AC 2009-1064: APPLICATION OF WIRELESS SENSOR NETWORKS IN A MIDWESTERN MANUFACTURING COMPANY

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APPLICATION OF WIRELESS SENSOR NETWORKS IN A MIDWESTERN MANUFACTURING COMPANY

Abstract

This paper reports the results of the received signal strength index (RSSI) in a Midwestern manufacturing setting in an attempt to design and construct a secured wireless sensor network (WSN) for manufacturing application. The purpose of this wireless application is to replace the existing cables with wireless nodes to enhance workers mobility and reduce the cost of cables' maintenance in a Midwestern agricultural manufacturing plant.

Introduction

ZigBee is a standard form of wireless sensor networks (WSNs) based upon the Institute of Electrical and Electronics Engineers (IEEE) 802.15.4 standard. ZigBee protocol was engineered by the ZigBee Alliance to provide OEMs and integrators with low-power consumption wireless data solution with multiple network structures and secure connections for monitoring applications [1].

This paper describes an experimental study for the design and implementation of a ZigBee IEEE 802.15.4 wireless network to offer low power and low cost wireless networking applications in an industrial setting. The experiment has been driven by the problems associated with the use of the cables in industries such as the high cost of maintenance, limited mobility of workers, and potential hazards. With the ZigBee wireless technology, workers can operate and monitor processes beyond the limitation of cables. Although ZigBee applications are becoming well-known technology for industries, the harsh industrial environments such as electro-magnetic interferences may affect the stability and reliability of the wireless network. As a result, the performance of the wireless network under the harsh industrial environments must be investigated before the deployment of the wireless ZigBee nodes.

In order to overcome the problems associated with the cables and to investigate the performance of the wireless network under the harsh industrial environments, a project has been started at the Industrial Technology Department of University of Northern Iowa. The project was preceded first with a testing phase to verify that the harsh manufacturing environment will not affect the performance of the wireless sensor network. Figure 1 illustrates the DM 1810 wireless development kit used to test and analyze the performance of the wireless ZigBee network in a manufacturing environment. Instrumentation setup is demonstrated in Figure 2. It contains 11 nodes (one base station, five routers, and five field nodes) and three IM-1810 module boards.

Each node is known as DM 1810 module mounted to the board IM-1800 module as illustrated in Figure 3.

The DM 1810 development kit operates on 916 MHZ frequency. It can hold up to 1 base station per network, and 1023 field nodes (including 15 as routers). It can be set up into three network topologies: point-to-point, star, and mesh as seen in Figure 4.

Literature Review

Market demands for high quality products has led to more research of wireless sensor networks (WSN) to monitor manufacturing processes and control operations. The research is rich in measuring variables related to manufacturing that could increase quality, productivity, and reduce cost. Introducing wireless sensors to the manufacturing processes is not new; it started decades ago with the introduction of wireless transmission media by Konig, Altintas, and Memis[2]; their research is based on recent studies in the sensor technology to assist in machining grinding operations. The criterion was to measure the acoustic emission (AE) signals in RMS value to produce smooth surface finish in a minimum grinding time. They used the AE sensor and transmitted the signals to a receiver where a rectifier is used to rectify and analyze the signals. The results of using sensors in the grinding operations have found a correlation between the sensors and the surface roughness. This means that sensors can be used as process monitoring devices report the quality of operations in manufacturing. Furthermore, the research indicated an increase of 5-10% of productivity in using such an on-line monitoring technique which shows that sensors can play an important role in manufacturing processes if they are managed well for specific purposes. For example, instead of using just one sensor to measure the parameters, a multi-sensor system can be used to give a reliable system that indicates the tool wear state. Such system will be able to measure several features simultaneously [3]; they investigated the AE frequency, AE energy, and surface finish as inputs for tool wear prediction in milling operations measured by neural network nodes. Their study was empirical because the experiment showed that the performance of the neural network has improved when combining features together simultaneously and consequently using multiple sensors. A similar research by Govekar, Gradisek, and Grabec [4] ensures using the multiple sensor system to measure the AE signal of machining processes as an approach to improve the experiment characterization while application of nonlinear time series analysis (off-line analysis) is used to analyze the cutting process characterization. Such applications would open the eyes to more useful research of sensors in the manufacturing field and expects more possibility of using such technology in the future research according to Chung and Geddam [5]:

"Multi-sensor systems remove the drawback since loss of sensitivity in one sensor domain can be offset by information from other sensors within the system, thus allowing high decision making capability over a wide range of process conditions to be possible."

