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Wireless Communications in Nuclear Decommissioning Environments

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Abstract

The use of Wireless Sensor Networks (WSN) is now widespread, with well-documented deployments across a diverse range of sectors including aerospace, agri-science and consumer electronics. In the nuclear industry there have been successful deployments of the WSN technologies for instrumentation and control, however, there are significant challenges that need to be addressed before wireless sensing can be used in nuclear decommissioning environments. These challenges include: limited sources of power; the radiation tolerance of the sensor and communication system components; the severe attenuation of wireless signals through reinforced wall structures; and the need to deliver secure, interoperable and reliable communication.

Introduction

Robotics and Automation applications within the nuclear decommissioning industry are rapidly increasing to reduce the cost, time and dose exposure of workers [1]. In addition, there is the need to store nuclear waste and monitoring the condition of the packages in the stores [2]. The design, prototype and evaluation of Wireless Sensor Network with the capability to deliver remote sensing and control can result in reduction of the cost and time to install robotics application and improve the performance, collecting data from hard to reach places not designed to be decommissioned. As a result a successful application can lead to an increase of robotics and automation in the nuclear Industry.

Benefits and Challenges

Wireless Sensor Networks are extensively employed in agriculture, classic examples are application to monitor soil and crop properties [3] [4]. Similarly in the aerospace industry it is possible to find useful example of Wireless Sensors Networks in harsh environments, to monitor gas turbine engines [5].

In the nuclear industry there have been initiatives to deploy Commercial Off The Shelf (COTS) wireless instrumentation and control systems [6]. One such initiative resulted in Sellafield's first application of this technology [7], with reported time saving of 16 weeks and a cost saving of £185k. However, there remain a number of significant challenges to address if Wireless Sensor Networks are to be deployed in nuclear decommissioning environments. One key challenge is the damaged to COTS integrated circuits caused by the high radiation levels and elevated temperatures. There are also fundamental communication challenges resulting from the very high signal attenuation experienced by Radio Frequency (RF) signals propagating through reinforced concrete wall and floor structures. In addition, many legacy buildings in nuclear facilities were not designed to be decommissioning, and limited access and unknown conditions are a further problem. In these situations the wireless sensing systems will need to be battery-powered, with the possibility of power harvesting.

Wireless Sensor Network for Nuclear Decommissioning Industry

A research project, sponsored by the Centre for Innovative Nuclear Decommissioning (CINDe) and the University of Manchester, has been tasked with designing, prototyping and experimentally evaluating a Wireless Sensor Network with the capability to communicate through reinforced concrete wall and floor structures in nuclear decommissioning environments. Figure 1 shows the block diagram of the proposed Wireless Sensors Network system.

The system is composed of two main parts: a set of wireless sensing nodes in the nuclear decommissioning environment and a base station node in the operator environment. The sensor nodes and the base station node are separated by reinforced concrete wall / floor structures. Each sensor node comprises: a number of sensors; a wireless transceiver with the capability to transmit sensor data and to receive control and configuration commands from the base station node; a memory device to store sensor measurements; and

a control system to coordinate the function of the node. The sensor node will be powered using power scavenging and storage techniques.

The base station node comprises a wireless transceiver and a control system. The wireless transceiver receives sensor measurement data from the wireless sensing nodes and is able to control the function of the sensing nodes by transmitting control and configuration information. Whilst only one base station node is shown in Figure 1, it will be possible to incorporate multiple base station nodes to support operation over larger areas.

The communication system will be asymmetric, in that in the nuclear decommissioning environment we will deploy a device designed using simple electronic COTS components to limit the effect of radiation and to minimise power consumption. Conversely, the base station node will need to compensate for the imperfections, such as the frequency drift, in the transmitted signal resulting from the use of low-complexity COTS components. The control systems will play a fundamental role in the design of the Wireless Sensor Networks; in fact they will be designed with the capability of error detection and forward correction. Another key point of the Wireless Sensor Network will be to ensure an adequate and predictable operational life span, which guarantee benefits in terms of system costs and the dose exposure of workers. The operational life span will be dictated by the power consumption profiles of the sensor nodes (assuming that they are purely battery operated), and by the effect of radiation on the COTS electronics components. The second aspect will be investigated using the Dalton Cumbrian Facility irradiation capability [8], where the electronic components will be tested using the Cobalt 60 Irradiator and measuring the effect of total ionization dose on component characteristics.

The Wireless Sensor networks will ensure the security of sensitive nuclear information, by encrypting all transmitted data and by actively controlling the range of the wireless transmissions.

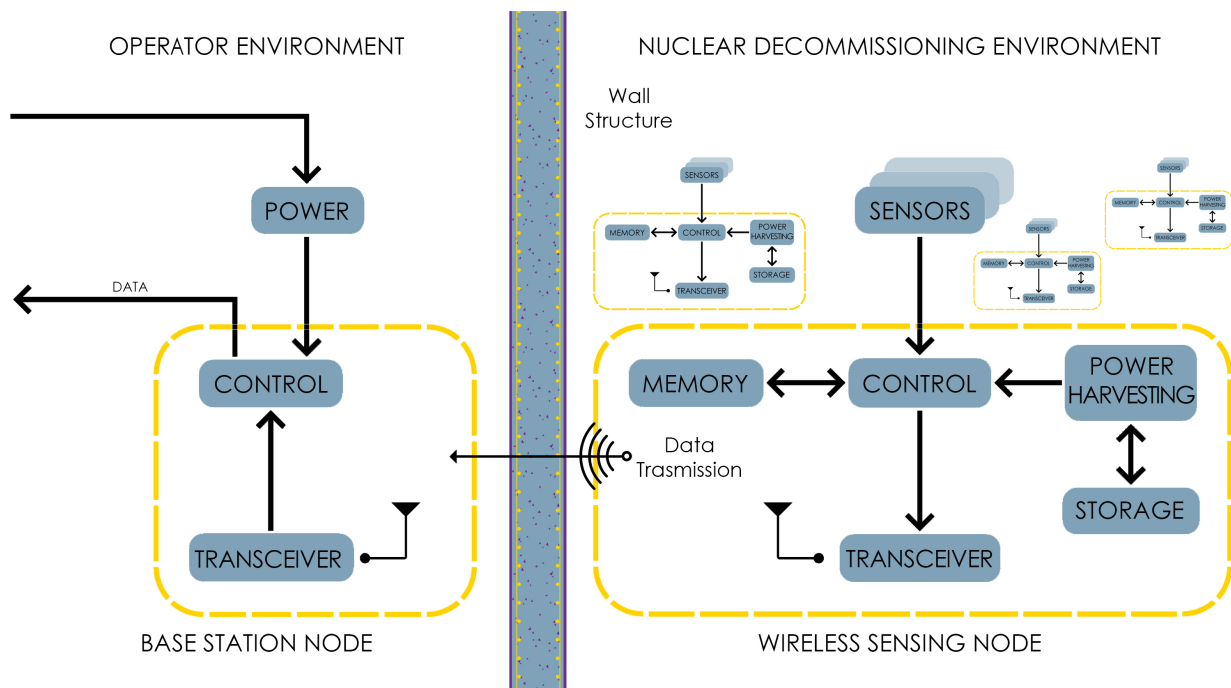


Figure 1 - Block diagram of Wireless Sensor Network System

Conclusion

This paper has shown the concept design of a Wireless Sensor Network System for application in nuclear decommissioning environments. A successful prototype will give the opportunity to increase the use of WSN technologies and hence support the deployment of robotic and autonomous systems in the Nuclear Industry. This will deliver the benefits of reduced installation costs and reduced completion times for decommissioning activities.

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