Devising a Dust and Noise Pollution Monitoring System for Textile Industry

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ABSTRACT

Textile industry is one of the most labor-intensive manufacturing sectors in developing countries such as Bangladesh, India, Pakistan, etc. During the manufacturing process, the textile machinery produces a high concentration of cotton dust as well as a high level of noise that affects workers' health, which eventually affects the production rate. To improve workplace health and safety, there exist several pollution monitoring systems in the literature that use commercially available sensors to collect data from the environment and send them to online storage (cloud) using wireless networks such as mobile data, Wi-Fi, etc. Although Wi-Fi is the cheapest option to transfer pollution data to the cloud, there is no Wi-Fi network in production areas of textile industries. Hence, state-of-the-art approaches are not readily applicable there. To this extent, in this paper, we propose a cloud-based dust and noise pollution monitoring system using a wireless sensor network. For this purpose, we transfer the sensor data from the production areas to the nearest Wi-Fi zone (e.g., office room) using nRF modules. After that, we upload the sensor data to the cloud using the Wi-Fi network and visualize them graphically. We evaluate our system inside several textile industries that demonstrate the applicability of our proposed approach in real cases.

CCS CONCEPTS

• **Computer systems organization → Real-time systems**; **Sensor networks**; **Embedded systems**.

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KEYWORDS

Dust pollution, Noise pollution, NRF24L01, Wireless sensor network, IoT, Textile industry

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1 INTRODUCTION

The textile sector is a major laborious intensive industry in today's world and employs approximately 75 million workers globally [21]. Bangladesh is the world's second-biggest exporter of clothing after China [18]. Ready-made garments make up 80 percent of the country's $24 billion in annual exports and 15 percent share of GDP. Currently, the textile industry accounts for 45% of all industrial employment in the country and contributes 5% of the total national income. Despite its contribution, this sector faces massive challenges [4].

The textile sector is one of the most polluting industrial sectors. During the spinning, weaving, and knitting process, textile machinery produces a high concentration of cotton dust in the air [17]. Workers in spinning mills experience constant and repeated exposure to this dust over months and years that result in several respiratory diseases such as byssinosis [13], chest tightness, shortness of breath, asthma, tuberculosis, lung function loss, and other diseases [1]. The developing countries such as Bangladesh, India, Pakistan, etc. are still far from improved dust control systems resulting in a large number of textile workers continuing to suffer from respiratory illnesses [21]. Along with the dust, this industry also produces a high level of noise. Because we cannot keep the machine as it is as it generates noise and secondly a lot of costs is involved on the machines is very high. Such type of high-level noise can damage the eardrum and cause hearing loss of the workers.

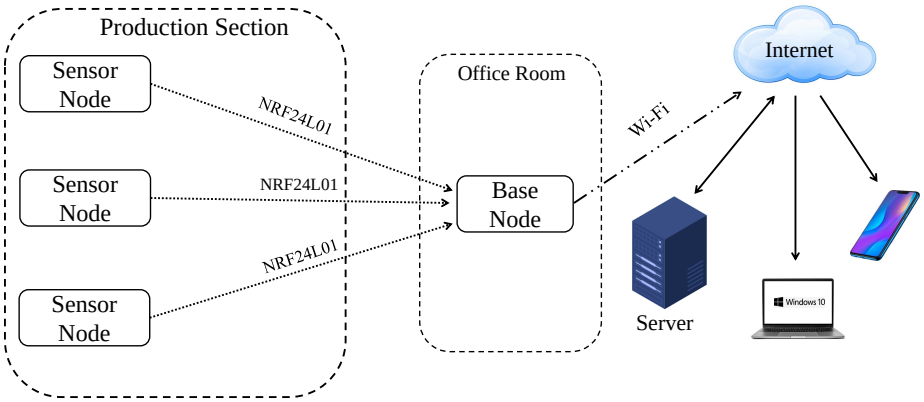


Figure 1: Block diagram of our proposed system

Besides, it can cause headaches, heart diseases, annoyance, anxiety, sleep disorders, and others [13]. Since these illnesses affect workers' health, productivity, and quality of life severely, the textile authorities need to use improved machines that reduce pollution. Besides, authorities should monitor the level of pollution in the industry area regularly to take further steps.

