International Journal of Instrumentation Control and Automation

Volume 1 | Issue 3 Article 6

October 2011

Development of RFID Based Smart Sensor Prototype for Wireless Industrial Monitoring and Control

Urmila Deshmukh
IT Engineering Dept., Indira College of Engineering & Management, Pune, India, urmishinde@gmail.com

R. N. Moghe
Electronics and Communication Engineering Dept., JNEC Engineering College, Aurangabad, India, rnmoghe@rediffmail.com

Recommended Citation
Deshmukh, Urmila and Moghe, R. N. (2011) "Development of RFID Based Smart Sensor Prototype for Wireless Industrial Monitoring and Control," *International Journal of Instrumentation Control and Automation*: Vol. 1 : Iss. 3 , Article 6.
DOI: 10.47893/IJICA.2011.1032
Available at: https://www.interscience.in/ijica/vol1/iss3/6

Development of RFID Based Smart Sensor Prototype for Wireless Industrial Monitoring and Control

UrmilaDeshmukh[1] & R. N. Moghe[2]

[1]IT Engineering Dept., Indira College of Engineering & Management, Pune, India
[2]Electronics and Communication Engineering Dept., JNEC Engineering College, Aurangabad, India
E-mail : urmishinde@gmail.com[1], rnmoghe@rediffmail.com[2]

***Abstract* -** The Purpose of this paper is to present one of the various wireless technologies currently available for industrial monitoring and control. Applications of wireless data transmission are universal. In industrial automation, the benefits of adopting wireless technologies in eliminating the needs for cables in hard to reach areas within the plant, increasing data availability and quality and monitoring and controlling remote assets, that otherwise were inaccessible. Radio frequency identification (RFID) technology is commonly used for object or animal identification and tracking. This article explores the feasibility of its use in a rapid solution to wireless real time monitoring of industry. A prototype system for wireless industrial monitoring and control was developed using a commercially available 12.5 GHZ RFID passive tags. Various parameters are sensed by respective sensors (Slaves), which are then monitored by low power, high performance, 8bit AVR microcontroller. Monitored signals are then sent to the RFID tag or transponder unit, hence the smart feature of the sensor. A receiving unit (Interrogator) emits an electromagnetic field which when detected by passive RFID tag causes it to transfer sensor information (data stored in memory) to the interrogator. Interrogator detects these parameters and sends them to the data collection PC (Master Unit). The architecture of the developed wireless sensor prototype allows for additional RFID tags (Slave Units) to be integrated into it without changes to the sensor designs. Design also provides means to update operating and monitoring parameters as well as sensors/RF link specific firmware modules 'over - the - air'.

***Keywords* -** *Smart Sensor, Wireless communication, RFID Tag, Interrogator, RFID Passive tag.*

I. INTRODUCTION

A wireless smart sensor platform discussed here is targeted for instrumentation and predictive maintenance system. This wireless smart sensor platform readily supports hardware interface, payload, communication needs of multiple position, internal sensors & actuators. For point to point communication between various sensors a RF-link (Wi-Fi, Bluetooth or RFID) is suitable. Wired industry automation involves bundles of lead wires & fibre optic tails are subject to breakage and connector failures. Long wire bundles represent a significant installation & long term maintenance cost, limiting the number of sensors that may be deployed and hence reducing the overall quality of the data reported

Wireless industrial automation based on intelligent sensor based controls emerges as a superior way out over wired industry automation on the account of better power management, reduced costs, effortless deployment in in remote and hard-to-reach areas, and ease in maintenance, fewer catastrophic failures and improved emergency response. Recent advances have resulted in the ability to integrate sensors, radio communications and digital electronicsinto a single integrated circuit – IC package. This capability is enabling networks of very low cost sensors that are able to communicate with each other using low power wireless data routing protocols.

