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Ensuring Correctness of Data When Faults are Caused During Communication between the Wireless Sensor Networks

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Abstract: A Manufacturing process generally involves several stages of processing and use many processing parameters such as pressure, temperature, humidity speed, rotations etc. The sensors connected at one stage need to communicate with the sensors or actuators situated at another stage through transmission of process data. The sensor and actuators are connected through wireless sensor networks as it would be feasible to connect the devices through a wired network. Any failure due to a fault within the wireless network will hamper the correctness of the data transmitted in between the sensing devices and actuators. The process of controlling the manufacturing process shall be affected when data transmitted gets inaccurate. Faults are bound to happen within wireless sensor networks (WSN) due to loss of signals, reflections, shading etc. When such kinds of faults occur, the data need to be corrected so that control function is implemented properly. This approach is correct as the faults within the WSN are temporary as the recovery process is very much built within it.

In this paper, an application development is presented that takes into account the occurrence of faults within WSN and correction of data emanating from the sensors and taking proper control actions that makes the regular manufacturing process always is undertaken as designed.

Keywords: Fault occurrence, wireless sensor systems, information correction, and automated manufacturing systems.

1. INTRODUCTION

Wireless sensor technology is being used to connect up and establishes communication within devices especially known as internet of things. In manufacturing industry, sensors are connected with mechanical systems to gather process information. Manufacturing as such is done in different stages. The data gathered at one stage is generally used to affect a control function within the same stage or transmitted to a sensor installed in some other stage of processing which may be used to alter the process parameters which are used for affecting the manufacturing.

Communication as such must take place between the devices that are installed at different stages of processing. Connecting the devices with cables is complex and therefore not a feasible solution to implement. Wireless sensors are used quite frequently for gathering process information and communication between the wireless sensors is effected through wireless communication protocols such as Wi-Fi, Zigbee, and Bluetooth etc. Data from one sensor situated in a stage is transmitted to an actuator, situated in another stage making it effective to implement the control function in one stage based on what happened in another stage.

Quite recently many low power microprocessors technologies that deal with power storage have been invented and these technologies have led to the development of broad range of wireless sensors and WSN platforms. Currently the wireless sensor networks falls into two categories that include low power–application specific and full featured-general purpose. The low power–application specific WSN are generally built

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using power efficient microprocessors and few devices that are required to implement the application. Application specific communication systems are quite useful to be used in manufacturing systems where process control is affected. Several architectures have been presented in the past which are quite useful for the development of application specific communication systems. MASS is one of those architecture that can be used for the development of wireless sensor based applications. Using MASS one can develop application specific senor networks.

Wireless communication as such is limited due to various ionization effects such as reflection, fading, interference, noise, bit errors etc. These effects are at times momentary causing errors in communication. Thus, there is a need for the correction of the received data and use the same for controlling the process as long as the data communication error persists. A process is required to detect that there is a communication error and a correction process is to be applied so that the data is corrected as long as the communication error persist. The data correction process needs to be avoided when the wireless communication system is functioning without any kind of error.

Thus the problem is to correct the received data as it may be distorted due to occurrence of faults within WSN.

2. RELATED WORK

Akerberg J et. al., [1] addressed safety and security measures which must be considered while using the sensor data in the automation industries for enabling the wireless applications. The information flow from a sensor through a wireless interface and the correctness of the same due to the existence of faults that occur due to vibrations or excessive heat has not be considered into the model presented by them.

Xiuming Zhu et. al., [2] presents a comparison between the consumer mesh networks and industrial wireless mesh networks in which the requirements for industrial wireless mesh networks is much more challenging and complicated compared to the consumer mesh networks. Due to this the chips existing for industrial wireless mesh networks need to undergo more stress. The physical and MAC layer standards of IEEE 802.15.4 are utilised by the industrial wireless mesh networks. Wireless HART is a technology that is used for the industrial process control. There are many challenges faced by IEEE 802.15.4 chips and the products targeted with Zigbee.

