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ANALYSING THE EFFECT OF INTERFERENCE IN WIRELESS INDUSTRIAL AUTOMATION SYSTEM (WIAS)

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ABSTRACT

ZigBee is a wireless standard recommended for low-data rate wireless personal area networks. ZigBee is widely used in much wireless Monitoring and control application domains due to its low cost, low power and implementation simplicity. ZigBee can work in a non-beacon-enabled mode using un-slotted Carrier Sense Multiple Access/Contention Avoidance (CSMA/CA) or a beacon-enabled mode using slotted CSMA/CA with or without guaranteed time slots (GTSs). GTSs can be allocated by the network coordinator to devices which require specific bandwidth reservation. Currently, there are many chip vendors, including Maxstream, Digi etc., producing commercially available products adopting the ZigBee specification. Wireless networks used in the industrial domain are expected to perform their operations smoothly under such a broad range of stringent operations conditions. As to the sensing networks designed for such purposes must consider the issues of co-channel interference, signal loss or fading due to metallic machinery, the presence of obstacles, the effects of variations of operating temperature, pressure, humidity, impact of noise and vibrations generated from engines, boilers, rotations of machinery, airborne contaminants etc., on the sensing and data communication ability of the network. This paper deals with the investigation of interference effects in Wireless Industrial Automation System (WIAS).

Keywords: industrial automation, relay model, RF module, routers, sensors, WSN, Zigbee.

INTRODUCTION

Wireless automation technology is mostly applied in monitoring applications, where the network requirements are low. Previously wireless solutions in the industrial setting have been based on expensive and inflexible proprietary protocols and devices. The introduction of commercial-off-the-shelf radios on the 2.4 GHz Industrial–Scientific–Medical (ISM) band, such as Bluetooth, WiFi, and IEEE 802.15.4 have dramatically reduced the cost of the radio based solutions, making their use more widespread (Kuang-Yow Lian, 2013). The IEEE 802.15.4 radio is used in several wireless sensor networks, including the ZigBee Wireless HART and the ISA100.11a standard. The latter two standards are designed for wireless automation systems, whereas ZigBee defines a protocol stack for short- range wireless networks, targeted at remote monitoring and control applications (Kamrul Islam, 2012).

In addition, the internet engineering task force IETF standardizes the use of IPv6 in wireless sensor networks, which encourages the use of wireless technology in all kinds of applications. In any automation system measured variables from the field by the sensors are passed wirelessly to the Planning and decision making system which initiates control action. Based on the manipulated variables generated by the control system further control action is passed to the field in order to keep the automation in controlled manner (Luigi Ferrigno, 2011). While implementing Zigbee Industrial Automation Network the most difficult thing when trying to remedy the interference problem between ZigBee and other devices that share same spectrum is due to the difference in their physical layers Sixteen channels are defined for this specification in the 2.4 GHz band but with a narrower band of 2 MHz and also do not overlap. Since XBEE PRO supports frequency hopping ZigBee PAN move from one channel to the other if overloading occurs in the former channel.

TECHNOLOGY OVERVIEW

Basic need for wireless

Despite its advantages, wired networking in industrial automation has well known drawbacks. Data cabling requires tremendous labour cost, in both initial run and also in reconfiguration. The cable themselves are unwelcome in many industrial environments, where they can represent nuisances and safety hazards. Cabling runs have severe length limits, leaving networks unable to address very remote sensors and actuators in hazardous environments (Lingfei Mo, 2012). Wireless networking will provide solution to these issues, in terms of preserving reliability. Because the industrial settings pose special challenges for wireless transmission, most notably in interference and multipath fading. Industrial wireless solution employs special techniques to compensate for noise and interference. One successful method is Frequency Hopping Spread spectrum (FHSS), which ensures reliable data delivery in point to point and star topologies. Another is mesh networking which uses automatic routing techniques to redirect transmissions in case of failure in any transmission path (Vehbi C. Gungor, 2009).

Wireless HART

Wireless HART is a wireless mesh network communication method designed to meet the needs for process automation applications. The time slots of

Wireless HART are of fixed length, 10 meters each and organized by the super frame. Frequency hopping on a packet-by-packet basis and channel blacklisting techniques are used in Wireless HART to enhance the system robustness. Currently, Wireless HART is supported by instrumentation suppliers like ABB. As an interoperable standard, Wireless HART provides an easy way to set up, operate, and maintain a WSN. In addition, it is compliant with the existing highway addressable remote transducer (HART) devices and systems (Paolo Ferrari, 2010). However, there were no commercial battery-operated Wireless HART development systems are not available.