There is a significant number of research works have already been done on dust and noise detection. But not many works are available that are applicable for industrial implementation. For instance, Budde et al., [6] designed a sensor concept in which the fine dust measurement is carried out with the aid of a passive clip-on attachment for a smartphone camera. However, we need to use an individual smartphone with each sensing device, which is costly. Siregar et al., [20] proposed an integrated pollution monitoring system for the smart city. This can sense humidity, noise, and temperature. However, it needs an expensive 3G network to upload the data to the cloud. An IoT-based pollution monitoring system using Raspberry Pi was proposed by Saha et al., [19]. It can monitor the air quality index of a region and upload it using a cheap Wi-Fi network. Nevertheless, the problem is that there is no Wi-Fi network in the production areas of textile and this work does not deal with sound sensing. Hojaiji et al., [10] proposed a low-cost dust monitoring system that uses Bluetooth for data transmission. These proposed systems have a really low range in data transmission and only one-to-one data transmission is possible. So multiple sensing nodes are not possible. So data can not be monitored on a large scale. Hence, these systems are not applicable in the industry.

To address those limitations, we propose a low-cost, customized, and portable dust and noise-monitoring device that provides real-time pollution information.

Based on our work, we make the following contributions to this paper:

- We propose a low-cost multi-node pollution monitoring system that measures the dust and noise pollution levels inside the textile industry.
- We design a wireless sensor network using nRF and WiFi modules to transfer the sensor data from production areas to the cloud. Here, the nRF modules transfer the sensor data to the nearest WiFi zone and the WiFi module uploads the sensor data to the cloud.
- We develop a web application to visualize the indoor dust and noise pollution levels graphically.
- We evaluate our developed system in several textile factories, which demonstrates the applicability of our proposed approach in real cases.

2 BACKGROUND AND RELATED WORK

In this section, we discuss the background of this study and studies on existing monitoring systems.

2.1 Dust and Noise Pollution in Textile Industry

Cotton dust is defined as dust present in the air during the handling or processing of cotton, which may contain a mixture of many substances including ground-up plant matter, fiber, bacteria, fungi, soil, pesticides, non-cotton plant matter, and other contaminants. The Micro-dust comprises 50-80% fiber fragments, leaf and husk fragments, 10-25% sand and earth, and 10-25% water-soluble materials [13]. Nearly about 40% of the micro dust is free between the fibers and flocks, 20-30% is loosely bound, and the remaining 20-30% is bound to the fibers [13]. The machinery of the textile industry also produces a high level of noise that causes hearing loss of workers [1]. Any machine while running is prone to develop noise and textile machines have no exception for the same.

2.2 Existing Monitoring Solutions

This section describes existing monitoring systems' limitations and contributions and proposed solutions to those limitations.

2.2.1 Studies on Sensing Pollution Data. Budde et al., [4] deals with the challenge that how fine dust can be measured using cost-effective sensors and with high resolution, both spatially and temporally. Alam et al., [2] proposed a system with a single sensor node containing multiple sensors with raspberry pi to monitor dust, noise, toxic gases, and temperature in the air for making a smart city. Parmar et al., [16] devised an IoT-based system using raspberry-pi, NUCLEO F401RE microcontroller, and ESP8266 Wi-Fi module to create the networking system which measures toxic gases in the air. These systems proposed a single node which is not enough to cover a large area of textile factories and is not suitable for any

industry application. They used high-cost modules like raspberry pi, ESP8266 for networking, and high-cost sensors.