Edmonds N et. al., [3] have presented a modular architecture for a sensor system to be connected to low power processors built within the power storage technology. This architecture involves development of application specific solutions which are more effective compared to the general purpose sensors in both hardware and software design of an application. Yet, this fails to cover the details of how the faults occur and how the modified sensors could compensate the actual results.

Jianping Song et. al., [4] have presented about the Wireless HART which is a wireless technology used nowadays by the industries. Process measurements and control applications uses Wireless HART which is officially released in September 2007. It operates in the 2.4GHz ISM band and it uses the TDMA mechanism. The architecture for Wireless HART is presented and a prototype for this specification is built. There are several challenges faced such as timer design, synchronization of the network, security of communication, network reliability and the central network manager. Also a solution is proposed for each challenge. While this being the case, no attempt as such has been made to apply corrections to data sensed and driven by the sensors when faults occurs within WSNs that connects various parts of the embedded systems which is primarily responsible for monitoring and controlling the manufacturing process.

Graphic processing unit and central processing unit are designed to execute programs that aim at graphic or number crunching. Fusing of both these processors gives an advantage of executing both types of programs on the same chip. Both the chips can use the same cache making it possible to handle the complexity of execution of both computing and graphic applications. Yi Yang et. al., [5] has presented a method to fuse both GPU and CPU. The faults that can happen when wireless communication is done for transmitting graphic and regular data can greatly reduce due to fusing CPU and GPU.

Faisal A. Al- Nasser et. Al., [6] have presented that traffic control systems using wireless sensor networks have proven to be useful and promising. It adapts the intersections to the traffic from each direction which helps the people in saving their time. They have used number of parameters that include the number of vehicles in stationary position, vehicle queue length during the red cycle which is used to perform a better control during the green cycle. They have aimed to reduce the waiting time of a particular vehicle at each signal which in turn reduces the queue length of the vehicles so that better management of traffic can be done. Also the people are alerted about the red light queue in advance which leads to reduction of speed of their vehicle. This will help reducing the chances of accidents.

Abusayeed Saifullah et. al., [7] have presented a network standard called HART that can be used for developing wireless sensor networks. HART is an open wireless sensor-actuator standard and it requires real time data communication between the sensor and actuator devices to be used in the industrial process automation. Some of the feature of Wireless HART networks includes architecture in a centralized manner, TDMA transmission using multi-channel. Some of the contributions made are creating an end to end transmission between the devices using Wireless HART, proof of NP hardness of the problem and a scheduling algorithm called Conflict-Aware Least-Laxity First (C-LLF). These algorithms however have not addressed the fault occurrence, detection and compensation for correctness of the data.

3. APPLICATION DEVELOPMENT FOR EXPERIMENTING

The block diagram connecting two stages in manufacturing system has been shown in Figure-1. The communication between two stages of processing in a manufacturing system is effected through wireless communication using Zigbee interface. The wireless sensors meant for sensing temperature, fire, pressure and emitting of gas are connected to a local computing location through a wireless interface using Wi-Fi communication system. The local computing is effected through an ARM 7 controller. Same set up has been placed at both the manufacturing stages. The communication between the processing stages has been effected through Zigbee. Any fault either in Wi-Fi or Zigbee based communication will affect the computing at the local base-stations. When error is noticed the data received must be corrected and the same must be used for undertaking several actuating signals.

Temperature sensor detects the temperature in the room and if the temperature exceeds a certain limit automatically the cooling fan will be turned on. Gas sensor detects the amount of a particular gas in the room and if the gas exceeds a certain limit there will an indication through the buzzer. PIR sensor detects any persons entering into a restricted area. If any person enters the room, a message will be sent to the person through GSM. Fire sensor detects the fire and if there is any fire accident occurring it will be indicated through the buzzer so that necessary action can be taken. Also Zigbee module is used which is a wireless technology through which all the communication between the transmitting and receiving section is done. A 9V supply is connected to the microcontroller for supplying power to the microcontroller, sensors and devices connected to the microcontroller. All the values of temperature, gas are displayed on the LCD along with the messages like fire, gas or increase in temperature.

