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Investigation of WSN Parameters for Realization of Quality of Service

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Abstract : Emphasizing the Quality of Service (QoS), the parameters of the Industrial Wireless Sensor Network have been investigated. Deploying an ubiquitous embedded technology, the smart sensor motes have been designed, wherein the standards of IEEE 1451 are realized. According to these standards, along with transduction and intelligent computing, the Network Capable Application Processor (NCAP) plays vital role on establishment of wireless communication. The zigbee device have been used to facilitate the sensor motes with smart communication module. The zigbee devices are operating according to IEEE 802.15.4 with amended PHY and MAC layers. Thus, the sensor motes have been designed, wherein two standards IEEE 1451 and IEEE 802.15.4 are suitably confluenced. The base station, inherent part of WSN, is also developed and utilized for establishment of the WSN in desired protocol. The parameters, such as Receiver Signal Strength Indicator (RSSI), Link Quality Indicator (LQI), Packet Reception Rate (PRR) and Delay Time (DT) etc, being QoS parameters of the dedicated WSN, are investigated for both indoor as well as outdoor environment. It was found that, values of RSSI and LQI are measured for both indoor as well as outdoor environment are in the limit of agreement. Both RSSI and LQI decrease with increase in distance of mote from base station. The packet reception rate is estimated from the rate of packets stored in the data base. It was found that, the PRR is within the range from 96% to 100%, which suggest that the data loss is less than 4%. The latency expressed by measuring delay time, is also very less. It was also found that, the values of these QoS parameters are mostly sensitive to the infrastructural obstacles. From results of investigation, it is found that the WSN under investigation provides good QoS and hence ensure its suitability of industrial deployment.

Keywords: *Wireless Sensor Network, Quality of Service, RSSI, LQI, PRR, Zigbee, etc.*

I. Introduction

Indeed, the Wireless Sensor Network (WSN) is revolutionary field of electronics and communication engineering. It is the composition of the sensor motes, coordinator and the Base Station [Gungor (2009)] [Christin (2010)]. According to the standard architecture, the WSN is Network of systematically distributed tiny sensor motes to exchange valuable information from actual field. Each mote is equipped with sensing, processing and transmission capabilities. Moreover, each mote is configured with function such as end device, router and coordinator, according their role in the network. On other hand the base station helps to preserve collected information from process field and to present the same in user friendly format as well.

The sensor motes (SM) should be intelligent and have computing capabilities [Ngai (2005)] and networking capabilities [Chipde (2013)] as well. Moreover, the SM should follow the IEEE 1451.X standards. These motes must be facilitated with the operating system, so that it would work autonomously. While designing the motes, energy efficiency should be emphasized [Xu (2014)]. The wireless communication is the inherent task of the motes. Therefore, motes should be designed by following the standards given by the IEEE 802.15.4. The ZigBee technology is the most suitable solution for wireless communication for WSN. The coordinator mote is full function device and must be able to collect the data disseminated by the systematically distributed motes. Moreover, the Base station plays vital role in demonstration of data and logging of the same. Therefore, for WSN establishment the Smart Base Station is essential. For demonstration of parameter values in real time, the GUI should be developed and installed on the computer of the base station. The base station should also have capabilities to detect the faulty motes and the range of wireless communication as well. It should also recognize the path of the data flow. Therefore, the WSN must be facilitated with the proper simulating GUI. Emphasizing these requirements, the Sensor Motes, Coordinator and the Base Station have been successfully designed and designing issues have been presented in [Mane-Deshmukh (2016)].

By employing the sensor motes, coordinator and base station, the Wireless Sensor Network is established and the parameters of the WSN are investigated to interpret the issues regarding Quality of Service (QoS). The paper comprises six sections. The section 2 emphasizes development of the network and configuration of the same. Section 3 describes QoS parameters of the WSN. Section 4 discusses experimental setup and section 5 is devoted to the interpretation of the results.