ISA 100.11.a

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Wi-Fi

The IEEE 802.11 network is a specification of the Wireless Local Area Network (WLAN). In its low band mode, IEEE 802.11 (b, g, n) transmit data from 11 Mbps and up to 54M bps and goes up to 32 meters indoors and 95meters outdoor. The IEEE 802.11n standard uses double the radio spectrum compared to 802.11a or 802.11g. However, IEEE 802.11a, c transmit data is up to Gbps and can exceed range by more than two times of the b and g technologies. Wi-Fi which belongs to low band transmits in the ISM 2.4 GHz band while the high band transmits in the 5 GHz band. BPSK and QPSK digital modulation technique is used to transmit data up to 54 Mbps and each channel in the ISM band is 22 MHz wide and are overlapped (Hayoung Yoon, 2010). Consider two channels with channel numbers differ by five or more do not overlap. Wi-Fi's Enhanced Isotropic Radiated Power (EIRP) is limited to 20 dBm (100 mW).

Bluetooth

The IEEE 802.15.1 standard is a proprietary open wireless technology standard for exchanging data over a short distance. It uses the short wavelength radio transmission ISM Band in the 2400-2480 MHz. It is desired for the Wireless Personal Area Network WPAN adopted solely to replace the cable technology. Class 1 device of output power of 100 mW transmit up to 100 meters while device of 25 mW output power transmit can reach up to 10 meters.

Zigbee

ZigBee is a specification for low-rate wireless personal area networks. ZigBee is widely used in much wireless Monitoring and control application domains due to its low cost, low power and implementation simplicity.

COMPARISION OF ZIGBEE WITH OTHER Wi-Fi AND BLUETOOTH

Wi-Fi and Bluetooth are the alternative standards suitable for wireless networking. Zigbee is supposed to do What Wi-Fi or Bluetooth are not doing - two way communication between multiple devices over a simple networks using very low power and at very low cost. It uses free 2.4 GHz band and IEEE defined 802.15.4 standard (Sajd Ondej, 2006). Unlike many licensed wireless technologies it is an open standard. Zigbee typically transfer few bytes sensor values between the devices. It requires very low bandwidth and very low power. The comparisons of various wireless standards are given in the Table-1.

Table-1. Comparison of Zigbee with Bluetooth and Wi-Fi.

Technology	Zigbee	Bluetooth	Wi-Fi
IEEE standard	802.15.4	802.15.1	802.11b
Application	Monitoring and control	Replacement of cable	Web applications
Battery life (Days)	100 to 1000+	7 to 30	5 to 150
Network size	264	7	32
Bandwidth (Kbps)	20 to 250	720	11,000+
Coverage range (Meters)	1to 100+	1to10+	1to100+

DESIGN OF ZIGBEE NETWORK FOR INDUSTRIAL AUTOMATION

Based on architecture, WSNs are generally classified as flat and hierarchical. A flat sensor network is one in which a node may act as sensor or router or both. Hence, a node sensing the physical parameters transmits data to a nearby router and in turn the router forwards the data to the base station in a multi hop fashion. In a hierarchical sensor network, the network is typically organized into clusters with cluster members and cluster heads. While nodes are responsible only for sensing, cluster heads are responsible for collecting data, processing them and forwarding them to base station through coordinator (Muhammad Hafeez Chaudhary, 2013). A prototype model of flat sensor network has been developed to perform Industrial parameter monitoring. Zigbee Industrial Automation Network developed could establish wireless communication between sensor nodes and base station through Zigbee Protocol. The block diagram of Zigbee Industrial Automation Network is shown in Figure-1.

The Figure-2 given below depicts the operation of monitoring networks by utilizing ZigBee network protocol. The networks include a master node connected with a server PC and a series of client nodes, which are classified into master, sensor, gatherer, actuator and controller. Server issues commands the networks and collects responding information from the sensor network. Database Logs the system configuration data and monitoring data. Master Node: Collects original monitoring data and reports to management software; connects with the Server through USB or RS232 port. Gathering Node (Reader) composes the backbone of data collecting and status monitoring network. Equipment Controller Controls the actuator action to start or close the connected equipment/machine.

