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Retraction

Retracted: Secure Wireless Networks Based on Fuzzy Logic for Smart HVAC Systems in Small-Scale Industries

Security and Communication Networks

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] S. Sanober, D. K. Goyal, S. Keshari, F. Arslan, and B. N. Dugbakie, "Secure Wireless Networks Based on Fuzzy Logic for Smart HVAC Systems in Small-Scale Industries," *Security and Communication Networks*, vol. 2022, Article ID 3659961, 10 pages, 2022.

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Research Article

Secure Wireless Networks Based on Fuzzy Logic for Smart HVAC Systems in Small-Scale Industries

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The traditional heating, ventilation, and air conditioning (HVAC) system depends on wired mechanical thermostats and regulators deployed at various points in the industrial environment for temperature monitoring. Due to ineffective dynamic changes according to the environment, the traditional HVAC system consumes more electrical energy. Next-generation wireless network (NGWN) systems play a vital role in improving the overall efficiency of the system by continuous monitoring and analysis. A small-scale industry using HVAC systems needs an active smart energy saver technique for maintaining an economical budget. This work uses MATLAB software to simulate and analyze the utilization of fuzzy-based NGWN to reduce the energy consumption requirements of small-scale manufacturing. In the model, a fuzzy rule is designed and applied to a small-scale enterprise divided into five sectors, one of which is temperature sensitive, with the goal of lowering the energy bill. The model employs fuzzy rules to enhance the NGWN, which minimizes the energy usage cost by 30% as compared with the traditional existing HVAC systems.

1. Introduction

The small-scale industries (SSIs) are among the second largest energy consumers, accounting for more than 30% of overall energy consumption in many nations. The heating, ventilation, and air conditioning (HVAC) systems are responsible for a significant amount of SSI's energy usage, accounting for up to 50% of overall energy use [1, 2]. Building administration spends so much money on heating and cooling. Smart building technologies are used by owners to effectively control spending and ensure the efficient operation of heating, ventilation, and air conditioning (HVAC) systems. These Web of Things-enabled HVAC systems may turn on and off equipment at predefined intervals, check environmental parameters and issue alerts when readings exceed thresholds, and provide energy use statistics [3, 4]. As a result, increasing SSI's energy efficiency, particularly through optimizing the HVAC system, is crucial and will have a significant influence on overall energy consumption reduction. Typically, air cooling and heating systems must keep the surrounding temperature within a specified range. Traditional air conditioning systems rely on wired temperature sensors/regulators and thermostats located at fixed places to monitor temperature variations [5]. We all know that air conditioning units are crucial parts of buildings' mechanical systems that provide thermal comfort and acceptable indoor air to residents. HVAC systems might well be split into central and local systems based on various zones, position, and distribution. HVAC equipment is classified into three types: heating, ventilation, and cooling or conditioning systems [6, 7]. Moreover, the primary purpose of a heating, ventilation, and air conditioning (HVAC) system is to meet the environmental needs of occupant comfort and a business. Heating systems are used in a variety of settings, including industrial and residential [3, 8]. These traditional controllers are inconvenient to install and ineffective at dealing with dynamic changes in building thermal behavior. The temperature distribution, in particular, is not uniform throughout space [9]. Because of transient and non-stationary human activity, sensors set at fixed and constrained areas are unable to respond to rapidly changing room circumstances. To solve this problem, a more innovative, flexible, and quick technique is required, which forces this research to think about the next-generation wireless network (NGWN).

Nonetheless, there are various constraints to examine while selecting a system. These restrictions include availability according to regulations, building design, space available, construction cost, available utility source, and air conditioning systems' structure loads [10, 11]. The NGWN prepares the way for the sensor to use the cloud Internet to connect various sensing units, actuators, and other smart equipment deployed in various environments, allowing for unprecedented awareness and interaction with the world [12, 13]. It will also enable a slew of new applications, including real-time monitoring, health sector digitalization, and smart home energy management, all of which have the potential to yield huge economic benefits. Demand-responsive air conditioning control, which dynamically adjusts the room temperature based on intelligent monitoring and tracking of human behavior and room variables, can be constructed using wireless sensors [14, 15]. Wireless sensors can also be linked with home security and entertainment systems, allowing for more advanced smart home control [16, 17].