Above mentioned qualities make sure that wireless Industrial automation draws industry attention and provides effective solution to the several issues faced by the instrumentation system and predictive industrial applications. The design is a solution to cater to the issues faced by these applications. As instrumentation systems are open/closed loop control system like motor control, which are formed using sensors and actuators. The objective is to control certain parameters and monitor them continuously. For this all elements must be always in communication with each other,especially where real time performance is required. This also requires facility of in built fault tolerance for communication or node failures to return to a safe state within the deterministic amount of time.

The industry automation needs effective measures to provide predictive maintenance which should involve tracking the physical state of the machine in terms of various essential parameters and to take action if an acceptable or allowed range of those parameters is violated. But in order to conserve energy which is one of the crucial consideration for wireless smart sensors, predictive maintenance applications are not active all the time. The sensors deployed here can be periodic or event based. The system can employ different types of sensors such as position, speed, accelerometer etc. and actuators (Eg. Motors) may be deployed within the same network. All these sensors have different capabilities, interfaces and support different protocols for data and communication. The operational challenges are not limited to this only but when RF links are to be used to satisfy the requirements of bandwidth, delay, noise immunity, payload, jitter, range, cost etc. for communication.

The pick point of this developed system is its versatility and its ability to be configured for diverse applications.

The organisation of this paper is as follows –

Section 2 deals with the potential industrial applications to facilitate by wireless connectivity. Section 3 covers various sensor networks related work and some initiatives for industrial automation. Section 4 describes the application scenario in detail and Section 5 is about the proposed intelligent wireless sensor architecture.Section 6 deals with overview of RFID and section 7 is about conclusion.

II. INDUSTRIAL APPLICATIONS FACILITATED BY WIRELESS CONNECTIVITY –

In this section we present some of the applications of interest for testing the smart sensor platform.

The main purpose of developing such RFID based smart sensor platform is to make industry automation simple and reliable. Open/close loop control instrumentation applications involve sensors and actuators to control certain parameters (eg. Speed, position, temperature etc.). For requirements of real time performance and their effect on the control parameters, all the system elements may always be in communication with each other. To tackle communication/physical sensor node failures, all system elements require in-built fault tolerance capability.

Industrial automation in terms of predictive maintenance involves tracking the state of system to take immediate control action/corrective measures, if system parameters violet the limit value. These system parameters can be physical (Temperature, pressure)/ mechanical (Speed, Position).

From energy consumption point of view, all these predictive measures are not active all the time which is further categorised dependant on their pay load transmission intervals as – event based monitoring, periodic monitoring, store and forward system.

For event based monitoring, a strict violation range is specified and an event wakes the system to perform a pre-defined action such as recording these violations and / or issuing an alert. Otherwise it remains in a passive and power save mode. In case of periodic monitoring, the state of the system is periodically determined and a predefined control action / corrective measure is performed – typically used to monitor the system. This helps to locate the problems before the machine breaks down. For store and forward applications, the communication link is not available all the time and the system has to store data and forward it whenever the communication link is available. The link unavailability can be due to channel problems such as signal interface, noise etc. or in order to improve overall system performance in terms of improving battery life and avoiding data collisions.

All the applications discussed above employ different types of sensors and actuators with different capabilities and supporting different protocols for data collection and communication.

III. RELEVANT WORK:

The field of industry automation has continuously evolved right from register level programming for data acquisition and point to point wired links for communication to the current virtual instrumentation, a wired communication era for networking industrial system.

A. *Industry related initiatives* –

Industry related initiatives include the design of industrial open protocols for wired communication (CAN), several DeviceNet, ControlNet to various system formation tools such as virtual instruments from National Instruments, Factory solutions from ABB etc. Related further development involved open data exchange or messaging framework e.g OPC foundation tried to establish a standard data exchange so that inter portability between hardware and software can be achieved [6, 7]. Potential for wireless is envisaged in Industry asset monitoring and maintenance on an open protocol for communication like Zigbee. Industry initiatives to some extent failed to extract the advantages of wireless technology.

B. *Academic initiatives*:

Wireless sensor network has become more mature [6, 7, 8 & 10] but the entire focus is been on environment monitoring, homeland security, military and defence applications. In past decade studies have been conducted for using wireless communication in the field of industry automation but much of the focus was not on full monitoring system deployment. But interestingly some application specific wireless communication implementations had been proposed and tested successfully but a generic system building approach has not been investigated.