They also concluded that using sensors is not only involved to detect and monitor machining processes, but they can also help in the decision making of the manufacturing systems if they are used to monitor certain features within the processes [5]. Thus, the use of the sensors in manufacturing is not a new idea or technology, it has been there for some time and researchers are still trying to figure out ways to integrate this feature in different shapes and kinds with manufacturing process. The literature, so far, has proved, the need of using the sensors in the industry as a need for the manufacturing operations as it increases productivity, enhances the performance of machines as monitoring device, and acts as a decision making device. Sensors also could be used for process quality characteristics in machining processes. Quality can be maintained in-process and in real time monitoring using system of multiple sensors to overcome nonconforming parts that might be manufactured; Ertekin et. al [6] used multiple sensory system to measure the surface roughness values showing that "their integration gives more reliable and accurate prediction of above tolerance than when using a single sensory feature." Ertekin et al. contented that using the multiple sensors can provide the information collected to plan the time for the change of the tools. In other words, it indicates the quality characteristics of the tools.

Wireless sensors networks has been utilized lately in many applications: Lighting controls, Automatic Meter Reading (AMR), smoke and CO detectors, wireless telemetry, HVAC control, heating control, home security, environmental controls, drapery and shade controls, etc. In industry, WSNs devices can now measure almost any variable in the plant such as current, voltage, or even vapors; this is called condition monitoring as stated by Apprion [7]. Video monitoring is one application which that uses wireless cameras and alarm systems sensors that can increase safety and security of plants. Advantages of such wireless systems from the industrial point of view are probably best described by Apprion as follows:

1. Reducing hazards and increasing safety.
2. Reducing costs of manual monitoring and inspection
3. Reduce the cost of wiring systems.
4. Helps in faster and better decisions with incident response.
5. Increase productivity as it provides better mobility for the workers.

Methodology for Deploying the Wireless nodes for Testing Phase

The received signal strength index (RSSI) is used to test the signal strength between a node and the base station. To best rate this value, it is recommended to compare the results between two environments. Therefore, the first environment was selected to be in a manufacturing plant of a Midwestern company, while the other was selected to be in an office area with no serious activity of electro-magnetic interferences. Measurements of the RSSI of the wireless nodes was taken at eight locations for each facility (manufacturing plant and office area) using the DM 1810 controller software provided by the kit as seen in Figure 5. The values of the RSSI were saved in a log file (see Figure 6) and then the mean and the standard deviation of the RSSI were calculated for each location and demonstrated respectively in Figures 7 and 8.

Comparing the mean RSSI values shown in Figure 7, for short distances the mean RSSI values in the manufacturing plant are lower than those in the office area, but a stable and reliable communication link between ZigBee nodes and the base station can still be maintained. For long distances, there is almost no difference between the mean RSSI values in the manufacturing plant and those in the office area. Figure 8 confirms these results when comparing standard deviation of the RSSI values; on short distance, the variation in the RSSI of the manufacturing plant was less than in the office area due to the wide space and the lack of the concrete walls which is the case in the office area. However, it is noticed that on long distances RSSI values are not affected by the harsh industrial environment. Therefore, wireless nodes can be deployed in this manufacturing plant securely.