II. Heading Development Of Wireless Sensor Network

In order to investigate typical parameters, the wireless sensor network (WSN) is designed. As discussed earlier, it is an organization of smart sensor motes and the base station. Therefore, for realization of the WSN, the components such as sensor mote, coordinator mote, the base station etc have been designed, wherein the embedded technology is deployed. Both hardware and firmware have been co-designed and presented in this section. The points such as development of smart sensor motes, development of base station, establishment of WSN, configuration of sensor motes for cooperative communication etc are emphasized.

Designing Of Smart Sensor Motes

The commercially different types of motes are available but they are integrated with specific basic parameters hence it is proposed to design the mote and investigate the QoS. The sensor mote is designed for detection and monitoring of industrial environmental parameters. Each sensor mote is equipped with, six sensors such as Alcohol gas, Ammonia gas, Liquid Petroleum Gas (LPG), Hydrogen Sulfide gas, carbon monoxide gas and Environmental Temperature sensor. Emphasizing the standards of IEEE 1451.X and that of IEEE 802.15.4 [Somani (2012)], the hardware of the motes have been designed. As presented figure 1, the Mote is designed about PIC 18F4550 microcontroller, which causes to introduce the intelligence into the Mote. On-chip resources of this microcontroller such as Analog to Digital Convertor (ADC), Digital to Analog Converter (DAC), USART, etc. are dynamically configured. The microcontroller also helps to provide the output in various formats. These peripheral helps to interact analog as well as digital signal from external devices. The microcontroller also plays commendable role on the accessing of the Transducer Electronic Data Sheets (TEDS). Present Motes comprise an array of six sensors, which physically interact with the environment. The sensors deployed for present design are LM 35 for temperature, TGS 2620 for Alcohol, MQ-6 for Liquid Petroleum gas, MQ-135 for Ammonia, MQ-6 for carbon monoxide and MQ-135 for Hydrogen Sulfide gas. The sensor outputs are transducted by using proper signal conditioning circuit [Hernandez (2006)]. The values of the parameters, in real units, are also displayed on the smart LCD. Moreover, to fulfill the design requirements of the sensor mote and to ensure networking capabilities for wireless communication, the ZigBee device is interfaced [Lee (2013)]. The details regarding designing of sensor motes is discussed in [Mane-Deshmukh (2016)] [Mane-Deshmukh (2013)].

According to the different industrial structures, industries are widely spread over large area with occupying different shapes. Moreover, at different locations, within the specified area, the variation in physiochemical parameters occurs, may be due to different process carried out at different locations in industries. This is the realization of Site Specific Variability (SSV) in the data.

According to the objectives of the present research work, the five sensor motes, Mote 1 Mote 5, have been designed and depicted in figure 1(a) - 1(e). Figure 1(f) shows, the coordinator node designed to facilitate the design of Base Station.

As depicted in figure 1(a-e), the sensor motes are designed about PIC microcontroller as computing unit and are associated with ZigBee devices as the RF modules. The ZigBee devices are interfaced to the serial port of the microcontroller. The stacks of the ZigBee devices are configured as per the need of establishment of the present WSN. Motes are powered with the rechargeable battery. Moreover, the Solar panel is used to charge the battery. This helps to enhance the life of the sensor mote. The WSN is dedicatedly designed for monitoring of typical industrial environmental parameters, wherein the motes should be systematically localized. The sensor mote is realization of an embedded system. Therefore, firmware is developed in CCS IDE in embedded C environment. In fact, the firmware encompasses the philosophy of RTOS, wherein the tasks have been created to perform dedicated applications. The pre-emptive scheduling mechanism is involved in current application. The firmware, in synchronization with operation of on-chip as well as off-chip resources of the microcontroller, executes continuously and helps to collect the physical data in real time.