Continuous research and studies in the field of wireless sensor networks leads to the successful deployment of wireless infrastructure in industries. The Motes and Smart Dust project [9] at UC, Berkeley focussed on creating low-cost micro-sensors, with emphasis on the development of sensors and an embedded operating system, TinyOS. The project is node-centric rather than system centric.

The field of wireless sensor networks has matured, but the focus has been on environment monitoring, military and homeland security applications. Though viability studies have been conducted for using wireless communication in industrial applications, not much impetus has been given over full system deployment. Application - specific wireless implementations [12] have been proposed but a generic system building approach has not been investigated.

Deployment of wireless infrastructure in industries will occur incrementally and interoperability (between differentsystems) and extendibility (different application needs) willform the requirements of prospective solutions. This smartsensor platform research initiative is an attempt to developsuch an end-to-end solution with support for incrementaldeployment, extendibility and scalability.

IV. APPLICATION SCENARIO:

Reliability of the nodes and lower routing redundancy are key departures from the conventional view ofsensor networks in industrial automation scenarios. Another difference is that nodes, although power efficient, often haveaccess to power sources, which facilitates providing differentlevels of service - enhanced support for sensing andcommunication for time-critical data, or to be able to ignore this feature for non-time-critical data. The sensor networkthat we envisage can be compared to “fixed-wireless”, wherethe equipment is static, but uses wireless technology forcommunication. Design issues of such a sensor network forindustrial applications are:

Scalability:

Though the number of sensors/actuators etc. which need to be interfaced is less than in atypical sensor network application; scalability stillremains an important issue. The idiosyncrasies of thedifferent components of the system have to becarefully examined and considered. For e.g. Bluetooth can support only a maximum of sevenconnections per device in a piconet setup.

Multiple interface requirements:

Cost sensitive and performance and range present a tradeoff – it may be required that performance be sacrificed forrange and vice-versa.

System building:

A modular and hierarchical system building technique enhances the system flexibility, robustness and reliability.

Interoperability:

Interoperability with existing legacy solutions is required. This can be achieved by using open and customizable message passing and network architecture.

Fault tolerance:

Level of service guarantee isrequired from the communication system - in the form of a confidence level for latency in a command/query message

Energy efficiency:

Though, energy-saving is not critical in system setup and organization of the applications under consideration, the system viability must reckon energy minimization.

V. SYSTEM ARCHITECTURE:

The motive of the smart sensor project is to create 1) a general purpose hardware interface for diverse sensors and actuators, which can be customized for an application through over-the-air firmware downloads and 2) create a data processing infrastructure at the backend to implement applications. The proposed solution consists of a collection of sensors, and actuators communicating with the central control unit using standard RF-links.

Each sensor or actuator is equipped with a reconfigurable generis wireless or Smart Sensor Interface (SSI). The interface extracts data from the sensors, commands the actuator, and provides a data communication interface to the central control unit. A sensor/actuator coupled with smart sensor interface is termed as a *smart sensor node* (SSN).

Hardware Design:

The sensors/actuators found in industrial applications can be classified by analog, digital, or serial (or combination of these) signals used for data communication. The SSI interprets sensors/actuators’ signals, and converts it into digital data/commands.

Software Design:

The digital data extracted by the hardware interface has to be bound by a context and processed to convert it into useful information. The software design of the node is shown in Figure 2. The software module stack on the smart sensor interface consists of three layers. The bottom layer is the device driver which directly interfaces with the hardware interface and extracts digital data. The device manager (middle layer) interfaceswith the device drivers and exposes a multiple-data channelinterface to the firmware layer. In the software framework,each sensor/actuator is composed of a combination of digital,analog or serial channels. Establishment of context to the extracted channel data is done at the firmware layer. Thefirmware layer (top layer) synthesizes the sensor bycombining data from multiple data channels. It also implements the application specific functionalities like real-time performance, data communication protocol with centralcontrol unit, smart sensor node management, etc.