HVAC devices require a distribution program in order to supply the proper volume of air in the defined environment conditions. The refrigeration type and delivery mechanism, including such as air conditioning, material handling, fan circuits, air vents, and water pipes, all impact the distribution network [18, 19]. Most of the studies in the literature deal with energy management systems for non-residential buildings [20, 21]. A smart HVAC system offers significant benefits over a traditional heating system, such as reduced energy consumption, ailment maintenance, predictive performance problems, and distant and automatic framework alterations. Tenants will be content to survive in increased ease, building managers will be able to manage more effectively, HVAC technicians will be prepared to operate more readily, and total building utility costs will be decreased [22–24]. In these circumstances, fuzzy, PSO, GA, artificial neural networks (e.g., [25]), and other approaches are used to provide separate autonomous temperature management for each of the different zones. When examining SSI as a whole, however, the quantity of energy utilized rises dramatically and should be taken into account. Watts et al. [26] based their study on the vent register control, which is comparable to Tong et al. [27]. A multi-zone HVAC control system was used to heat a two-story residence over the course of three days in this scenario. The total energy consumption of the house was compared to the total energy consumption of each of the selected zones, yielding energy savings of 50 to 94%. Finally, Rajith et al. [22] proposed an automatic control method for many independently controlled interior air conditioning units. Although this is not the case in this article, it is the case in many other homes that do not have centralized air conditioning and have consequently installed large split air conditioner units. Although there are many other methods to control the HVAC system like model predictive control, ANN, and statistical methods, in most of the other systems, precise input is required every time, but the fuzzy logic system does not require any precise input, making it suitable for different ranges of operation. The other methods are non-flexible in nature and cannot accommodate new features after the installation, but by using the fuzzy logic system, the HVAC system can accommodate new features.

In this research work, a new approach is discussed to improve the HVAC system using NGWN. The SSI taken into consideration consists of five areas, in which area 1 depicts the critical zone in which temperature control is of the most importance. The contribution of this research can be summarized as follows:

(1) Proposing an intelligent fuzzy-based rule for NGWN to monitor the critical areas of SSI.
(2) Calibrating SSI data for understanding the actual energy requirements.
(3) Increasing the efficiency of the HVAC system by knowing the operational timing through calibrated data.

The rest of the paper is laid out as follows. The traditional HVAC system and its operation are discussed in Section 2. The proposed fuzzy-based HVAC system using NGWN is described in Section 3. Section 4 presents the results of the present work. Section 5 discusses the simulation results. Finally, Section 6 concludes the findings of this research.

2. Design and Modelling of Traditional HVAC System for Small-Scale Industry

The general layout of HVAC system is shown in Figure 1, which consists of monitoring units to monitor the real-time parameters and sensors to gather real-time parameters. It also consists of controlling unit to control the temperature, humidity, and other related parameters according to the requirements.

Basically, it consists of four main parts as described below [28–30]:

(1) *Sensor Units*. In traditional HVAC systems, the wired sensors are located in a few locations due to their non-flexibility in adopting the environment. The main use is to detect changes in the surrounding environment and send signals accordingly to the

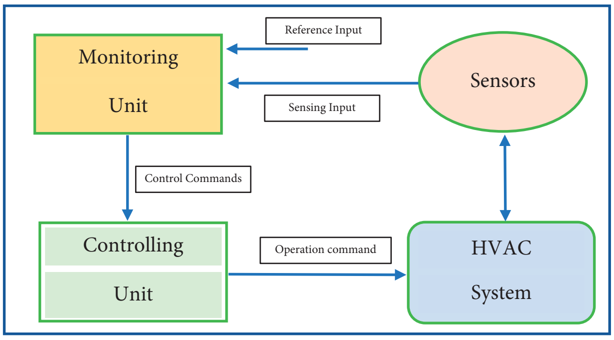

Figure 1: Traditional HVAC system for SSI.

monitoring units like temperature sensors, humidity sensors, and so on. After detecting the environment, it provides sensing input data to the associated monitoring systems. The major sensors used in the HVAC systems are as follows:

(1) Pressure sensors assess the pressure decrease across filters and other devices, efficiently alerting the system when maintenance and filter replacement are required. For optimal HVAC system functioning, accurate pressure measurement is critical.
(2) Temperature sensors assess air and water temperatures and adjust heating and air conditioning to raise or lower the air temperature based on a preprogrammed setpoint, saving energy. You may also learn about a room's airflow and air quality by looking at the data from the sensors. The use of temperature sensors keeps the system from working harder than it needs to.
(3) Humidity control in buildings is essential for occupant comfort, safety, and the protection of building infrastructure, manufacturing processes, stored commodities, and museum artwork. Temperature and humidity sensors combined offer a versatile and cost-effective solution. To raise space humidity, humidity management normally injects clean steam into the airstream.