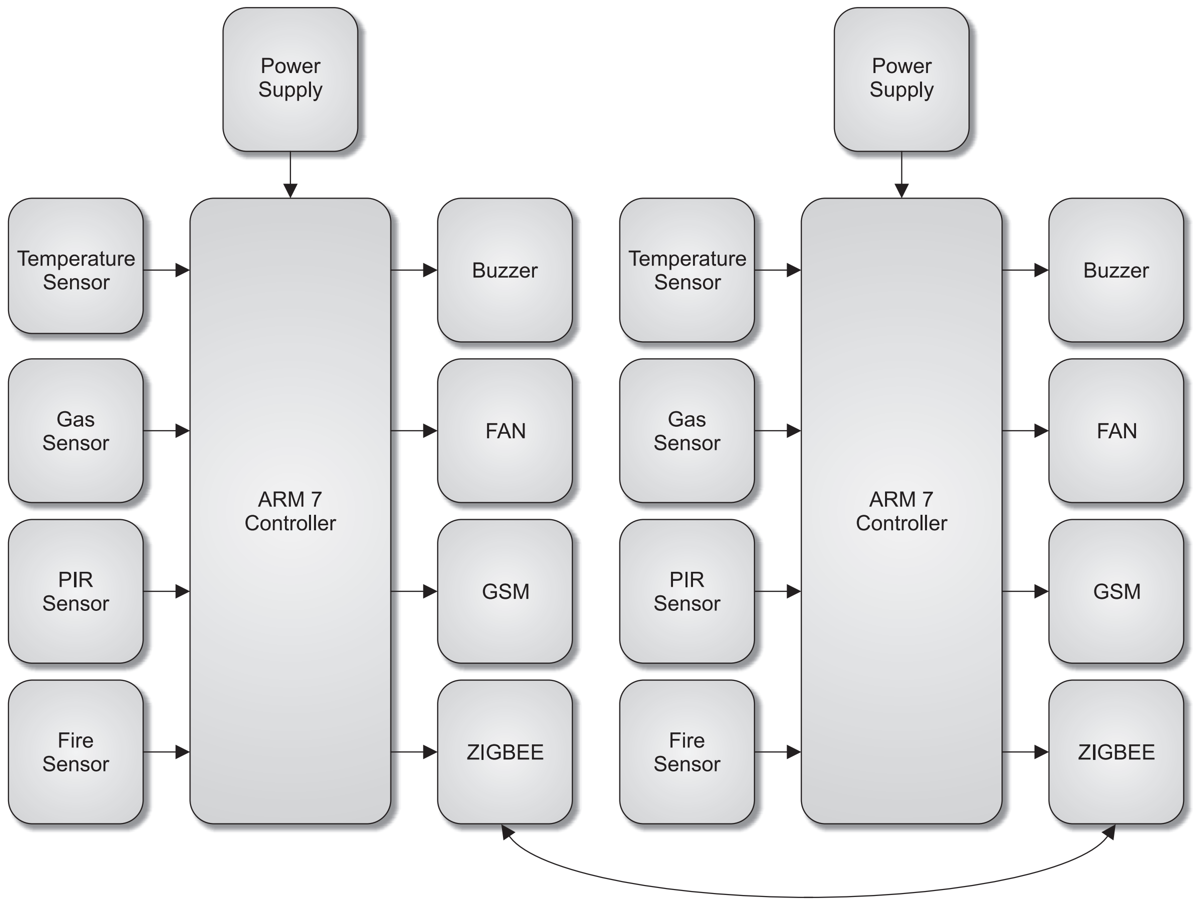

Figure 1: Wireless senor networks for a manufacturing system

ZigBee is based on IEE 802.25.4 specification which is used to create personal area networks with small low power digital radios. Compared to other wireless personal area networks like WiFi or Bluetooth, it is simpler and less expensive. Zigbee is being used in wireless light switches, home automation, traffic control systems which need low rate wireless data transfer. Its range is from 10-100 meters depending on the environmental characteristics and power output. Although its transmission range is short when the data is passed through the mesh network, data can be passed to more distances using intermediate routers. The baud rate of Zigbee is 250Kbits/sec which can be set before the commencement of communication.