Designing of the Base Station

As per the architecture of the wireless sensor network (WSN), the motes have been designed and routed by utilizing ZigBee technology. The motes collect and disseminate the site specific data by establishing cooperative wireless communication to the base station. Indeed, the base station should be smart to demonstrate the site specific data. Deployment of base station is inherent for any wireless sensor network as all active sensor mote forward the sensed valuable information to base station. A base station collects data and securely manages the database, also retrieve same when required. Base station not only collects information from the distributed sensor motes within investigation area, but it facilitates the remote programming of the typical sensor mote RF modules if necessary. The base station [Mane-Deshmukh (2016)] [Mane-Deshmukh (2013)] is integration of hardware as well as graphical user interface (GUI) firmware. The hardware composed of coordinator (Sink Node), which is head of the all sensor motes (End Devices) of the entire network or of typical cluster of the motes and Personal Computer (PC). Coordinator is also a node having full functionality in the WSN. It is associated with the RF trans-receiver and performs the task of collection of the information given by all members of the WSN. In fact, structure of ED and SN is identical. However, the coordinator node has to be configured in this mode by employing XCTU software. To establish the base station, the PC of sufficient specification is essential. A suitable GUI is also developed to facilitate the base station to make it smart [Mane-Deshmukh (2018)].

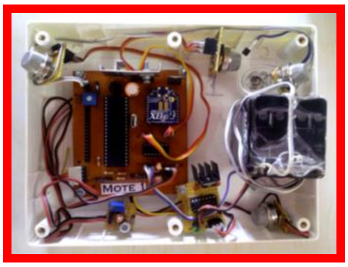
For present research work the readly available motes [Mane-Deshmukh (2018)].are taken and its wireless sensor network is configured and discussed through following point.

Configuration of Wireless Sensor Motes to Ensure Networking

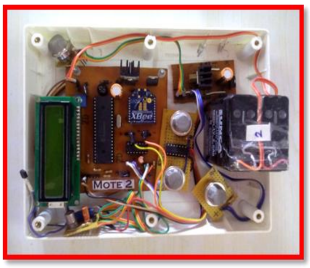
As discussed earlier, the wireless sensor mote is the realization of an embedded technology and supports the design of STIM (Smart Transducer Interface Module) featured as per IEEE 1451.6. According to these technologies, for sensor mote, the Network Capable Application Processor (NCAP) is an inherent part to ensure the wireless communication [Nadimia (2008)]. Therefore, the ZigBee device satisfies the need of NCAP and hence for present mote the ZigBee devices are deployed to ensure wireless communication in desired topologies. The ZigBee technology is supported by IEEE 802.15.4 standards and provided with typical stack for wireless communication. Out of the four layers of the stack, the two layers PHY and MAC layers are given by the IEEE 802.15.4 standards. However, the MAC layer may be configured as per the requirement. The two layers, network layer and application layer can be configured to establish the wireless sensor network. Thus, by configuration of layers of the stack, the ZigBee devices can be configured for proper setting as End Devices (ED), Router (R) and Coordinator (C). Therefore, by configuration of the ZigBee devices, the motes can be configured as End Devices, Router and Coordinator. For configuration of the Motes in desired functionality, the Digi corporation has provided a smart IDE called X-CTU "XBee Configuration and Testing Utility".

It is also known that, the network can be established either in Star, Tree or Mesh topology. Each topology is featured with its own limitations and advantages. Using an X-CTU, the ZigBee devices can be configured to establish the WSN in any of these topologies. Employing X-CTU, the WSN is configured, in the beginning, in Star topology. Moreover, to suit it for industrial deployment, the WSN is configured in the Mesh Topology as well.

Establishment of Wireless Sensor



a



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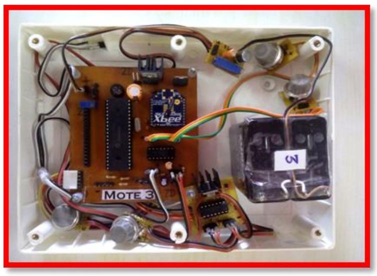

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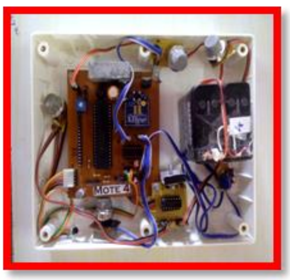

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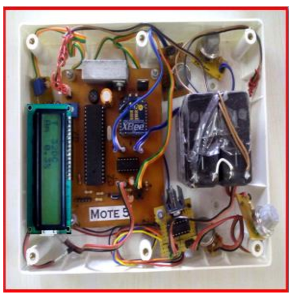

