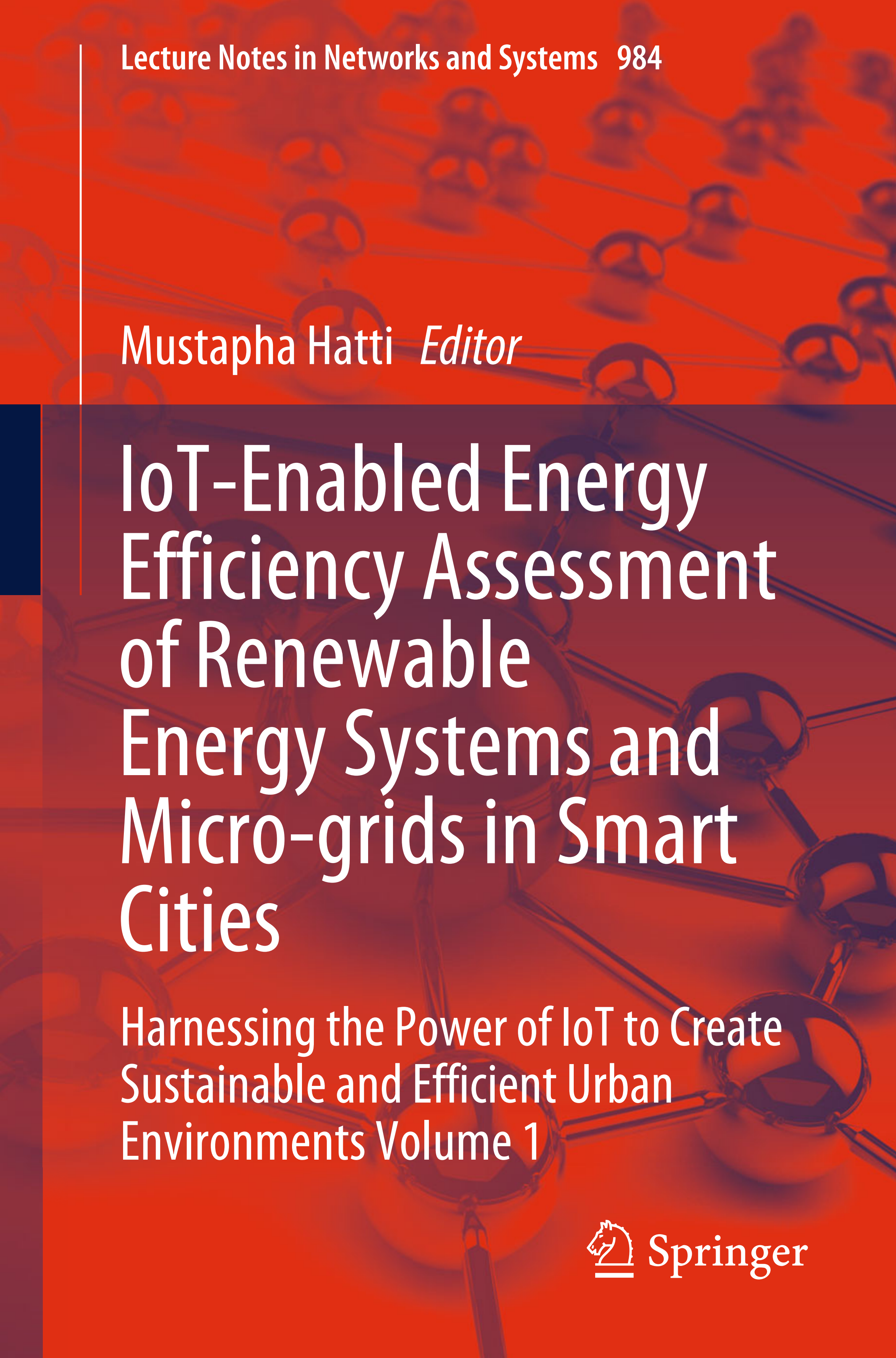

Lecture Notes in Networks and Systems 984

Mustapha Hatti *Editor*

IoT-Enabled Energy Efficiency Assessment of Renewable Energy Systems and Micro-grids in Smart Cities

Harnessing the Power of IoT to Create Sustainable and Efficient Urban Environments Volume 1

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Mustapha Hatti
Editor

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Editor
Mustapha Hatti
UDES, Unité de Développement des Equipements
Solaires
Bou Ismail, Tipasa, Algeria

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Editors Biography

Dr. Mustapha Hatti was born in El-Asnam (Chlef), Algeria. He studied at El Khaldounia school, then at El Wancharissi high school, obtained his electronics engineering diplomat from USTHB Algiers, and his post-graduation studies at USTO–Oran (Master's degree and doctorate). Worked as research engineer, at CDSE, Ain oussera, Djelfa, CRD, Sonatrach, Hassi messaoud, CRNB, Birine, Djelfa, and senior research scientist at UDES/EPST-CDER, Bou Ismail, Tipasa, "Habilité à diriger des recherches" HDR from Saad Dahlab University of Blida, Algeria. Actually, he is Research Director in renewable energy. Since 2013, he is an IEEE senior member, he is the author of several scientific papers, and chapter books, and his areas of interest are smart sustainable energy systems, innovative system, electrical vehicle, fuel cell, photovoltaic, optimization, intelligent embedded systems. Chair of the Tipasa Smart City Association. An eBook editor at International Springer Publishers, guest editor and member of the editorial board of the journal Computers & Electrical Engineering, he has supervised, examined and reviewed several doctoral theses and supervised master's degrees. He organizes the conference entitled Artificial Intelligence in Renewable Energetic Systems. Enrolled in several European project in smart and sustainable cities.