Future Implementation

As the testing phase was completed, the proposed project is in progress to design and build a WSN capable of replacing the cable between a potentiometer and a PLC. In order to accomplish the project, the following three configurations must be undertaken: (1) the connection between potentiometer and the wireless node. The function of this configuration is to detect information from the potentiometer and convert the information into a data format suitable to be transmitted with WSN. (2) Wireless connection between the wireless node (at the potentiometer) and the wireless base station (at the PLC). The function of this configuration is to provide a wireless solution replacing the cable between the potentiometer and the PLC. (3) The connection between the wireless base station and the PLC. The function here is to convert the data received by the wireless base station to a new signal format that can be accepted by the PLC.

After completing the project, the expected outcomes will result in arousing the reseracher's' interest to deliver more productive ideas towards innovation for creating wireless solution for manufacturing processes. The project itself will be a model that could be repeated for other applications as well. It will be a great learning experience that both undergraduate and graduate students could invest different skills such as C-programming skills and electronics knowledge. Furthermore, Engineering Technology programs at University of Northern Iowa could witness more collaboration between the institute and the industry.

Proposed WSN as an Undergraduate and Graduate Education Teaching Module

WSNs have attracted significant interest from academia especially in computing programs and industry. One of the challenges that face the Education Technology (ET) is exposing students to various hardware and software courses that can be provided from the Electrical Engineering program because WSNs applications require the students to interact with the devices to support student projects. Laboratories therefore, should facilitate teaching WSNs or related core such as Wireless Communication Networks by providing dynamic facility system where students can explore the WSN devices on their own and come up with their own WSN applications [8].

The Electrical Engineering Technology program at the University of Northern Iowa is prepared for the ABET accreditation and one significant missing component was the lack of laboratory tools in wireless communication networks and electronics communication classes. This proposed applied WSN project is already introduced to the curriculum as a teaching module in the wireless communication class. Undergraduate students who are mostly hired part time by local agricultural manufacturing plant enjoyed the theoretical and practical aspects of the project. The department of Industrial Technology recently established a new MS in EET graduate program and one class titled Advanced Wireless Sensor Networks will be using this lab setup as a laboratory component beginning Fall 2009 semester. The laboratory component will include investigation of other industrial application, electromagnetic interference (EMI) issues in industrial environments. According to the company requirements, the frequency of 2.4GHz cannot be implemented due to the incompatibility issues associated with the surrounding electronic equipment. Therefore, one objective of this project was to verify that 916 MHz frequency range devices can be deployed securely in the manufacturing plant without affecting operation.

Conclusions

The testing phase was completed successfully and shows that the tested manufacturing plant is suitable to deploy wireless sensor networks for industrial applications. These results make the current researchers in the Industrial Technology Department at the University of Northern Iowa full of confidence to proceed with the proposed project. Now work has progressed to design and implement a wireless application to improve manufacturing process. On the other hand, the testing phase turns to be a very useful procedure to train both undergraduate and graduate students on how to apply their knowledge learned from curriculum into practical problem solving.