(2) *Monitoring Units.* The major role of this unit is to detect possible errors and deviations in the sensing input data compared with reference input data. Accordingly, it gives control commands to controlling units. The HVAC system uses SCADA/HMI to use as one of the interfaces to communicate the real-time information to the user. The goal is to give real-time information regarding energy consumption, failure, and maintenance requirement. By using wireless sensors to monitor every part of your system, you may get real-time notifications for HVAC occurrences that demand your attention. These air conditioning and heating system monitors for commercial and industrial use can alert you to unexpected temperatures in ducts, A/C units, or boilers. Many other variables and symptoms, such as motor power draw and vibration, may be monitored using the SCADA/HMI coupled with sensors and remote HVAC monitoring software.

(3) *Controlling Units.* The aim of this subsystem is to give the operational commands to the HVAC system according to the needs of the environment. The direct digital control program code for central controllers and most terminal unit controllers can be changed for the intended usage. Time schedules, set points, controllers, logic, timers, trend logs, and alarms are among the program's features. The unit controllers typically feature analog and digital inputs that allow measurement of the variable (temperature, humidity, or pressure) and analog and digital outputs for control of the transport medium (hot/cold water and/or steam). Analog inputs are often voltage or current measurements from a variable (temperature, humidity, velocity, or pressure) sensor device, while digital inputs are typically (dry) contacts from a control device. Analog outputs are often voltage or current signals used to control the movement of medium (air/water/steam) control devices such as valves, dampers, and motors, while digital outputs are typically relay contacts used to start and stop equipment.

The SSI is basically having an area buildup size of around 4000–7000 square feet, like the bakery industry, water bottle manufacturing and filling, and so on. The average electricity consumption by the HVAC system ranges between 0.5 kW and 5 Kw [30–33].

For analysis purpose in this research, we are considering the HVAC system in range of 0.5–2 kW. The detailed specifications of the system are given in Table 1. The details consist of module parameters taken to perform this research. Module parameters include room size, type of communication link, and temperature range. Figure 2 shows the general architecture of SSI, where the operational activities are performed in area 1. In this research, we are considering 5000 square feet of SSI, of which 3500 square feet are required for operational activities. So, in some SSI areas, 1 is sensitive and in others, 2 is sensitive to temperature. The HVAC system must be capable of controlling the required temperature.

3. Improved Smart HVAC System Modelling Using Fuzzy-Based NGWN

This section discusses in detail about the fuzzy-based NGWN-HVAC system.

3.1. NGWN-Based HVAC System. The improved HVAC is shown in Figure 3. The main difference with traditional HVAC system is stated below.

(1) It has an analyzing unit which helps the controlling unit to give best parameters for HVAC control.
(2) To make the system smarter, a fuzzy logic-based unit is implemented, which enhances the operations while reducing the electrical energy burden. It helps the system operate according to requirements and

Table 1: Traditional SSI HVAC system details.

Name	Value	Description
Total rooms	5	1 operational room, 4 staff rooms
HVAC power	0.5–2 kW	According to area
Sensors	5 numbers	Traditionally wired
Operating temperature of area 1	74 F–170 F	Operational range for many SSIs
Controller logic	Semiautomated	Reference error based
Communication platform range	50–150 meters	Wired network

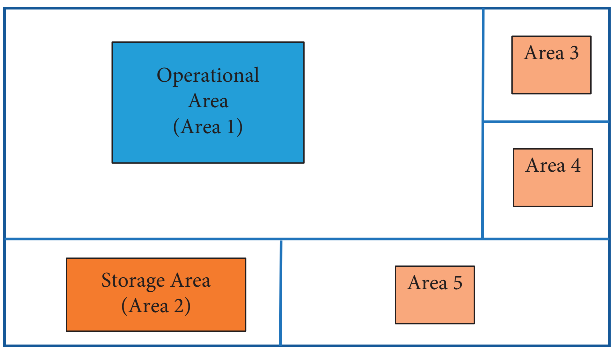

Figure 2: General architecture of SSI.