2.2.2 Studies on Sensor Data Transmission. Hojaiji et al., [10] proposed a low-cost dust monitoring system that uses Bluetooth for data transmission. Choi et al., [5] proposed a dust monitoring system that transmits the dust sensor data to a smartphone via a Bluetooth module. All these systems have a really low range in data transmission and only one-to-one data transmission is possible. So multiple sensing nodes are not possible. Hence, these systems are not applicable in the industry.

Siregar et al., [20] Proposed integrated pollution monitoring system for a smart city. This can sense humidity, noise, and temperature. As a communication protocol, they used 3G connectivity to store the data into the cloud system. Another pollution monitoring system using Raspberry Pi was proposed by Saha et al., [17]. Many possible solutions have been highlighted in this paper, as to how they can monitor air and sound pollution levels along with humidity and temperature using the Internet of Things. Zhilarasi et al.,[6] have proposed a monitoring technique to monitor the various environmental parameters using a Zigbee wireless sensor. Fioccola et al., [7] have proposed Polluino, an Arduino-based air pollution monitoring system. Kim et al., [12] have designed a monitoring system that uses an environmental parameter analyzer and sends the results to a server through an LTE communication network.

Khan et al., [11] used multiple sensors with ATmega328 microcontroller and GSM module to send data to the server. But GSM module is expensive so less feasible for the application in a textile factory. Li et al., [14] proposed a system that uses optical air quality sensor GP2Y1010AU0F MQ138, formaldehyde gas detection sensor, and a temperature and humidity sensor module DHT11 and transfer the data by Nrf24L01 module. But it uses one-one Nrf24L01 connection, can not send the data very far. Hence, not applicable in the textile industry. Song et al., [22] proposed a system of distributed fire alarm system that uses NRF24L01 to transfer and store data on the computer. But, as it only uses the NRF24L01 module for data transmission, can not transmit the data very far. Nimmaka et al., [15] proposed an indoor pollution monitoring system using MQTT protocol using ESP32 to send data via Wi-Fi that is not suitable in an industry.

2.2.3 Studies on Sensor Data Visualization. Telagam et al., [24] proposed a system that allows smart cities to monitor air quality conditions on a Desktop/Laptop computer through an application designed using graphical programming based LabVIEW software. Gunawan et al., [9] monitors air pollutants in LCD display.

We offer a new device by addressing some limitations, which is a low-Cost dust and noise pollution monitoring System for Textile Industry. It can detect not only dust density, noise level but also temperature, and humidity of this workplace.

3 PROPOSED METHODOLOGY

In this section, we describe our system design, how we implemented and the working process of our proposed system.

Table 1: Costing of necessary hardware equipment

Component name	Model name	Qt	Unit price (USD)
Sharp GP2Y1010AU0F Dust Sensor	SEN-00076	3	40.56
Sound sensor	MOD-00214	3	4.44
DHT22 Sensor Module	SEN-00186	3	17.34
NRF24L01 RF board	WIR-00076	4	17.96
Arduino Mega 2560	ARD-00047	3	31.44
Power Bank	Baseus 10000mAh	4	51.46
Breadboard	MIS-00117	3	3
RTC Module DS3231	GGG-00045	3	7.89
ESP8266 NodeMCU V3	WIR-00093	1	5.76
Total cost			**179.85**

3.1 System Design and Implementation

Our proposed system is composed of sensor nodes, a base node, and a remote server. Sensor nodes send data wirelessly to the base node through the NRF module. Then the base node collects data from sensor nodes and uploads it to the remote server from where real-time sensor data can be monitored through smartphones, laptops, etc.

3.1.1 Sensor Modules. This system contains multiple sensor nodes and each sensor node contains an Optical dust sensor, sound detection sensor (Sen00054), humidity and temperature sensor (DHT22), Controller module (Arduino Mega 2560 R3), DS-3231 clock module, and RF24L01 module.

These sensor nodes (shown in Figure 2a) send data to the base node (shown in Figure 2b) through the NRF24L01 module.