Acknowledgements

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Figures

Figure 1: DM 1810 Wireless Development Kit

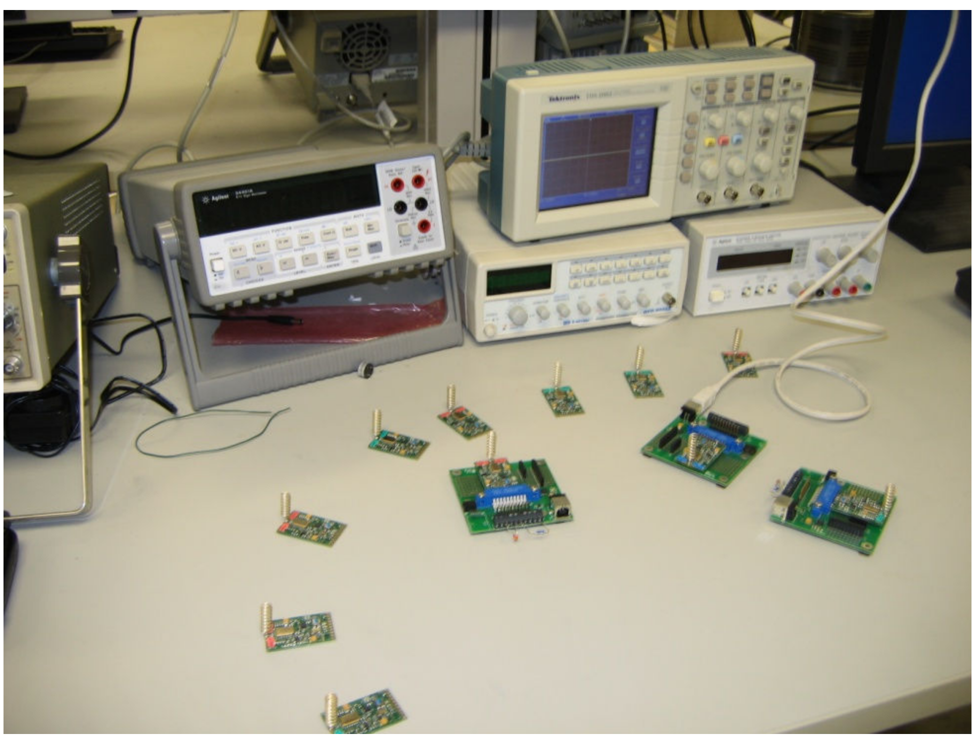


Figure 2: Instrumentation Setup

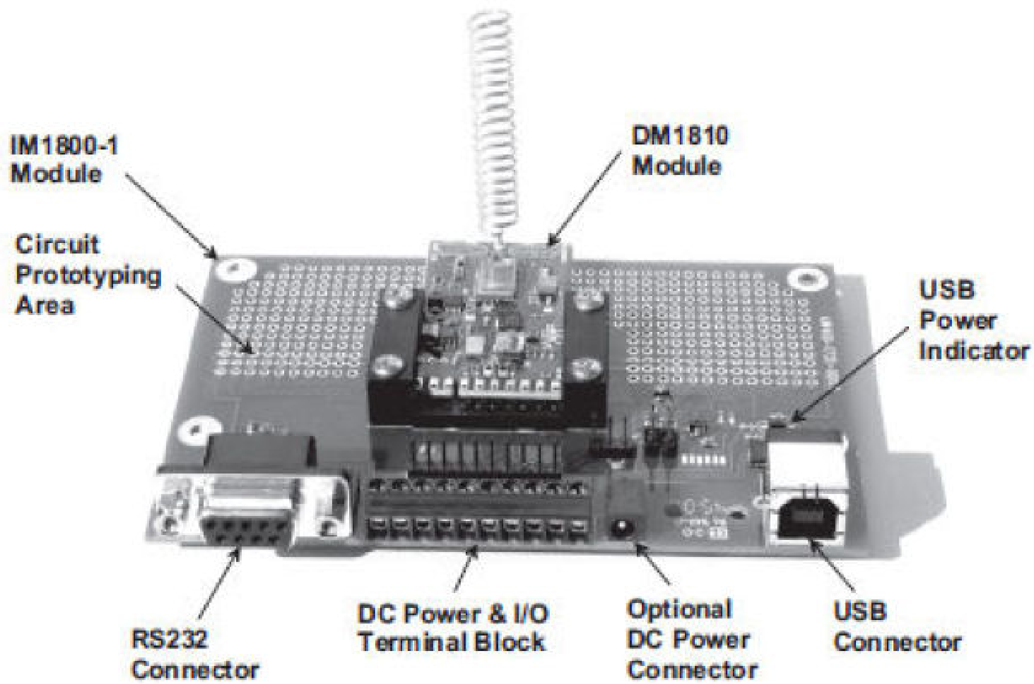


Figure 3: IM 1800 with the DM 1810 node

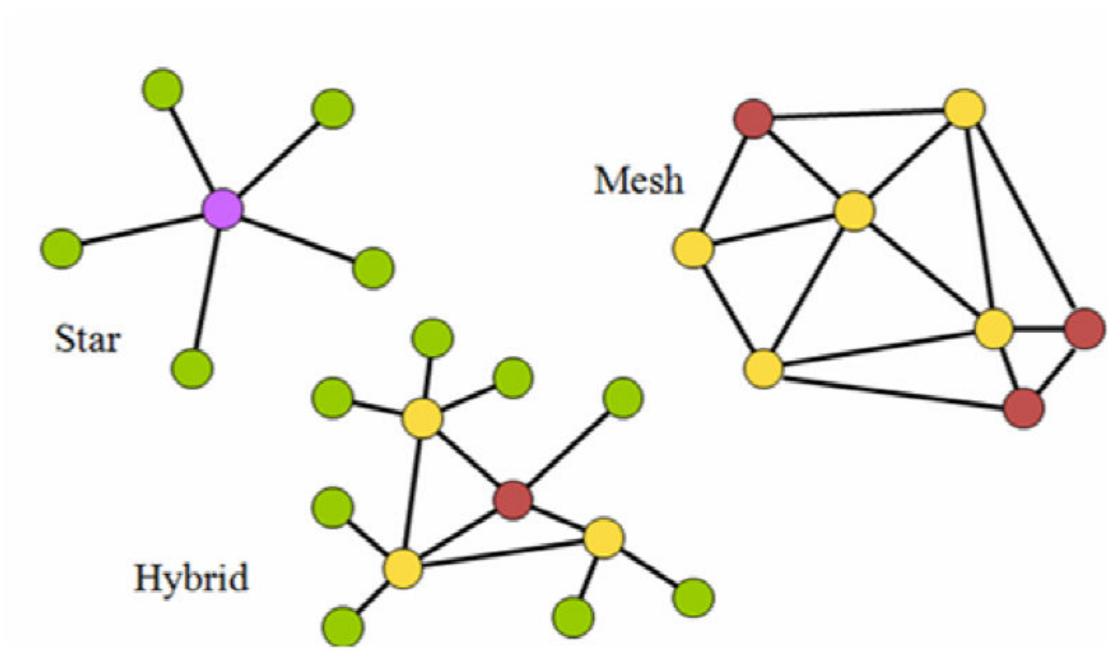


Figure 4: Wireless Topologies

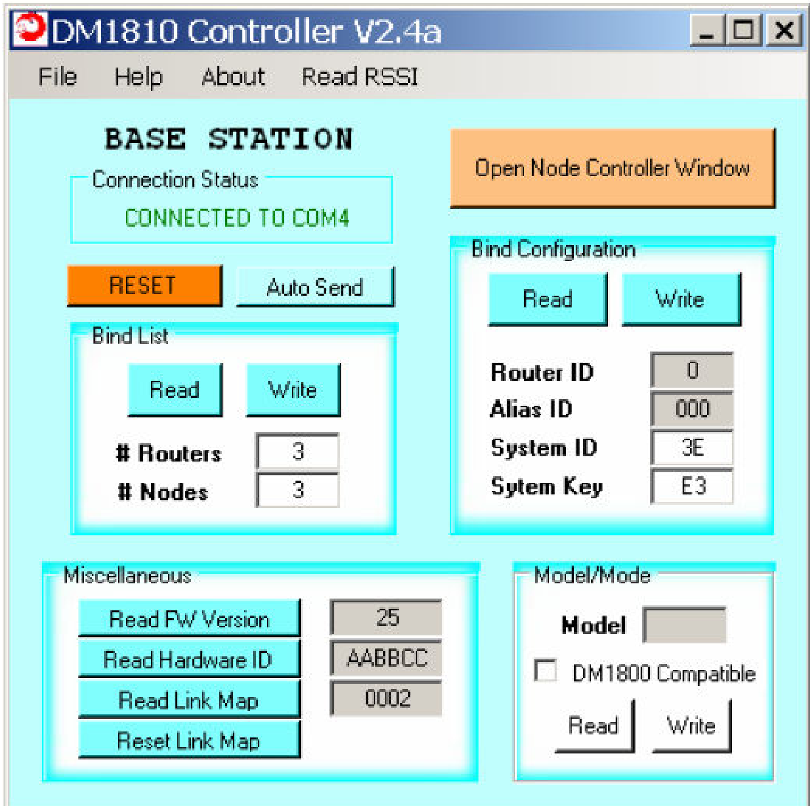