This separation of data acquisition tasks across three layersin the smart sensor interfaces helps support functionalitiessuch as over-the-air update of parameters, plug-n-play ofsensors, multiple sensor support, multiple wireless technology support, universal data interface, etc.

RFID is an acronym for radio frequency identification. Briefly the RF stand for “radio-frequency” and ID means “identifier” that allows an item, for instance a library book, to be identified, accessed, stored, reprogrammed and communicated by using radio waves.

VI. RADIO FREQUENCY IDENTIFICATION (RFID)

RFID is a generic term for non-contacting technologies that use radio waves to automatically identify people or objects. There are several methods of identification, but the most common is to store a unique serial number that identifies a person or object on a microchip that is attached to an antenna. The combined antenna and microchip are called an "RFID transponder" or "RFID tag" and work in combination with an "RFID reader" (sometimes called an "RFID interrogator").

An RFID system consists of a reader and one or more tags. The reader's antenna is used to transmit radio frequency (RF) energy. Depending on the tag type, the energy is "harvested" by the tag's antenna and used to power up the internal circuitry of the tag. The tag will then modulate the electromagnetic waves generated by the reader in order to transmit its data back to the reader. The reader receives the modulated waves and converts them into digital data.

There are two major types of tag technologies. "Passive tags" are tags that do not contain their own power source or transmitter. When radio waves from the reader reach the chip’s antenna, the energy is converted by the antenna into electricity that can power up the microchip in the tag (known as "parasitic power"). The tag is then able to send back any information stored on the tag by reflecting the electromagnetic waves as described above. "Active tags" have their own power source and transmitter.

The power source, usually a battery, is used to run the microchip's circuitry and to broadcast a signal to a reader. Due to the fact that passive tags do not have their own transmitter and must reflect their signal to the reader, the reading distance is much shorter than with active tags. However, active tags are typically larger, more expensive, and require occasional service. The Sunrom RFID Card Reader is designed specifically for passive tags.

Frequency refers to the size of the radio waves used to communicate between the RFID system components. Just as you tune your radio to different frequencies in order tohear different radio stations, RFID tags and readers must be tuned to the same frequency in order to communicate effectively.There really is no such thing as a "typical" RFID tag. The read range of a tag ultimately depends on many factors: the frequency of RFID system operation, the power of the reader, environmental conditions, physical size of the tags antenna and interference from other RF devices. Balancing anumber of engineering trade-offs (antenna size v. reading distance v. power v. manufacturing cost),the Sunrom RFID Card Reader's antenna was designed with a RFID operation at a tag read distance of around 7 cm.

A typical factory environment is considered, where the health of the machinery/equipment is regularly monitored and any digressions/violations from the tolerable behaviour during operation are recorded. The recorded information of a machine typically consists of information like threshold violations, time of the event, extent of the event, etc. The status of machines is typically checked by a qualified machinist who inspects the machine when the main power has been switched off. Any proposed solution should thus operate passively and data should be stored locally.

In the current implementation, smart sensor nodes equipped with sensors to monitor the status of a machine,store the health information in a RFID tag. RFID tag is used as a plain wireless non-line-of-sight data storage [9]. In this mode, the maintenance personnel can retrieve the required health information by querying the tag even when the central computer has been switched off, using a handheld RFID reader.