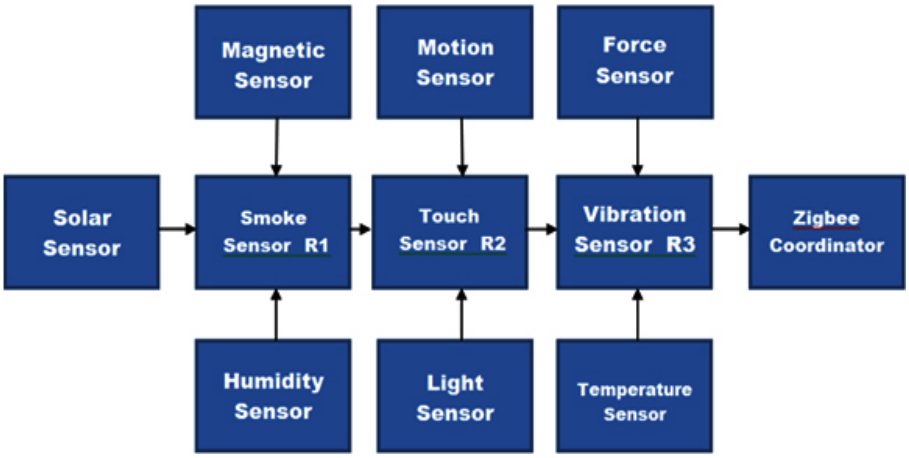

Figure-1. Block diagram of Zigbee industrial automation network.

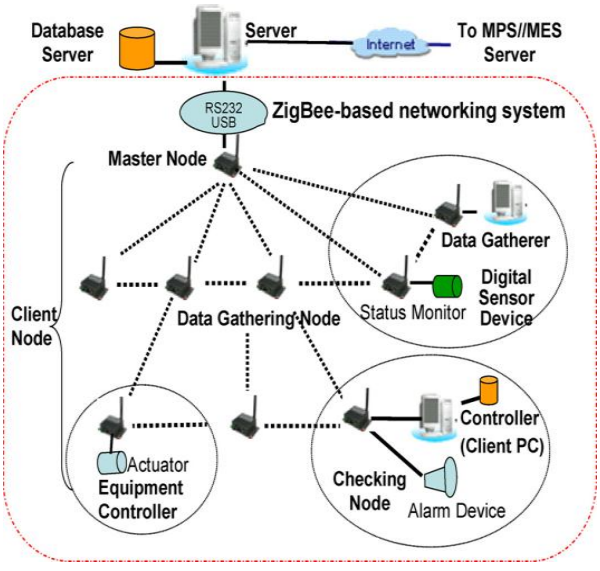

Figure-2. Operation of ZigBee network protocol.

Checking Node (controller) acts as a checker a client PC can connect with a checking node used to display the real-time message of the system and issue control commands to the network when a specified event occurs. Alarm device Functions as an emergency reporter used to notify the production controller. Since the proposed system is going to get implemented in wind power station, where the presence electrical and electro mechanical components is predominant. During the working of the proposed modern wireless control system, operation and performance of the system may get affected due to the presence of electromagnetic interference which arises due to the utilization of numerous numbers of electrical appliances in industrial environment.

The proposed system recommends utilizing Zigbee communication protocol for data transmission which works on 2.4 GHZ license free band. Employees working in the organization may utilize the mobile phone and laptop with Bluetooth and Wi-Fi applications which may cause interference with the functioning of Zigbee protocol. Hence suitable mechanism to be developed to

overcome the effect of these interferences and to improve the performance of the proposed system.

INTERFERENCE IN ZIGBEE NETWORK AND HANDLING METHODS

Interference is a big problem in the industry. It is caused due to many sources and can easily affect the wireless network by disrupting communications since wireless technologies use unlicensed bands.

Handling interference in Zigbee network

The most difficult thing when trying to remedy the interference problem between ZigBee and other devices that share same spectrum is due to the difference in their physical layers Sixteen channels are defined for this specification in the 2.4 GHz band but with a narrower band of 2 MHz and also do not overlap (Huang-Chen Lee, 2014). Since XBEE PRO supports frequency hopping ZigBee PAN move from one channel to the other if overloading occurs in the former channel Handling Interference in Zigbee Network (Fadillah Purnama Rezha, 2014).

Spread spectrum modulation techniques, in which the bandwidth of the original signal is deliberately spread in the frequency domain, is standard ways to handle interference since they are naturally resistant to interference and jamming and offer secure communications and multiple accesses.

