The initial version of the monitoring tool was developed and implemented with the cross-platform environment Unity3D. Versions on mobile phone and tablet were included in the first year demo in September 2012. LinkSmart proxies were developed for the PLC and Arduinos in the first year demo.

The work continued with a study of the State-of-the-Art of Event Discrete Systems and Supervisory Control which also included a study of how to develop and deploy the control logic for WSANs. A model of the plant and specifications to define the supervisory controller were created, as was the modular control logic for the final demonstrator. Subsequently, the implementation into the final demonstrator began. The work to create the control logic included: an events table, asynchronous plants, specifications, reduced supervisors and the control architecture. At the same time, work on the following tasks began: SNMP wrapper for monitoring and control protocol of WP4, planning of updated GUI, trace debugging functionality, and user-friendly reporting of monitored data. Finally, interfaces for the Final LinkSmart enabled environments were implemented by the end of year 2.

The final tasks in WP5 have focused on the implementation of the modular control logic for the PLC and on ontology driven virtual objects and service wrapper to create LinkSmart objects. A network administration tool for the wireless sensor and actuator network was created using the SNP-based protocol developed in WP4.

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Production Monitoring and Control Systems

WP6 addresses the integration of the different system components developed in WP3, WP4, and WP5 into a unified production monitoring and control environment, leveraging on the LinkSmart middleware.

The first steps in WP6 focused on the initial requirements analysis and the specification of the architecture. Moreover, an investigation of query languages for the sensor fusion module was carried out as was an investigation of algorithms to be used for sensor fusion (fusion of continuous-valued sensor measurements using confidence-weighted averaging). Also sensors from the production environment were selected and integrated into WSANs. As the first year was coming to an end, several results had already been achieved, including:

- Device storage management functionality to facilitate data fusion over large data sets.
- Data fusion engine, first experimental prototype using XSL-T
- Control mechanisms to allow for easy and configurable control of the manufacturing process.
- First prototype Contiki UDP-based proxy for wireless sensor nodes
- First robot proxy prototype
- First PLC proxy prototype
- Integration of following components using LinkSmart:
    - o Robot
    - o Pressure sensor
    - o Camera
    - o Accelerometer.

Finally, in relation to task 6.5 “Integration of overall Production Monitoring and Control Framework”, a first desktop demo was ready by the end of year 1.

Year 2 began with an investigation of Service-Oriented Control Architectures that focused on the control interfaces. Initial steps were made with respect to the integration of the WSAN with the overall system. This included completing various tasks such as implementing a clamp monitoring application on WSAN nodes, in order to enable a WSAN node to detect whether a clamp is locked or unlocked, and provide state confirmation events, and implementing a skid orientation monitoring application on WSAN nodes, allowing a WSAN node mounted on the skid, to monitor the skid orientation by means of accelerometer readings. Asynchronous warnings are generated whenever the skid is not correctly oriented.

Tests were carried out to assess the accuracy of events obtained from sensing of different production processes and responsiveness of the system. Several investigations related to data fusion of heterogeneous monitoring of data were conducted, e.g. on the ontology for distributed domain modelling, on SPARQL, on ontology modelling tools (Protégé, TopBraid), on using Drools rule language for context reasoning, on model driven development using ontology engineering and SysML and finally on sensor fusion for RFID based on the EPC Global standard.

In connection with the first year demo, WP6 carried out software and hardware integration of the wireless camera, the WSAN, and of the Robot, Skid & Grippers. The Network Manager and Event Manager was put inside the camera (with a Linux Distribution) to enable the C# client to publish events inside the camera. Since the Network Manager requires the installation of Java and the Event Manager is written in C#, a MONO distribution was employed to compile a C# solution and generate the binary code. Also, the illumination and position parameters of the camera were examined. Finally, the demo integration was tested and bugs were fixed.

After the first year review, work continued and more results were achieved. The monitoring functionalities (e.g., skid orientation, clamp status) for Contiki-based single-radio WSAN were specified and the WSN integrated platform (reported in the deliverable D6.2 WSN integrated platform) was implemented. During the second half of year 2, the prototyping tools for sensor application were developed and the first prototype of the data fusion engine was completed. By the end of year 2, several investigations had been carried out. These included state-of-the-art approaches for querying data base and report generation using natural language, HTML5 based mobile interface for plant monitoring, device discovery with semantic backend, and Service-oriented control Architecture, WSAN control and programming. In addition, the PLC proxy was developed, the communication between OPC and Link Smart was detailed, and the first specification of control interfaces was finalised.

During the final months of the project, efforts were spent improving the communication performance of the integrated WSANs within the overall system. Next, WSANs were integrated with production environment and industrial devices. Finally, the test-bed for context awareness and sensor fusion was prepared and the components developed in WP4 and WP5 were integrated into the BEMO-COFRA platform to provide production monitoring and control system with monitoring and control data.