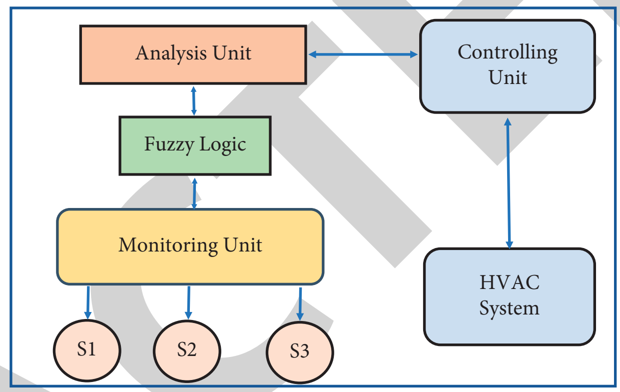

Figure 3: Fuzzy-based NGWN-HVAC system.

keeps the system in an economical mode during the rest of the time. Due to this, the overall operational cost of HVAC systems has become more economical and cheaper.

Table 2 highlights the description of fuzzy-based NGWN-HVAC system. A NGWN is used for sensor communication through IoT platform.

3.2. Fuzzy Rules. The two main driving forces that have motivated academics to develop intelligent systems are comfort and energy savings. These NGWN-based HVAC systems can manage and monitor the environmental factors of a SSI, resulting in a comfortable microclimate while lowering energy consumption and operating expenses. In an NGWN-based HVAC system, fuzzy approaches can be utilized, which may result in significant better results compared to typical HVAC systems.

The rule is shown through the fuzzy graph as shown in Figure 4. It is a two-input one-output type graph in which temperature and humidity play the input roles and HVAC output is output which controls the closed area climate. The two inputs are temperature and humidity, and the output is HVAC output. To understand the graph, an example is stated; if the temperature variation is of 0.4 and humidity variation is of 0.6, then HVAC output will work with variation of 0.55. The main aim of the rule is to control temperature and humidity as a function of HVAC output.

The best point is that the operator can change the rule according to the requirement of the industry and environment. The NGWN sensors collect data from different locations and provide it to the control and monitoring units for real-time operations.

4. Results

The sensors of NGWN monitor the temperature of different areas of the SSI as shown in Figure 5. The range is from 75 F to 79 F. In this paper, the major work of HVAC system is in area 1, where SSI operates its important temperature-controlled work. The temperature-controlled operation in SSI is to vary between certain temperature ranges in regular interval, due to which the HVAC system gets minimum time to react. This leads to adoption of the NGWN system for HVAC.

A total of five sensors were deployed in various places of the SSI. Generally, many SSIs work in time range of 10.00 A.M to 8.00 P.M. So, the sensor giving the data in the same range of SSI operation is shown in Figure 6. Sometimes, these data have some errors and variations due to technical and non-technical constraints. To have good data for operation, data calibration is done periodically. Data calibration is done to provide correct measurement (Figure 7) and help in performing different uncertain calculations. So, finally, the calibrated data of each sensor are shown in Figure 8. To show how the NGWN-HVAC system performs well compared to the traditional method, two cases are taken into consideration.

(1) Case 1: traditional HVAC system.
(2) Case 2: performance with the NGWN-HVAC system.

4.1. Case 1. Figure 9 shows the working of the traditional HVAC system. The temperature drops significantly until the HVAC system is activated. As a result, the system requires a lot

Table 2: Fuzzy-based NGWN-HVAC system.

Name	Value	Description
Total rooms	5	1 operational room, 4 staff rooms
HVAC power	0.5–2 kW	According to area
Sensors	5 numbers	Wireless IoT based
Operating temperature of area 1	74 F–170 F	Operational range for many SSIs
Controller logic	Fuzzy logic	Fuzzy rules
Communication platform range	IoT	Cloud

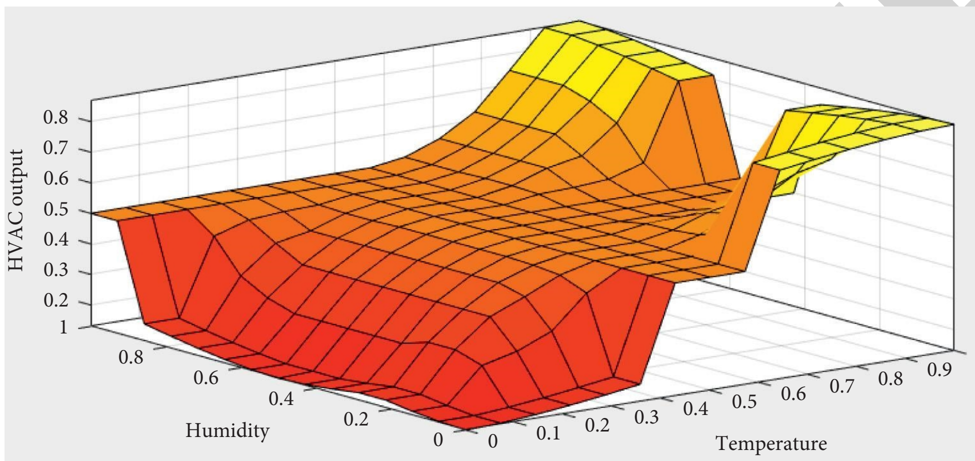

Figure 4: Fuzzy input/output variation.