3.1.2 Networking Architectures. We use three sensor nodes that communicate with the base node through the NRF24L01 module. The base node consists of a Wi-Fi module (ESP8266 NodeMCU) and an NRF24L01 module. Then base node receives data from sensor nodes through the NRF24L01 module and uploads it to the server which is shown in Figure 2.

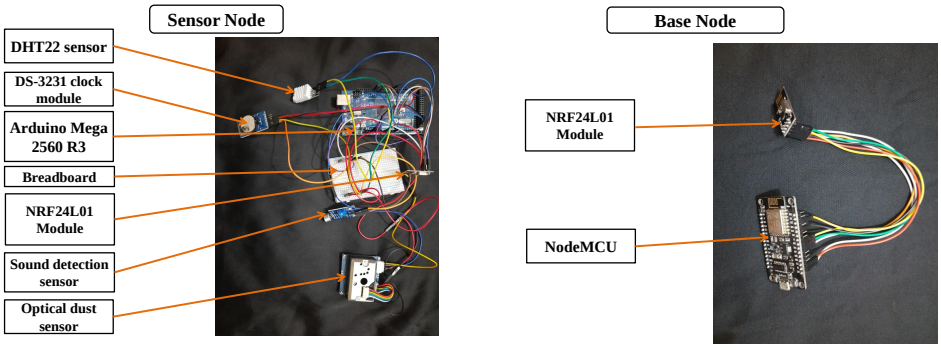
3.1.3 Web Application. The WiFi module makes a request to the webserver. Then the API takes the data from it and inserts these data into the database. When a user tries to access the website, its browser makes an HTTP request to the webserver. And then the backend HTML codes select the data from the database and display them on a webpage.

3.2 Cost Analysis

Costing of our proposed system is shown in Table 1. All the unit prices are collected from TechShopBD [23] and AMAZON [3]. Our system costs a total of 179.85 USD which is cheaper than existing systems. For example, Saha et al., [17] costs a total of 326.54 USD, and Guanochanga et al. [8] costs a total of 572.18 USD which are relatively high prices for industry applications.

3.3 Working Process

This section describes the working process of sensor nodes, the base node, and our web server.



(a) Sensor node of our proposed system (b) Base node of our proposed system

Figure 2: Design of our proposed system

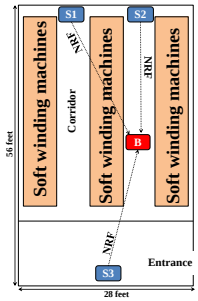


Figure 3: Testing scenario in Gangeetal Thread Factory

3.3.1 Sensor Code. The first three sensor nodes of similar construction measure the dust density, sound intensity, temperature, and humidity of the surrounding environment. The sender node sends the data wirelessly to the single base node through an NRF24L01 module. The base node receives the data by the NRF24L01 module. Then it sends the data to the cloud server through Wi-Fi.

3.3.2 Networking Code. For implementing our system, we combine the sensor codes and add the data transmission code of the NRF24L01 module. We apply this code to the sender node. Then we combine the receiver code of NRF24L01 and the code for posting data on our remote server. We apply this code to the base node. Then, the sensor data starts to transmit to our web server wirelessly after giving power to the multiple sender nodes and single base node.

3.3.3 Web Code. To build the website, we have used the Laravel framework (version 8), and PHP (version 8.0.5). We have made two controllers, one for receiving the input data from Arduino and put them in the database, and another for viewing those data on the webpage. We have shown the data both in the table and graphically. For showing the graphs, we have used Google Charts. To send data from Arduino to the database, we have used the post method. In the presence of WiFi, data have been sent via API.

4 EXPERIMENTAL EVALUATION

We collect real data by testing our device in R.K. Group of Industries, Unique Designers Limited, and Gangeetal Thread Factory (shown in Figure 5). After that, we analyze the data for getting important findings.