On the other hand, FHSS is robust and can resist interference from spurious RF signals much better than DSSS and noises, reflections, and other radio stations have little effect (Ondrej Kreibich, 2014). Various other methods could be used in industrial environment to attain interference free Industrial Automation Network. The multipath routing technique is a natural and robust way to increase reliability which comes at the cost of energy. If signals in one path are blocked by obstacles and cannot propagate, the data may still be transmitted through other paths. In mesh networks, multiple paths are used to deliver a single message to guarantee its reliability to 99.9.Different radios may be utilized for operation of various ranges with a view to switch to different frequencies in case certain frequencies fail to operate due to interference. In addition, a sensor's radio transceiver can be capable of changing its transmission power to achieve different transmission ranges (R. Challoo, 2012).
Time synchronization techniques are used to synchronize all the nodes by time stamping the data with a global clock. This technique is suitable for small networks. For special applications, the process data are also location-stamped. Redundancy could play a vital role in establishing highly reliable communications systems by making sure that there will always be stand-by sensors which can take over in case some of them fail. To increase reliability in data communications and provide a high degree of confidence in successfully transmitting packets, components in WSNs are made redundant, for example, dual gateways are highly recommended for increased reliability (Shyr-Kuen Chen, 2012). However, redundancy can also be achieved through the use of multiple frequencies at the expense of additional hardware/software capability. In WLAN interference occur due to following reason a) communication over radio channels is usually very sensitive to electromagnetic interferences which may cause excessively high transmission error rates b) even in the case there is no electromagnetic noise, interferences might be generated by the presence of wireless networks nearby, including other WLANs that are not under control of the system administrator this is resolved by Carrier Sense Multiple Access (Stefano Savazzi, 2014).

IMPLEMENTATION OF WIRELESS INDUSTRIAL AUTOMATION SYSTEM (WIAS)

Wireless Industrial Automation System (WIAS) developed was capable to record the system parameters like temperature, pressure etc., continuously to satisfy the requirements of a continuous process. Figure-3 depicts the prototype model of a transmitter and Figure-4 depicts the prototype model of a receiver.

A transmitter is composed of sensor, signal conditioning unit, ARMLPC2148 Processor, LCD Display, RF Encoder/Decoder, Battery, Charge Controller and RF Transceiver (Anuj Kumar, 2014). The developed transmitter may be installed either in the presence of normal power supply or through the battery power or through solar power. In case when the transmitter is powered through battery there is a possibility of getting dried, so charge controller is provided to recharge the battery if dried.

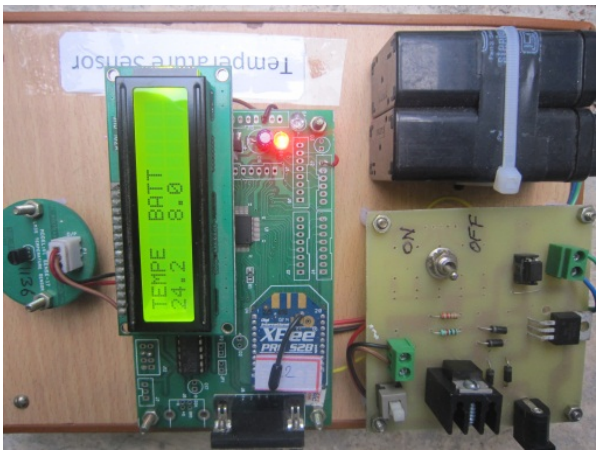

Figure-3. Prototype model of a transmitter.

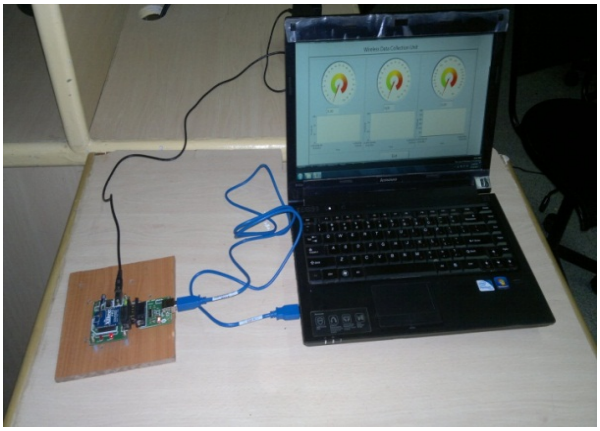

Figure-4. Prototype model of a receiver.