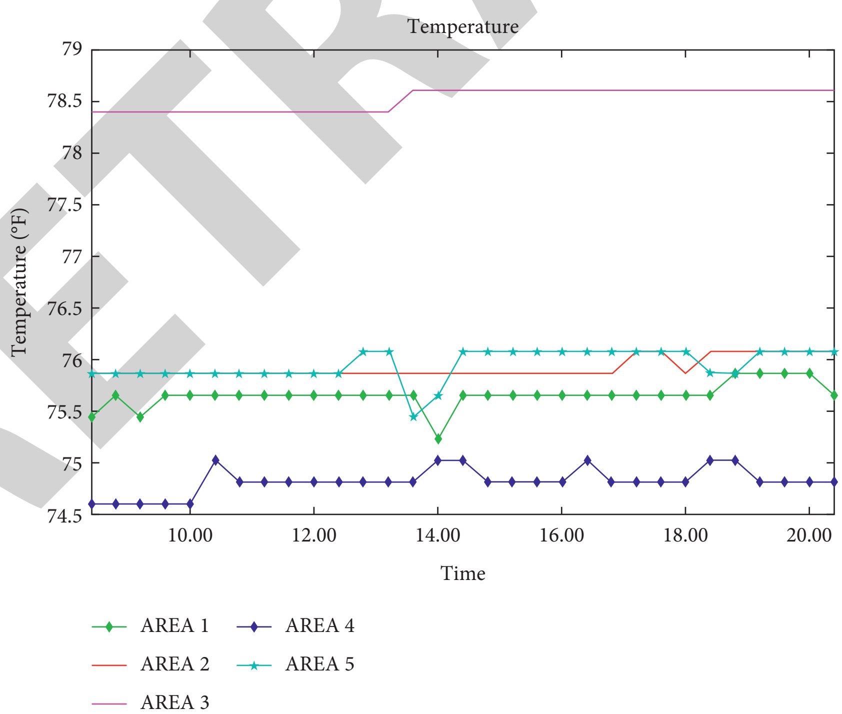

Figure 5: Area-wise temperature graph.

of power to perform temperature monitoring and maintenance. The red point in the diagram represents the starting point at which the HVAC system receives a signal to begin operation.

Although the temperature range in the traditional HVAC system is maintained, the energy requirement is high because it causes large variation in temperature. The dark

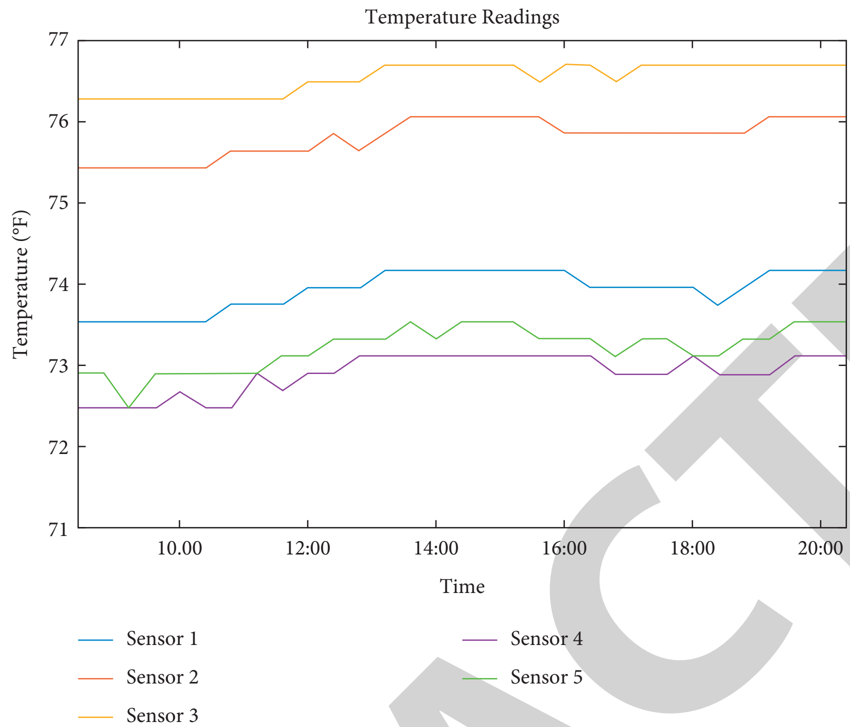

Figure 6: Sensors gathering temperature information.

