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Integrated system for control and monitoring industrial wireless networks for labor risk prevention

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ABSTRACT

The FASyS (Absolutely Safe and Healthy Factory) project, aligned with the European Factories of the Future (FoF) concept, has been set-up to develop a new factory model aimed at minimizing the risks to the worker's health and safety, and guarantee their welfare and comfort in machining, handling and assembly factories. To this aim, ICT (Information and Communication Technologies) and wireless communication technologies in particular may represent very valuable tools to implement distributed and mobile sensing applications capable to continuously sense the working environment and the workers' health and safety conditions. The effective deployment of such applications in critical environments, like the industrial one, require the availability of a platform capable to monitor the operation and performance of the heterogeneous wireless networks that will connect the mobile sensors to remote control centers. This paper presents the platform implemented for this purpose in the context of the FASyS project. In addition to monitoring the status of heterogeneous wireless networks, the implemented platform provides the capability to reconfigure remotely the communication settings of wireless nodes based on possible malfunctioning or QoS degradation notifications. These functionalities will help guaranteeing the reliable and robust wireless communications required in industrial environments to implement innovative labor risk prevention applications exploiting ICT technologies.

1. Introduction

Safety technologies for industrial environments have evolved considerably in recent years, but there are still risks related to the worker's safety and health. In this context, the European Factories of the Future (European Commission Ad-hoc Industrial Advisory Group, 2010) concept focuses on the development and integration of engineering technologies, ICT, and advanced materials for adaptable machines and industrial processes. In this new framework, workers represent an even more important asset for the manufacturing competitiveness and productivity, and all necessary actions must be done to improve their health and safety in their working environment. As a result, monitoring physical activity has become increasingly important as many studies link physical activity with overall health status. More precise measurements and relation with ambient and environment measurements can be achieved using a more advanced setup. However, interfacing sensors and controlling multiple events and data in an integrated way are challenges in terms of communications, logical and semantic processing. Achieving this objective requires a complete platform for pervasive sensing, distributed and ubiquitous communication capabilities with strict QoS (Quality of Service) requirements, advanced reasoning capabilities and a more autonomous response towards risk mitigation and worker information and training. This sensor-based platform should be monitored in real time and in a detailed hierarchical or sectored way. Everything happening in the factory, from ambient levels, to the position of all elements should be tracked and potential risks should be anticipated through automated preventive actions.

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Achieving these objectives can be realized through the integration of the IoT (Internet of Things) in industrial environments, and the use of wireless communications to connect distributed mobile sensors with remote control sensors. The architecture of industrial wireless communication systems and its management are key factors to achieve perfect coverage and the most adequate information gathering in real time. However some systems utilize on-sensor signal processing, other rely on raw data transmission, where data are processed on an external computer or personal server, and other use a hybrid approach. Increased sensor intelligence reduces the need for communication, therefore minimizing power consumption and extending battery life.

There is not a factory without risk, but decisive actions should be taken to realize a factory that has the technical, organizational and human resources to identify, detect, monitor and manage continuously the relative risks to health and safety throughout the life cycle of the factory. In this context, the FASyS project (Absolutely Safe and Healthy Factory) (FASyS) has been set-up to develop a new factory model aimed at minimizing the risks to the worker's health and safety, and guarantee their welfare and comfort in machining, handling and assembly factories. ICT and wireless communication technologies in particular may represent very valuable tools to implement distributed and mobile sensing applications capable to continuously sense the working environment and the workers' health and safety conditions. In the context of the sensing enterprise, FASyS has to deal not only with the detection of risks but also has to support the actuation and deployment of the preventive actions selected by the safety and healthy manager through the personalized decision support tools. This implies a service oriented scenario, where the factory is populated by a large amount of services, sensors and actuators involved in risk management life cycle, where services exchange messages to perform the designed actions by means of smart objects. These services may have heterogeneous sources, which can become available, temporarily unavailable or even disappear suddenly. To address this changing environment, FASyS has proposed a highly effective service messaging and service management and coordination semantic solution that would use choreography techniques focused on browsing FASyS service topology. With this solution, FASyS is able to adapt its reactions to available services at any time and ensure the best possible service performance based on the precedence of the risk to be addressed and the service load in the enterprise bus.