4. INVESTIGATIONS AND FINDINGS

Many types of faults can be inducted into wireless communication system in terms of reflection, fading, noise and electromagnetic radiation. Due to these faults distorted data received on the controller side are bound to be incorrect. It will be disastrous to initiate a control action based on the erroneous data received on the controller side. Corrections are to be applied on the received data considering the kind of faults induced into the system. The corrected data then can be used for actuating the control functions. To install a correction model at times it becomes necessary to add more sensors directly connected to the microcontroller to sense the fault occurring during the process of transmission. Using the wireless communication for transmitting data from such a sensor must be avoided as the reference data might also get inaccurate due to the presence of a fault. In the application model shown in Figure 1 an EMF radiation sensor has been added for detecting the presence of a person near the file. The revised block diagram showing the connectivity between the sensors and the newly introduced sensor is shown in Figure 2.

Three correction methods have been used for correcting data received from Wi-Fi sensors that include temperature compensation method based on distance, fire compensation method based on Temperature

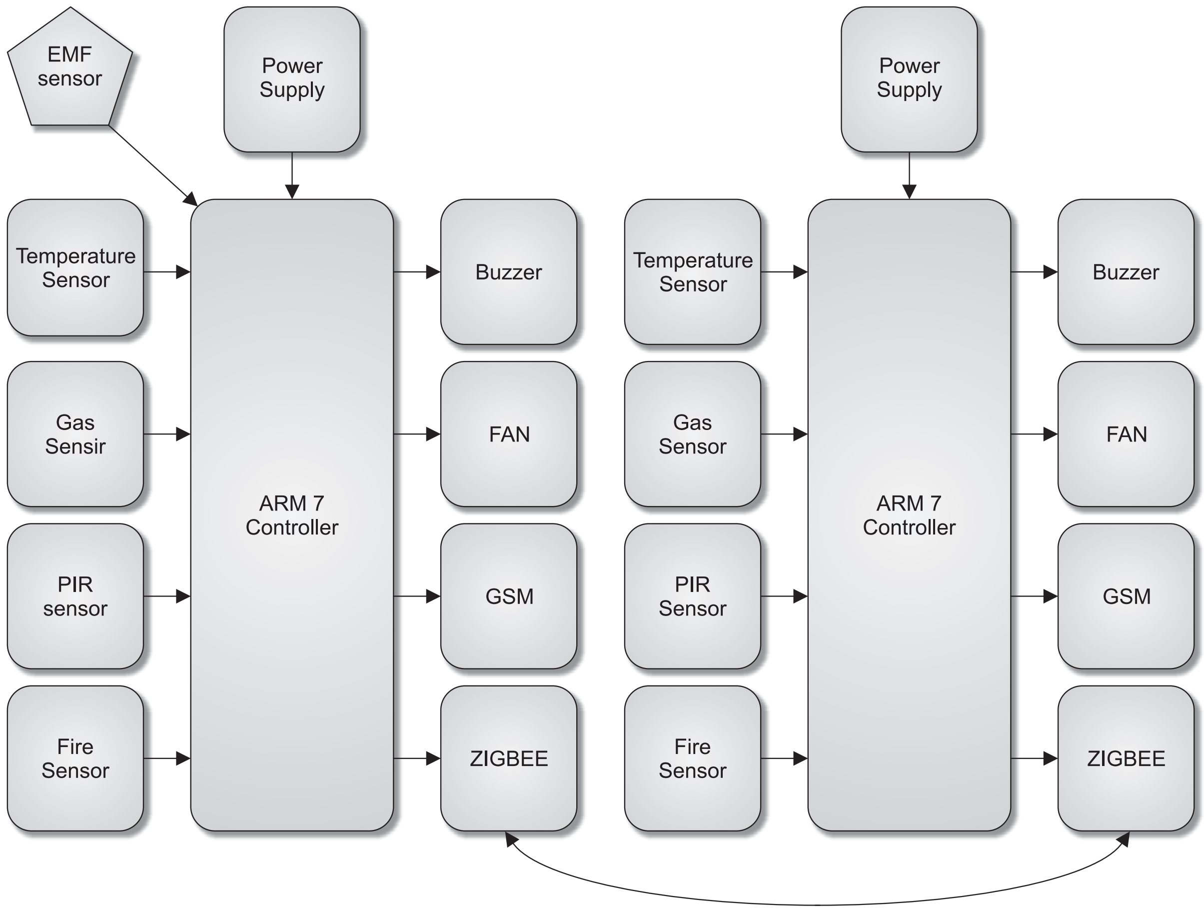

Figure 2: Modified application model connected with additional sensor for correcting data communicated through wireless sensors

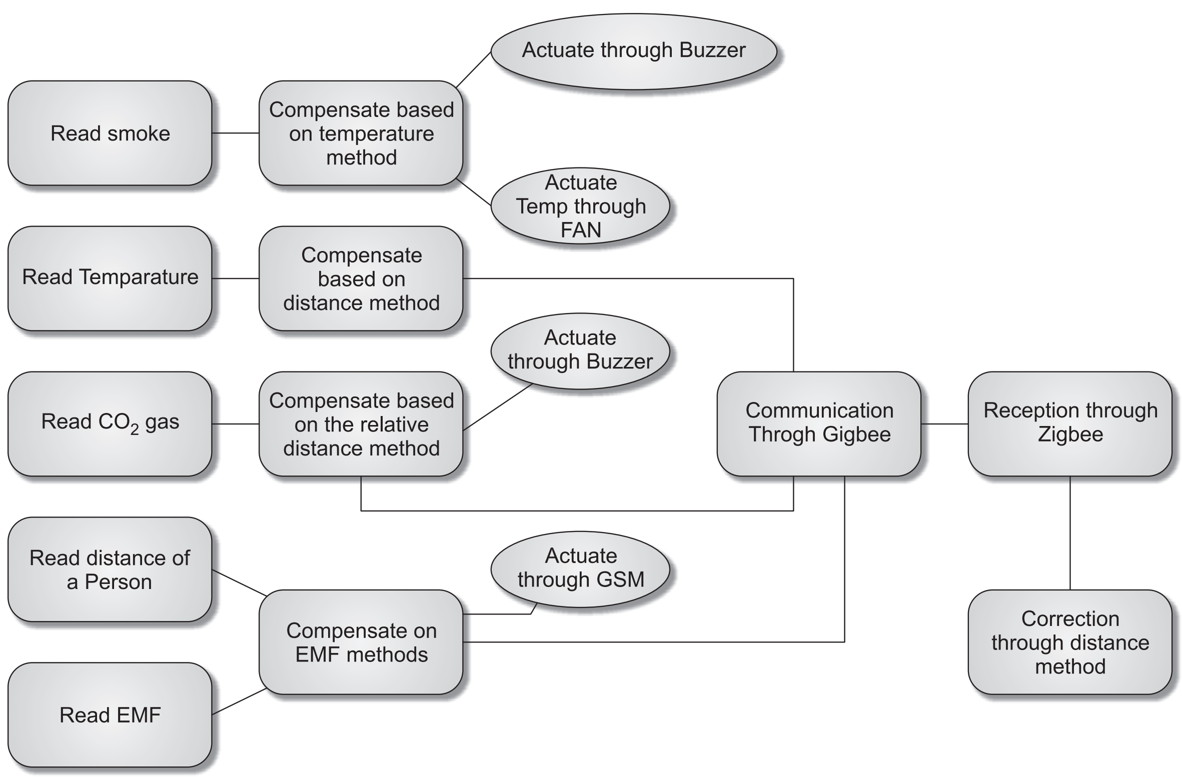

Figure 3: Process model for correcting data through wireless communication due to existence of faults

and GAS compensation method. The errors that may occur while communication are effected between the two Zigbee interfaces connecting two stages of processing that have been corrected based on the distance method. In this paper it has been considered that fading is directly proportional to the distance between the transmitter and the receiver. The process model used for correcting the data is shown in Figure 3.