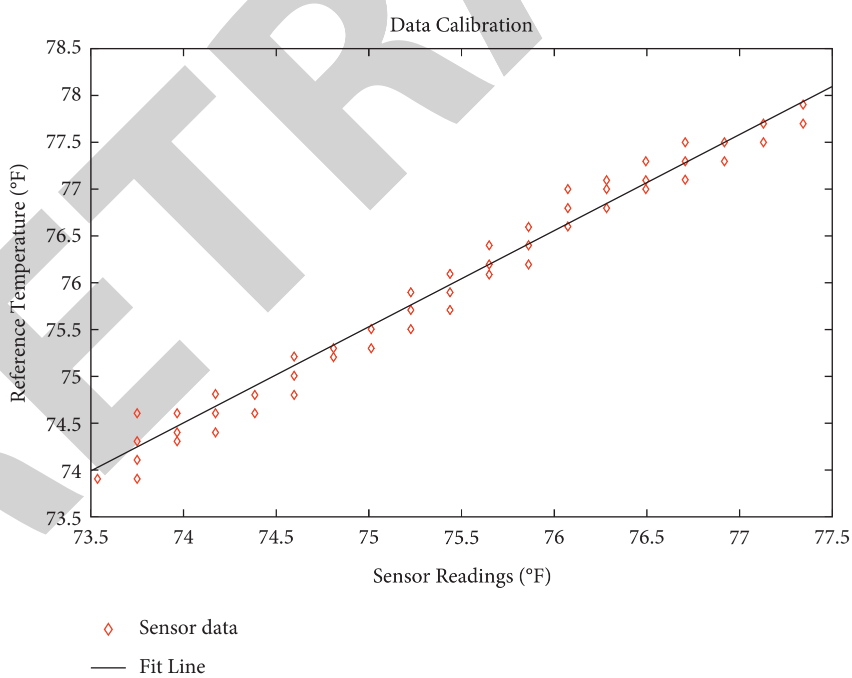

Figure 7: Calibration of data.

color indicates the rise and fall in temperature with the traditional system.

4.2. Case 2. With the NGWN system, the exact point of temperature drop and max point are monitored and given to the HVAC system for its operations. Figure 10 shows how the NGWN indicates the max temperature point and drop point. Using this information, the intelligent system using fuzzy rules plays a vital role. With minimum energy consumption, the system tries to maintain the operating temperature range in SSI. The HVAC system turns ON/OFF

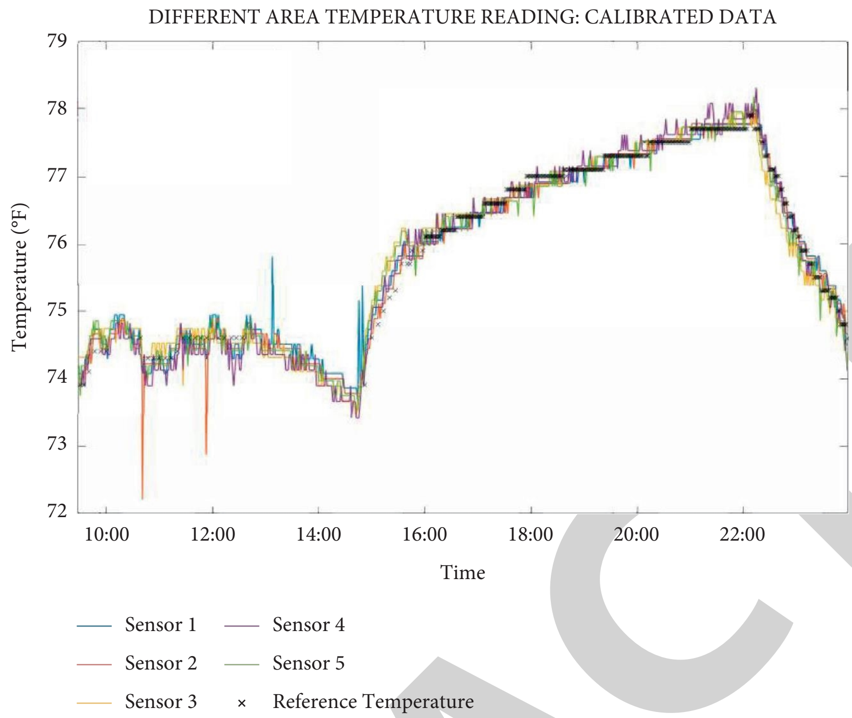

Figure 8: Calibrated data of all sensors with reference temperature.