To achieve its objectives, FASyS relies on a heterogeneous wireless communications network in charge of transporting the data gathered by the sensors. The reliable provision of the envisioned services in a distributed environment characterized by harsh propagation conditions requires a platform capable to continuously monitor and manage the communications QoS to ensure the robust reception of the sensed information and the capacity to ubiquitously connect to any distributed node. Several monitoring and management platforms have been developed for wireless networks. However, there is yet the need for a platform capable to monitor the operation and performance of heterogeneous wireless networks in industrial environments. An additional feature of interest would be the capability to reconfigure remotely the communication settings of wireless nodes based on possible malfunctioning or QoS degradation notifications. All these functionalities will help guaranteeing the reliable and robust wireless communications required in industrial environments to implement innovative labor risk prevention applications exploiting ICT technologies. The development of this kind of tools has been one of the objectives in FASyS and the subject of this paper.

The paper is organized as follows: next presents the related work with the proposed solution. Section 3 introduces the FASyS ICT approach to the FoF. Section 4 presents an overview of the monitoring and management software platform. The following three sections describe the main components of the platform and their functionalities (SOS, Toolbox and Human Machine Interface). Section 8 presents a performance evaluation of the management framework. And conclusions and main benefits of the proposed solution are summarized in final solution.

2. Related work

One of the main motivations of the work presented in this paper is the analysis of the effective deployment of distributed and mobile sensing applications in critical environments, like the industrial one. These applications require the availability of a platform capable to monitor the operation and performance of the heterogeneous wireless networks that will connect the mobile sensors to remote control centers. There is little research regarding the FoF environment in order to increase levels of industrial safety where the operational environment refers to industry and critical operations. Risk assessment is evaluated in Matthias et al. (2011) for collaborative robots in a human shared environment, following the relevant guidelines in the standards ISO 10218 (Matthias et al., 2006a) and ISO 13849 (Matthias et al., 2006b) to determine the requirements on the implementation of the risk reduction measures used. On the other hand, the work done in this paper is more focused on the standard ISO 31000. This standard provides generic guidelines for the design, implementation and maintenance of risk management processes throughout an organization, but our paper will focus on the machinery industry group. Considering the worker as the nuclear entity of the risk assessment process, its health condition and health information is also of significant relevance to evaluate safety risks.

FASyS relies on a heterogeneous wireless communications network in charge of transporting the data gathered by the sensors. This data is decisive to take actions to realize a factory that has the technical, organizational and human resources to identify, detect, monitor and manage continuously the relative risks to health and safety throughout the life cycle of the factory. The design and implementation of a platform that is capable to monitor the operation and performance of a heterogeneous wireless network and that connects the mobile sensors to remote control centers required the revision of existing network management protocols, management platforms and studies that characterize the deployment of wireless communications in industrial environments.

The benefits of exploiting wireless communications technologies in general, and WSN (Wireless Sensor Networks) in particular for industrial communication distributed systems, have been highlighted in several studies (Gaj et al., 2013; Gungor and Hancke, 2009; Akerberg et al., 2011; Willig, 2008; Nickerson, 2012; Fortino et al., 2012; Mueller et al., 2007; Jonsson and Kunert, 2009). These benefits include deployment flexibility, low cost and reduced power consumption. However, the deployment of heterogeneous wireless communications in industrial environments presents significant challenges. On one hand, industrial environments are usually characterized by challenging propagation conditions (obstructions, multipath propagation, interferences, etc.) that make difficult the establishment of robust wireless links. On the other hand, safety-related industrial applications are characterized by strict reliability and timing requirements, and therefore require a reliable mobile sensing and communications platform. As a result, different studies have analyzed wireless communications in industrial environments. For example, the work in Coll et al. (2012) has characterized three factory automation infrastructures at 439 MHz, 440 MHz, 570 MHz, and 2.45 GHz. The study revealed that the analyzed