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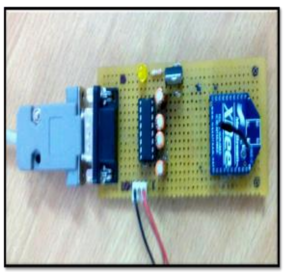

f

Figure 1 (a-e): Wireless Sensor Motes and Coordinator designed to establishment the WSN to monitor Industrial Environmental Parameters

The coordinator is responsible for network establishment and it set up network by scanning for existing Personal Area Network IDs (PAN IDs) from active End devices and Routers within the RF range. Also, it scans for available channels and allows them to join the network of identical PAN IDs. Furthermore, Routers provide path for coordinator and End devices, particularly, when an end device is located away from the coordinator range in the network area. Coordinator sends network association request frame, to associate routers and end devices and receive an association response to verify inclusion of the same into the network

III. Indentations And Equations Quality of Service (Qos) Parameters Of The WSN

The Wireless Sensor Network of five sensor nodes (Motes), coordinator and the Base Station is developed for monitoring of environmental parameters of the industrial sector. The present network is deployed in Star as well as Mesh topology depending upon the area of the coverage and infrastructural obstacles present within the WSN area. Therefore, before on site implementation, the performance of the WSN should be investigated and optimized to improve Quality of Service (QoS). The major parameters, which are considered for performance evaluation of any Wireless Sensor Network (WSN) are Received Signal Strength Indicator (RSSI) [Alhasanat (2014)], Link Quality Indicator (LQI) [Rasin (2009)], Packet Reception Rate (PRR), delay time and packet loss. The RSSI is the signal strength level of a wireless device measured in dB of the last received packet. It could be defined as a ratio of received power to the transmitted power of last packet.

IV. Experimental Set Up For Measurement Of WSN Parameters

As discussed earlier, two environments, indoor and outdoor environments, are considered for investigation of WSN parameters. The WSN parameters to be investigated to present the Quality of Service (QoS) of the WSN are RSSI LQI, Packet Reception Rate (PRR) and delay time [Rorato1 (2013)]. For measurement of parameters such as RSSI, LQI, PRR, etc the development tool X-CTU is playing commendable role. This X-CTU has the dedicated module, which depicts the data regarding RSSI and LQI. To obtain these values, the X-CTU has the function called Range Test. Upon execution of this function at the Base station, the X-CTU demonstrates the values of RSSI and LQI as well. The WSN of five motes is established in indoor as well as outdoor environment. The values of RSSI and LQI are measured with increase in the distance from base station.

