Electromagnetic Challenges of Wireless Sensor Networks for Industry 4.0

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The current development of the Internet of Things (IoT), besides opening innovative scenarios in gaming, leisure and demotics, fosters changes in modern manufacturing, energy, agriculture, transportation. Indeed, in many industrial branches the possibility to wirelessly interconnect humans, objects and machines promises unprecedented technical and economic opportunities [1]. Gathering information about environments and processes will increase the capabilities to control complex systems and to predict events thus optimizing the production, the security and the overall efficiency. This particular implementation of the IoT is denoted as *Industrial IoT* and finds its main applications in the emerging frame of Industry 4.0 [2]. The most exploited technologies for the implementation of industrial wireless sensor networks are ZigBee, Bluetooth and Wi-Fi [3]. Great advantages are expected from passive Radio Frequency Identification (RFID) technology which nowadays enables sensing functionalities [4] besides the basic identification.

The deployment of WSNs into industrial scenarios requires the comprehension and hence the control of several challenging electromagnetic issues, especially in case of low-power/battery-less architectures are deployed. Indeed, respect to conventional communication systems, industrial environment is characterized by dynamic operative conditions, capable to sensibly affect both channel and antenna performances.
The sensing network must be able to correctly work in a time-variant harsh environment, where multiple scattering and reflecting metallic objects randomly approach and leave the radiating elements hence sensibly modifying the network planning. In addition, sensors can be placed on high speed moving objects, e.g. turbines and fans that continuously changes their position and consequently the network configuration. The boundary conditions of the electromagnetic problems are hence not univocally defined neither in space nor in time. Furthermore, miniaturized wireless sensors are often required to work when embedded in lossy media, whose dielectric properties are generally unknow at radiofrequency and not stable with the production process, e.g. vulcanization of rubber compounds. Antenna hence experiences possible impedance mismatching and efficiency degradation with not negligible impact on the communication capabilities. The working conditions are even more compromised by the possible shape variations of the hosting object: antenna can undergo to repeated mechanical solicitations and deformations. New paradigms of antenna design are hence required, in which radio-chemical-mechanical models are exploited to dynamically and jointly optimize the different parameters.
Finally, the strong thermal gradients and the electromagnetic interferences produced by the machineries produces non-linearity in the electronic components capable to sensibly affect both sensing and communication performances. Shielding strategies must be implemented without worsen the complexity of the devices and of the whole system, as well as calibration procedures to extend the usability of the components also to non-standard applications.

Starting from real case studies, the contribution quantitatively analyses the different electromagnetics challenges and proposes possible countermeasures and design guidelines.

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