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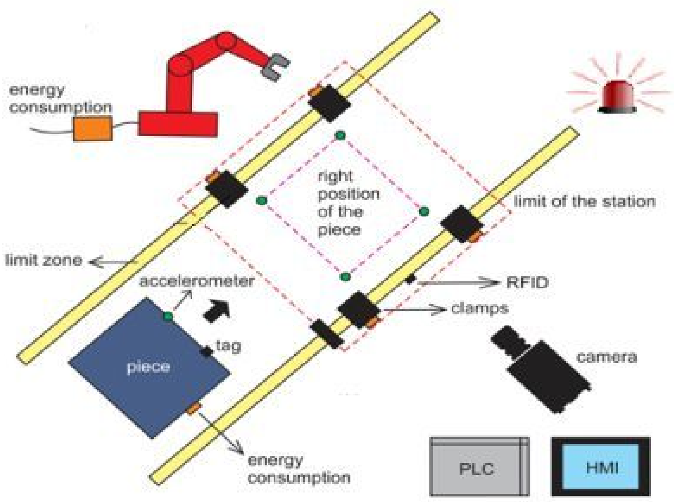
Solution Integration and Deployment

WP7 aims to demonstrate the functionality of the monitoring systems framework developed in the project in a real industrial environment.

This work package started its activities in the second year of the project (M13) by adding more detail to the defined scenario, thereby improving its usefulness for the future test demo. Particularl attention was given to defining which existing devices could be replaced with wireless devices. It was also decided that the final demo and validation should focus on three key requirements, namely, re-configurability, monitoring and control, and raw materials measurement.

The scenario was discussed in more detail during a consortium meeting in Belo Horizonte, Brazil, in March 2013 where the consortium also visited the FIAT factory in order to gain further insight into the harsh environment the BEMO-COFRA platform must be adapted to. This led to a deeper analysis of the final scenario which will be demonstrated and validated in the test bed provided by COMAU. The demo will simulate the welding process in a car manufacturing plant, thus demonstrating how the car body moves to a specific position where a robot performs welding tasks. The welding station in the demo will deal with two different pieces, (e.g. sunroof and regular roof), which will be produced at the welding station. The goal is to enable the welding station to produce two different pieces without a previous production plan, thereby allowing for a very flexible and simple production process according to demand. During this process, wireless sensors, cameras, accelerometers, etc., will collect data such as energy consumption. By the end of year 2, the planning of the final demo and test bed were coming to an end and all key devices that will be used in the demo had been identified. The figure below illustrates the final demo scenario.



During the final months of the project, WP7 activities continued to focus on setting up the test bed for the final demonstration and validation of the BEMO-COFRA platform. Final integration work was carried out as nodes were integrated into electronic devices and into dummy sensors.

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Published Papers

The BEMO-COFRA project has had five scientific papers published and presented at large international conferences. The conferences have represented unique opportunities for disseminating the project's achievements.

In this article we briefly present the papers that have been published and presented at different conferences related to the work carried out in the project. Full abstracts and download links are available at the project website.

Model Driven Development for Internet of Things Application Development

This paper present an architectural view for the Internet of Things prototype development that emphasizes the separation of domain modelling from technological implementations. Using the provided model driven tool, domain experts are able to construct domain models by composing virtual objects and link them to the specific technologies.

The paper was produced and presented by FIT at the 5th International Conference on Software Engineering and Knowledge Engineering (SEKE 2013).

Prototyping the Internet of Things for the future factory using a SOA-based middleware and reliable WSNs

In this paper, we describe a SOA-based middleware to integrate Internet-of-Things technologies in industrial setups. The middleware allows a seamless horizontal integration among heterogeneous technologies and vertical integration with applications and business systems.

This paper was produced by FIT and ISMB and presented by ISMB at the IEEE 18th Conference on Emerging Technologies & Factory Automation (ETFA 2013).

Underlying Connectivity Mechanisms for Multi-Radio Wireless Sensor and Actuator Networks

This work proposes mechanisms enabling connectivity in multi-radio wireless sensor and actuator networks, namely: network discovery, interface/channel switching, and connection-loss recovery. The considered mechanisms are optimized with the aim to maximize the availability of system services (minimize network down-time) and achieve an increased overall robustness.

This paper was produced and presented by ISMB at the IEEE 9th International Conference on Wireless and Mobile Computing, Networking and CommunicationsLink (WiMob 2013).

A channel monitor for emergency wireless networks

This work describes the design and development of a radio spectrum analysis tool for monitoring the spectrum occupied by a wireless system operating in the unlicensed 2.4 GHz ISM frequency band. Based on the open GNU radio library, the tool makes use of a USRP (Universal Software Radio Peripheral) generic hardware.

This paper was produced and presented by UFPE at the IEEE Consumer Communication & Networking Conference 2014 (IEEE CCNC 2014).

Building an emergency network with off-the-shelf devices

We describe in this paper two approaches for the integration of GSM, VoIP and PTT services. This underlying heterogeneous network aims to provide a reliable communication system robust enough to be used in an emergency situation.

Paper produced and presented by UFPE at the IEEE Consumer Communication & Networking Conference 2014 (IEEE CCNC 2014).

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