4.1 Evaluation of Sensor Modules and Findings

We perform some factory-level experiments to obtain certain data. The experimental work is stated below:

4.1.1 Dust Pollution. The history of parameter data recorded for the dust particle density from day to day is visualized in the form of a graph in Figure 4a. The knitting section and utility section (dirty area) have a high concentration of dust in the air compared to other sections. The spinning section deals with cotton that has a larger size (dirt) than regular dust (particulate matter) hence, less dust has been detected there.

4.1.2 Noise Pollution. The graph is shown in Figure 4b that showing the sound level in different sections. We can see the spinning section has a higher level of noise compared to other sections. The utility section also shows high noise intensity as the boiler and generator exist in this section. Gangeetal Thread Factory has conventional hard winding and soft winding machinery which create high noise, that's why the graph shows the higher value.

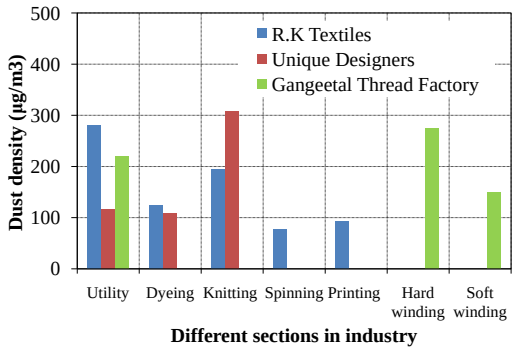
4.1.3 Temperature. The recorded data of temperature in the different floors of two different industries can be seen in Figure 4c. The graph shows Utility section has the highest temperature as a boiler exists there. In a spinning machine, friction between the machine parts and material (cotton) produces heat that makes the section warmer.

4.1.4 Humidity. The recorded data of humidity in the different floors of two different industries can be seen in Figure 4d. Due to the involvement of water in the dyeing and printing sections, more humidity is available there.

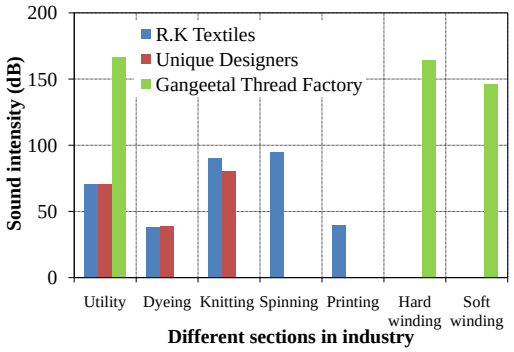
4.2 Evaluation of Networking Architecture and Findings

This section shows the testing architecture of our system for outside and inside of a factory and the latency of data transmission.

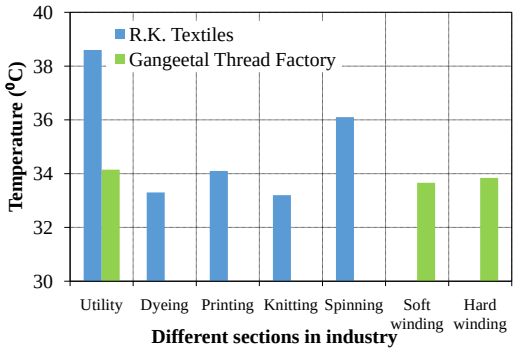
4.2.1 Inside latency. We go to the Gangeetal Thread Factory to test the latency of the system inside a running factory. The testing scenario is shown in Figure 3. We plot Figure 6a from the data obtained. We test for the same distance (20 feet) in every section and find the highest latency in the soft winding section.