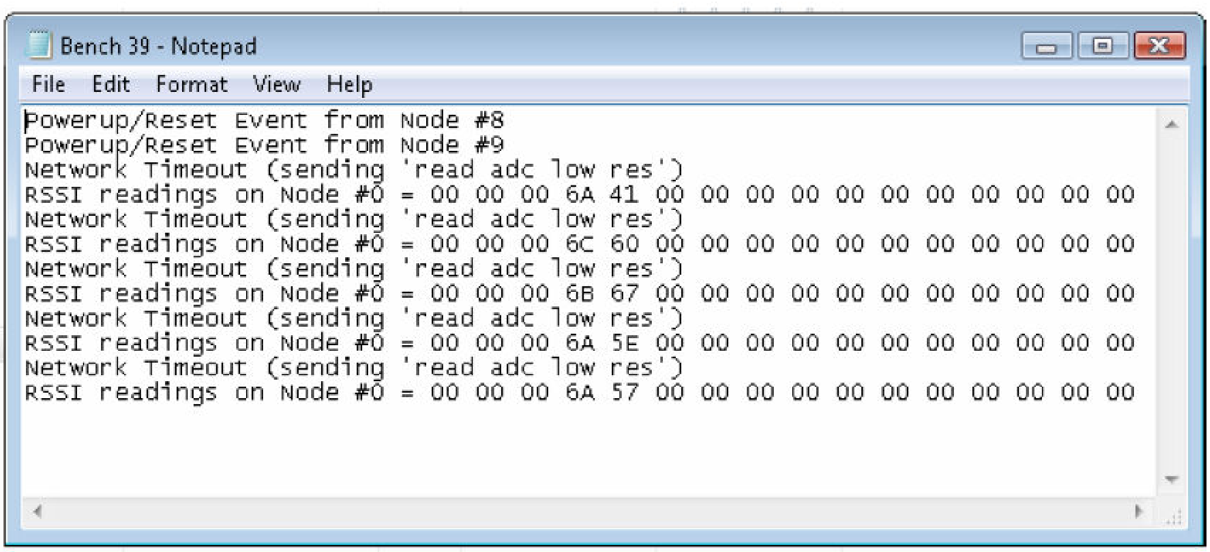


Figure 5: Controller software provided by the 1810 DK




```
Powerup/Reset Event from Node #8
Powerup/Reset Event from Node #9
Network Timeout (sending 'read adc low res')
RSSI readings on Node #0 = 00 00 00 6A 41 00 00 00 00 00 00 00 00 00 00 00
Network Timeout (sending 'read adc low res')
RSSI readings on Node #0 = 00 00 00 6C 60 00 00 00 00 00 00 00 00 00 00 00
Network Timeout (sending 'read adc low res')
RSSI readings on Node #0 = 00 00 00 6B 67 00 00 00 00 00 00 00 00 00 00 00
Network Timeout (sending 'read adc low res')
RSSI readings on Node #0 = 00 00 00 6A 5E 00 00 00 00 00 00 00 00 00 00 00
Network Timeout (sending 'read adc low res')
RSSI readings on Node #0 = 00 00 00 6A 57 00 00 00 00 00 00 00 00 00 00 00
```