Other than sensor and signal conditioning unit receiving unit utilize all other components present in the transmitter. Code has been developed in Embedded C and embedded in processor to interface transmitter and receiver. The transmitter sends the processed physical parameters to the receiver. Experiment was conducted in Industrial environment by placing various sensors in different location of an industry and receiver interfaced with a personal computer was kept in a control room. Changes occurred in physical parameters are observed by varying them. Results are displayed and logged on the LABVIEW (short for Laboratory Virtual Instrument Engineering Workbench) is a system-design platform and development environment for a visual programming language from National Instruments based graphical user interface (GUI) running on a PC The acquired data can be displayed locally on an LCD with backlight, showing text on 2 rows and 16 columns, by pressing a button or at a remote location.

RESULTS AND DISCUSSIONS

Wireless Industrial Automation System (WIAS) developed to monitor and record the process parameters like temperature, pressure etc. Operation of temperature and light sensor has been observed by providing the transmitters in industrial environment where engine, boiler and allied machineries were present and receiver interfaced with a personal computer was kept in a control room. Powered on the transmitter, receiver modules and initiated the data transmission by varying the process parameters. Results has been observed by recording value of the transmitted process parameter through LCD Display and also through the serial port provided in the transmitter connected to the Personal computer (Silviu C. Folea, 2015). Then the received values of the process parameter are observed through the Graphic User Interface provided serially through the coordinator which was act as a receiver. The above mentioned experiment was conducted around 45 minutes and observed the results. Results are displayed and logged on the LABVIEW based graphical user interface (GUI) running on a PC. Figure-5 and Figure-6 depicts the transmitted vs. received values of temperature and light sensor respectively.

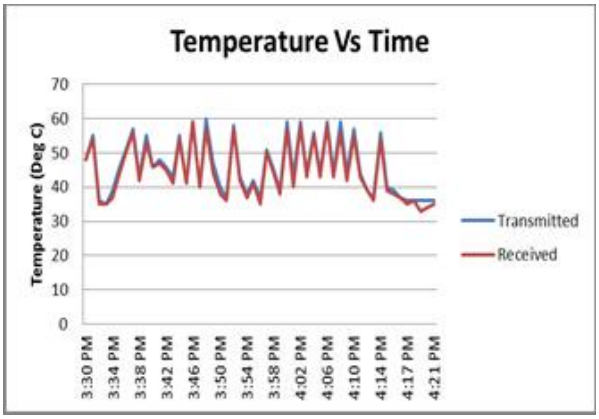

Figure-5. Transmitted vs received values of temperature sensor.

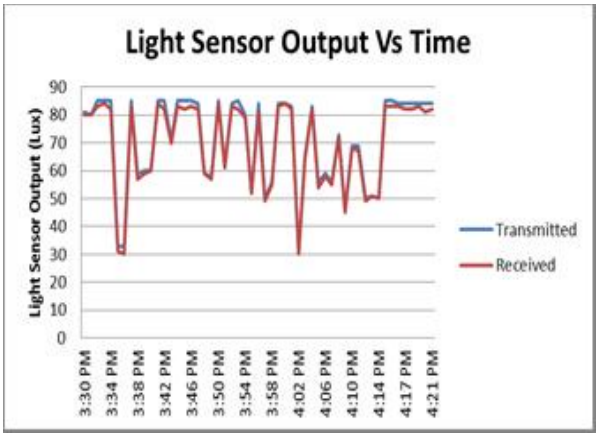

Figure-6. Transmitted vs received values of light sensor.

Result shown above clearly indicates that there was not much deviation between transmitted and received values. But some deviation exists due to interference raised from the electro mechanical components present in the industrial environment. The effect occurred due to electromagnetic magnetic interference may considerably be reduced if implemented in real-time with high quality sensors and its accessories.

CONCLUSIONS

This paper presented the development of Wireless Industrial Automation System (WIAS) by smart sensor network based on the ZigBee protocol that monitors and record the temperature, relative humidity, light, motion, vibration, solar power etc., which consume low power and offer a communication range about 300m.The range can be further extended by employing more number of routers. WIAS was made to function under industrial environment and analysed the performance of transmission. The core contribution of this work is to investigate the effect of

interference of WIAS in industrial environment. Tests and experimental results revealed that the system can operate continuously in industrial environment with minor impact of electromagnetic interference that may considerably be reduced by carefully selecting the board components, sensors and allied components. Further future work will also be directed towards the optimization of the performance of Industrial Automation System (WIAS) by incorporating interference avoidance mechanisms in different challenging environments.

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