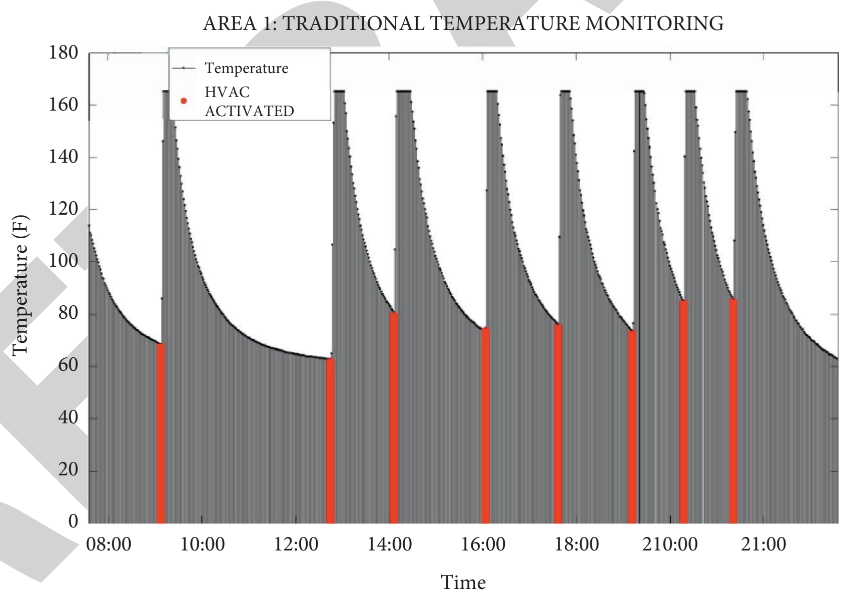

Figure 9: Case 1: traditional HVAC system performance.

according the command given by the fuzzy logic system. Due to maintenance of operating points, the overall accuracy is increased.

The overall energy consumption for each case is shown in Figure 11. The NGWN-based system uses only that much of energy which is required to maintain the temperature of the SSI area. But in the traditional system, the HVAC system operates continuously due to which a large amount of energy is consumed. At last, Figure 12 shows the overall efficiency of the system at different timings. In this, we can see that the performance in terms of efficiency is very high for the NGWN-based system compared to the traditional system.

5. Discussion

While intelligent systems for SSI have been a popular area in research, the use of the NGWN technique has received less attention. By using fuzzy-based NGWN for SSI, this work analyzes a new breed of research challenges. We present a new analysis on the SSI HVAC system. We

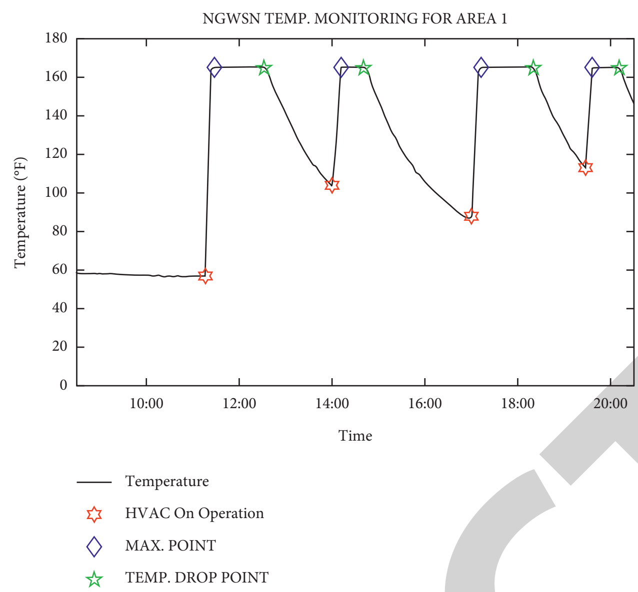

Figure 10: Case 2: NGWN-HVAC system performance.