Figure 6: Log file containing measurements of the RSSI values

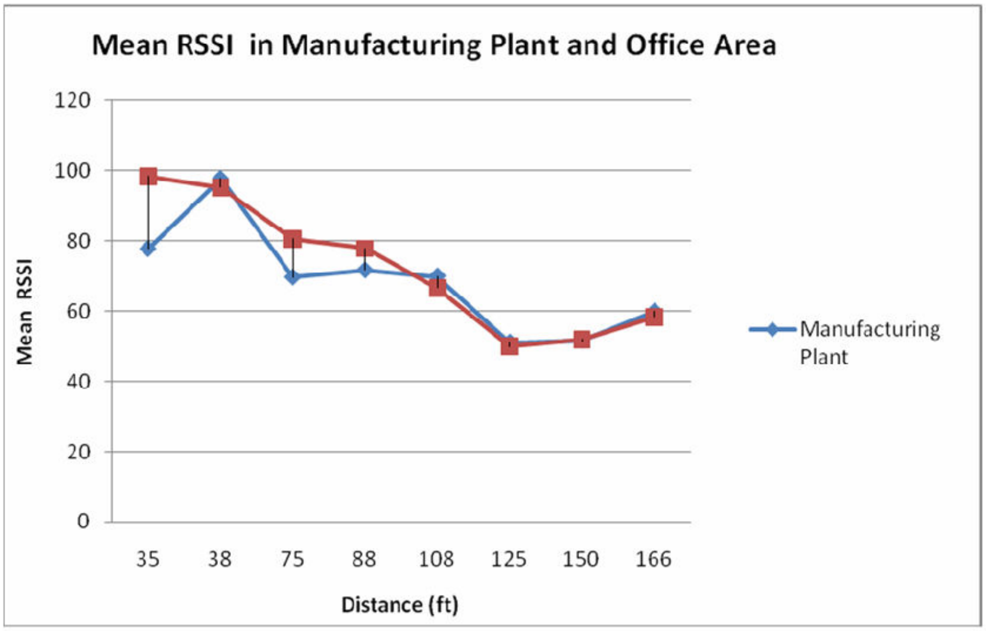


Figure 7: Mean of RSSI Values

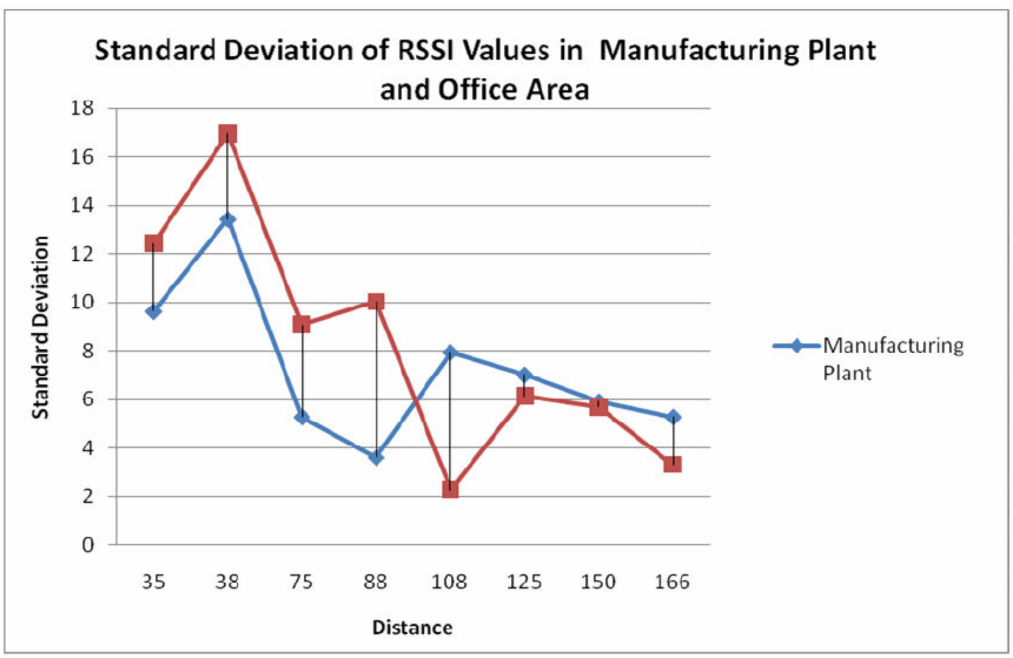


Figure 8: Standard Deviation of RSSI Values

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