Simple methods have been used to correct the inputs sensed by various sensors due to the induction of various kinds of faults. Some of the correction methods used are explained below:

Temperature compensation method based on distance

Corrected Temperature = ABS (Reference Distance – Actual distance) × Reference Temperature Rate + Actual Temperature.

Reference temperature rate is the rate computed when the sensed temperature is same as the actual temperature at a particular distance.

Fire compensation method based on Temperature

Corrected Fire Thickness = Actual Thickness – (Reference Thickness/(Reference Temperature/Actual Temperature))

The fire thickness is compensated considering the reference thickness at the occurrence of a particular temperature. The correction is applied prorate on the basis of reference temperature and the actual temperature.

GAS Compensation Method

The amount of the GAS generated is dependent on the distance at which the GAS sensor is situated from the occurrence of the fire. Minimal amount of distortion in the gas emission is noticed when the fire occurs and GAS senor is connected quite away from the fire. Such a distance is considered to be a reference distance. As the distance of the GAS sensor from the fire is reduced, more Gas is emitted distorting the measurement of actual gas existing near by the manufacturing system. Thickness of the fire when it happens also has the effect on the GAS distortion.

Corrected GAS = GAS sensed – (Reference GAS volume/References distance) × (Fire Thickness/ Distance between the Fire and GAS sensor)

PIR and Zigbee compensations are undertaken in similar manner.

Experimentation and Results

Experiments have been conducted by inducing various kinds of faults. The sensed data and the received data have been corrected and tabulated and it has been seen that the transmitted data is same as the received data even when a fault has been persisting. When no correction has been applied the data received has been found to be erroneous in the presence of a fault. The experimental results have been shown in the Table 1.

Table 1
Experimental result – correcting sensed and transmitted data due to presence of Faults within wireless communication

Source Sensor	*Data sensed*	*Data Received*	*Type of fault induced*	*Data correction method implemented*	*Data Received*
Temperature	80 Degrees	72 Degree	Fading due to increase in distance by 100 Meters	Compensation for increased distance	80
Fire	12” thickness of the smoke	20”	Noise within communication channel	Correction based on the temperature method	12”

Source Sensor	*Data sensed*	*Data Received*	*Type of fault induced*	*Data correction method implemented*	*Data Received*
GAS	32 Cubic centimetres	30 Cubic centimetres	Reflection	Compensation based on the distance between the Fire sensor and GAS sensor	32 cubic centimetres
PIR	Person at 100 Meter distance from the fire sensor	10 Meters from the fire sensor	Increase in electromagnetic radiation	Compensation based on EMC	100 Meters
ZIG bee Communication interface	Fire Data = 12” thickness of the smoke	18” Thickness of the smoke	Fading due to increases in distance between two Zigbee systems	Correction based on the distance method	12”

It can be seen from the table that different kind of faults can be induced into the system in terms of fading, reflection, noise and increase in electromagnetic radiation. An EMF sensor is connected for sensing the person situated near the fire.

5. CONCLUSIONS

An application has been developed that senses various process parameters within a manufacturing process and for display of the same on a LCD. The communication that gets effected due to faults arising within a wireless sensor network can be corrected by introducing fault correction mechanism which must take into account various kind of faults happening within wireless senor network. In this paper, a fault detection mechanism has been implemented and a process that corrects the data when a fault occurs is presented. The process as such is implemented within an application which has been developed using an ARM processor. Experiments have been conducted by inducing faults into WSN and have been shown that the correct data has been received by the sensors even when faults have persisted in the wireless sensor networks.

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