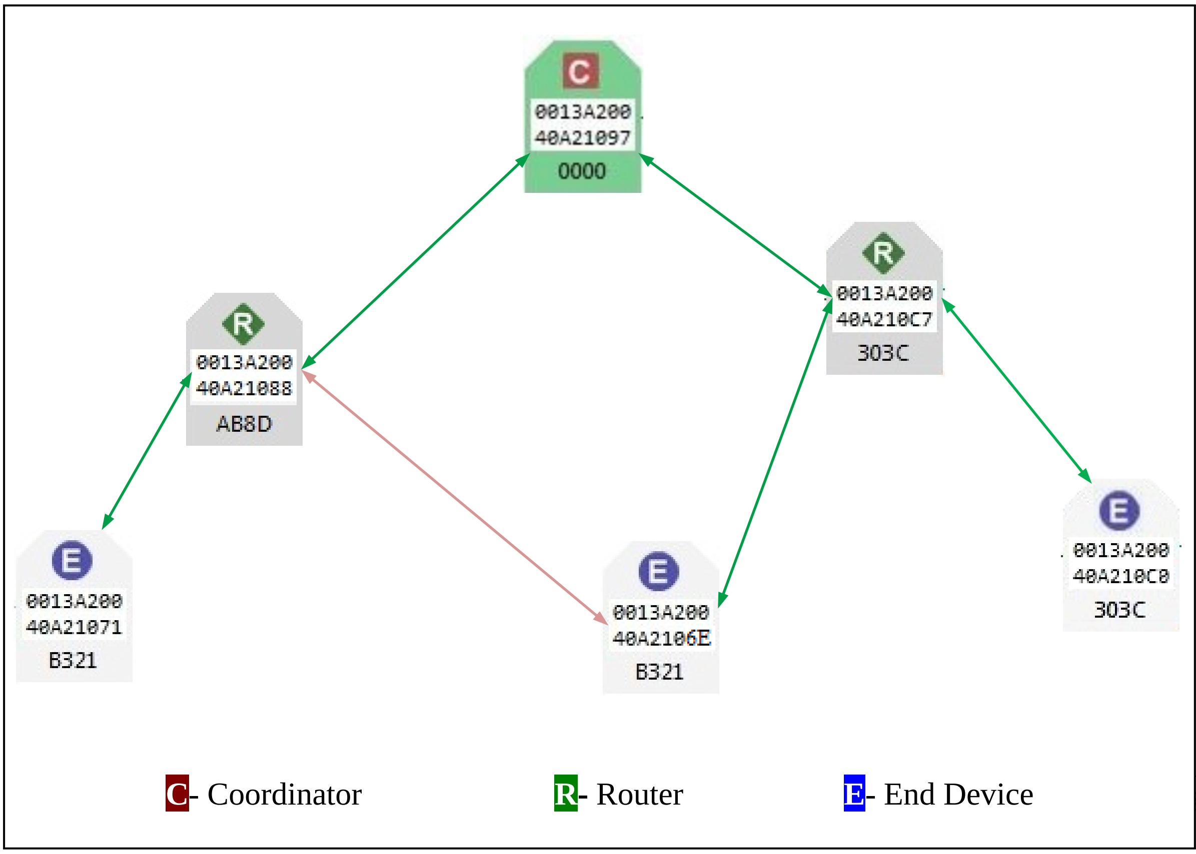

Figure 2: Mesh Network Setup of Wireless Sensor Network under Investigation.

Figure 3: Experimental arrangement of motes and the Base Station for measurement of WSN parameters for outdoor deployment.

Experiment of measurement of RSSI and LQI is carried out for five motes. However, typically two motes having ZigBee devices of serial number 13A20040A21097 and 13A20040A21088are configured as coordinator. For this configuration, only Personal Area Network (PAN) is configured to 9 (PAN ID = 9) using X-CTU and all other parameters are kept for factory setting and firmware is updated. However, during present investigation all motes, having deployed, are participating to realize the facets of wireless sensor network. The Base station is located at fix point and the motes under investigation are moved. By increasing distance (d_m) of each mote from the base station, the parameter values are measured and used for interpretation. Similarly, these parameters have been studied for investigation of QoS parameters for outdoor environment. The WSN under investigation is established on open ground of wide area. The base station is placed at one site of the huge ground and motes are moved for different distances away from the base station and values of RSSI and LQI are recorded with increase in distance (dm) of mote from Base station. Experimental arrangement for outdoor development is depicted in figure 3

V. Results and Discussion

For realization of Quality of Service (QoS) of the WSN, the network parameters such as RSSI, LQI PRR, DT, etc are have been investigated for both indoor as well as outdoor environment and results of investigation are interpreted through subsequent sub sections

VI. Conclusion

Wireless Sensor Network of five sensor motes have been successfully designed and established to investigate the Quality of Service (QoS) parameters of the WSN. The investigation is carried out for indoor as well as outdoor environment. The parameters such as Receiver Signal Strength Indicator (RSSI), Link Quality Indicator (LQI), Packet Reception Rate (PRR), Delay Time (DT),etc, have been investigated. For estimation of the value of RSSI and LQI, the software X-CTU is deployed. However, PRR and DT are estimated from instantaneous value of recorded by the GUI of the base station. The value of RSSI and LQI are systematically decreasing with increase in the distance of mote from the base station. Moreover, these values are sufficiently high, indicating good quality of the signal reception within area of investigation. The PRR values are in the range from 96% to 100%. This supports the fact that the data loss is very rare. On investigation of value of DT, it is found that average latency is also very less.

From results of investigation, it can be conclude that, present WSN is providing good QoS for establishment of the Personal Area Network (PAN) for industrial environmental parameter monitoring.

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