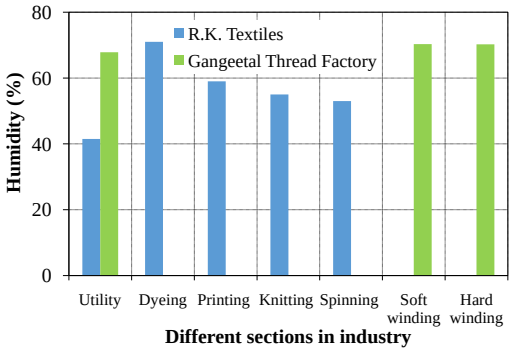
(a) Dust density in three different factories



(b) Sound intensity in three different factories



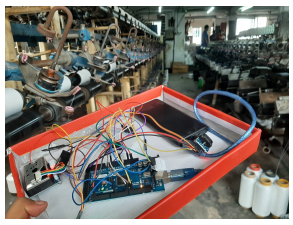
(c) Temperature in two different factories



(d) Humidity in two different factories

Figure 4: Sensor node data in different factories

4.2.2 Outside latency. We go to an open field to test the latency of our device in an open environment. Figure 7 shows our testing architecture. We plot Figure 6b from the data obtained. We find the highest latency for 40 feet and lowest for 10 feet which means latency increases by the increase of distance.



(a) Data collection in Gangeetal Thread Factory



(b) Data collection in R.k Group of Textiles

Figure 5: Data collection in two different factories

4.3 Evaluation of Sensor Data Visualization and Findings

We construct a web server for sensor nodes data visualization. The motivation for displaying the sensor data in a web server is to make the data accessible from anywhere in the world by Wi-Fi or mobile internet connection. Information related to the latency of data also can be acquired from the webserver. Moreover, there are options for viewing the graphical representation of real-time sensor data in the webserver (shown in Figure 8)

5 CONCLUSION

The textile industry in Bangladesh is the most pollutant sector. Many possible solutions have been highlighted in this paper. However, they are so costly and not applicable in industries. This paper presents a low-cost smart device that detects dust, noise, temperature, and humidity level of this workplace. So that, the authority of this industry can take necessary steps to fix the dust amount and noise level at optimum scale. In the future, we will work on it to get data that are more accurate by using better quality sensors. We plan to use the LoRa module to increase the range of our system.

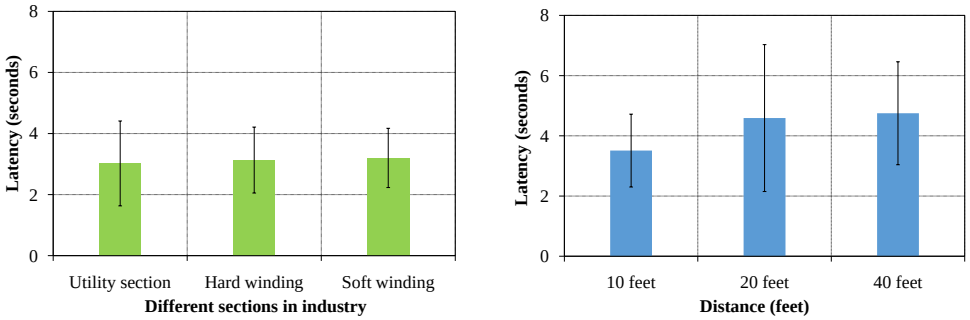
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(a) Latency while testing the device in Gangeetal Thread Factory

(b) Latency while testing the device in an open field

Figure 6: Latency test data in Gangeetal Thread Factory and open field

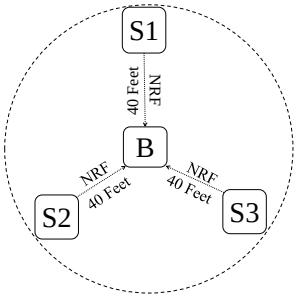


Figure 7: Testing scenario of open field latency

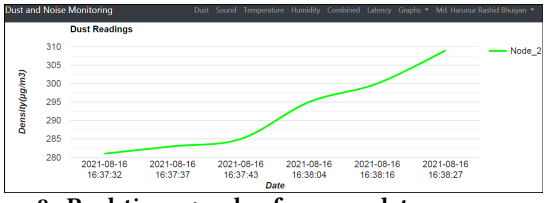


Figure 8: Real-time graph of sensor data on our remote server

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