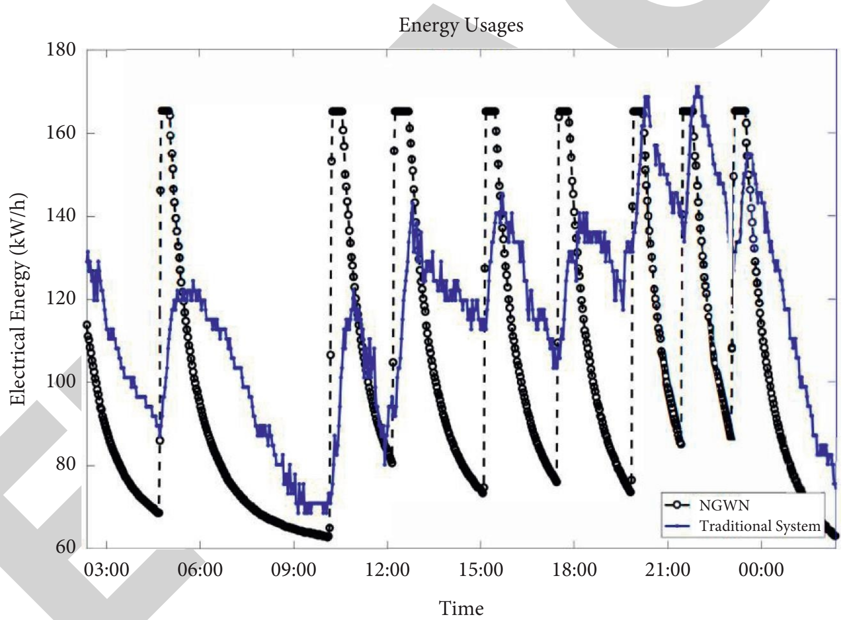

Figure 11: Energy consumption for case 1 and case 2.

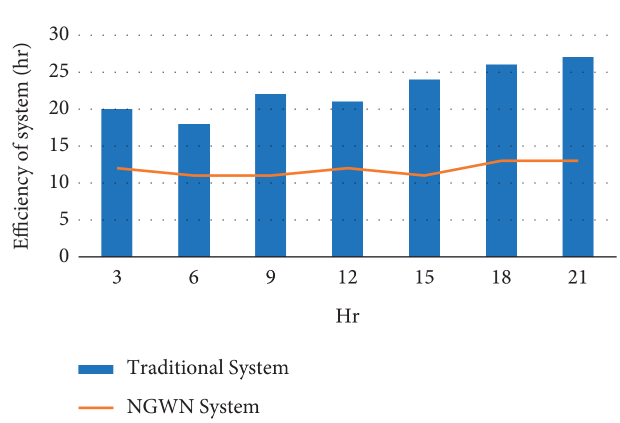

Figure 12: Comparison of traditional HVAC and NGWN-HVAC systems w.r.t efficiency.

compare the effectiveness of the proposed method to the traditional method. The experiment is conducted using MATLAB software, using the traditional SSI HVAC system logic. In this work, the conventional system is replaced by sensor-interacted NGWN platform for better performance.

Although the system performs well compared with traditional system by 30% more, it still needs more improvement. There are numerous research opportunities to apply the findings of this study to a broader setting. The future scope is stated below:

(1) An optimization technique can be used to increase the overall efficiency.

(2) Machine learning can be used for better accuracy regarding ON/OFF of the HVAC system.

(3) Multi-input and multi-control approach can be an important constraint for future.

6. Conclusions

According to current studies, improved control systems are essential to significantly minimize HVAC system energy usage while providing acceptable thermal comfort for SSI activities. In this paper, a fuzzy-based NGWN technique for HVAC control was designed and implemented. Two key criteria, temperature monitoring and energy usage, were used to compare the proposed NGWN-HVAC to traditional HVAC. In comparison to traditional systems, the simulation results demonstrated that NGWN and fuzzy-based systems perform better in terms of thermal comfort for SSI operation. The level of energy efficiency gained is determined by the type of HVAC infrastructure used in the structure. If different HVAC components run independently of one another, it is impossible to obtain thorough data and insight into how they work. Wireless IoT sensors can collect detailed data from essential HVAC assets in a building, such as fan speeds, flow rates, compressor run durations, vibration, and overall asset energy usage. This provides priceless insight into their genuine operational efficiency, highlighting areas where savings might be made. In the long run, the interaction of technology and applications will promote the adoption of mixed-mode systems as well as the introduction of new types of HVAC systems. The effects of societal scale on energy resources, environmental conservation, and the industrial economy are yet unknown. But certainly the HVAV system performance will get improved by using next-generation wireless technology.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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