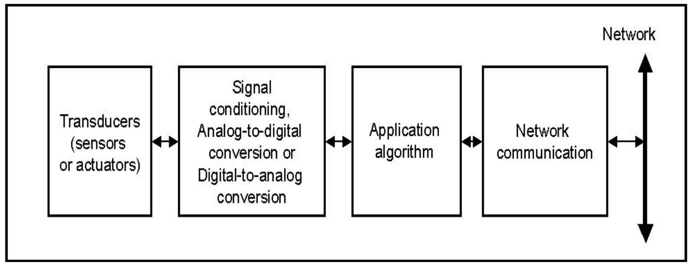

Fig. 1 : Block schematic showing working of sensors

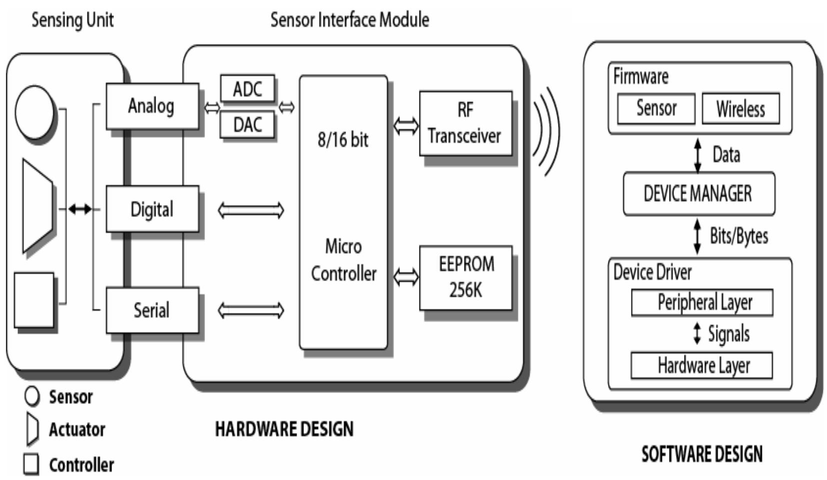

Fig. 2 : Smart sensor design [1]

VII. CONCLUSION:

The design and implementation of a wireless smart sensor platform targeted for instrumentation systems and predictivemaintenance was discussed and presented. Tests were carried out to determine system performance for both. Theresults were quite satisfactory. The experimentalinstrumentation and maintenance applications,show that a sustained near-real-time system can be setup with the smart sensor nodes, and the versatility of thesmart sensor interface allows implementing diverse applications.

We have proposed a low cost solution to conventional smart sensor platform. It is secure, robust & low power consuming. It can operate on multiple channels so as to avoid the interference with other wireless devices or equipments in the industry.

REFERENCES:

[1]. Harish Ramamurthy, B. S. Prabhu,RajitGadh and Asad M. Madni "wireless industrial monitoring & control using smart sensor platform"IEEE Sensors Journal (Fall 2007)

[2] H. Ramamurthy, B. S. Prabhu and R. Gadh, "Application of genericreconfigurbale wireless interface for industrial automation scenarios",US Patent Disclosure, UCLA Case No. 2006-002-1 (Pending).

[3] U.S. DOE, "Industrial Wireless Technology for the 21Century Report, Technology Foresight, Winter 2004/ TF-2004-1.

[4] R. Wynn, "Plug-and-Play sensors," Machine Design,75(10), May 2003,pp,S10.

[5] H. Ramamurthy, B. S. Prabhu, R. Gadh, and A. Madni, "Smart SensorsPlatform for Industrial onitoring and Control", 4 "IEEE sensors" 2005, Irvine, California, Oct 31 – Nov3, 2005.

[6] OPC HAD Specifications version 1.20.1.00 edition, 2003, Available for download at – www.opcfoundation.org

[7] IEEE standard for a Smart Transducer Interface for Sensors and Actuators – IEEE 1451.3 Edition, 2004.

[8] M. J. Dong, G. Yung and W. J. Kaiser "Low Power Signal Processing Architectures for Network Micro sensors" In Proc. Of InHsymp on Low Power Electronics and Design, August 1997 WINS project online at http://www.jennet.ucla.edu/WINS

[9] J. M. Kahn, R. H. Katz and K. S. J. Pister. "Mobile networking for Smart Dust " In Proc. Of. ACM/IEEE InH.Conf on Mobile Computing and Networking (MOBICOM), August 1999

[10] J. Rabaey, J. Ammer, T. Karalar, S. Li, B. Otis, M. Sheets and T. Tuan Pico Radios for Wireless Sensor Network: The Next Challenge In Ultra-Low-Power Design, InProc of the InH solid state circuits conf. Feb 2002

◈◈◈