Internet of Things and Sensors

An IoT-Based System to Control the Greenhouse's Microclimate

Seddiki Noureddine(✉), Belghachi Mohammed, and MokedDem Kamal Abdelmadjid

Algeria: Department of Mathematics and Informatics, University of Tahri Mohamed Bechar,
Bechar, Algeria
{Seddiki.nourddine,belghachi.mohamed,
mokeddem.kamal}@univ-bechar.dz

Abstract. In fact, data gathering and the creation of an active system with a range of actuators are the requirements for monitoring or control. Due to the intricacy of the greenhouse's microclimate, management measures can be used to increase plant production and quality while decreasing the use of energy. The microclimate is controlled by a microcontroller and sensors for multiple factors, including temperature, humidity, and soil moisture. The Internet of Things is an excellent infrastructure for collecting and processing this data. Interactive, observable elements are offered by web-based and mobile apps, which may have an impact on the greenhouse environment. The irrigation pump or the fan may switch on in real time based on the controller's optimum threshold values or user input. In this work, we propose a control system that can enhance crop productivity and generate a dataset for future research.

Keywords: greenhouse · control · microclimate · Internet of things

1 Introduction

The cutting-edge greenhouses are built to provide plants with protection from the elements outside and a climate conducive to intense food production. However, greenhouses are going through a profound change due to the quick transition to precision agriculture and the accompanying improvement in food security while safeguarding natural resources. This is because metering, communication, control, and monitoring systems have improved [1].

The management and automation of microclimate control within greenhouses have made agriculture in closed-field environments more sustainable. This is achieved through the reduction of resources such as water, fertilizer, and energy while increasing productivity and profitability [2]. The ideal environment for crop development is influenced by factors such as temperature, humidity, light intensity, and air circulation, collectively referred to as the microclimate. By accurately optimizing and controlling these parameters, an intelligent greenhouse can create an optimal environment for plant growth. This process of microclimate control involves monitoring and adjusting the environmental factors to provide the best possible conditions for the plants. This can be accomplished

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manually or with the help of advanced technologies such as sensors, automated systems, and computer software.

Recent developments in sensor technology have enabled the achievement of the highest greenhouse crop yield and production levels to date. Automation experts can now take advantage of tailored solutions specifically designed for greenhouse applications, thanks to digital technologies such as the Internet of Things (IoT). By utilizing wireless sensors and IoT-enabled devices, greenhouse environments can be monitored and managed in real time from any mobile or fixed device with a secure internet connection [3].

In this paper, we showcase a greenhouse automation system that we developed in our lab for experimentation purposes. Additionally, we introduce a web-based backend infrastructure and mobile application that harnesses the collected sensor data on the greenhouse microclimate to enable control and automation. To achieve this, we have divided the paper into several sections. In Sect. 2, we discuss relevant works and innovations related to the greenhouse microclimate. In Sect. 3, we present the greenhouse parameters used to control the microclimate. Section 4 provides a detailed explanation of the various technologies used to construct the prototype and platform. We then discuss the outcomes in Sect. 5. Finally, in Sect. 6, we summarize the conclusions of this paper and highlight the untapped potential of our forward-looking ideas for this dataset.

2 Related Works

Recent research in precision agriculture emphasizes the significance of managing and monitoring the microclimate within and outside greenhouses. The techniques involved in controlling the environment include gathering, analyzing, and processing data, while also visually identifying climatic parameters to alert of potential issues. All these measures are aimed at increasing agricultural productivity and reducing input costs. The importance of contemporary technologies such as wireless sensor nodes, embedded devices, and IoT-based and cloud-based data collection platforms in achieving these goals cannot be overstated.

The use of novel technology such as IoT in the domain can be seen in [4]. In this paper, the authors use a model-based implementation in Matlab Simulink to analyze a greenhouse microclimate utilizing IoT, sensors, and Node MCU (ESP8266) as controller. The goal of this study is to better understand how to interpret microclimate data variances about plant needs at various growth stages. The model-based analysis offered a way to accept these uncertainties due to the nonlinear dynamics of the system (i.e., solar radiation and wind speed) and reduce the production risk despite even though the precise behavior of the greenhouse environment from raw data and its impact on the plants [8].

The authors of [5] designed and implement a remote monitoring and control system for the greenhouse based on IoT. The greenhouse model is divided into four sections for planting various plants. Different levels of soil moisture are maintained in each area. This is used as the basis for monitoring and analyzing plant development. The microclimatic conditions in the greenhouse model are controlled by an automated control greenhouse system, which is made up of various separate subsystems (watering, lighting, temperature control, air quality subsystem, etc.). The greenhouse IoT component uses the ThingSpeak cloud.

In [6], the objective was to gather information on air temperature, air humidity, and light levels using a group control device (ESP) in a greenhouse microclimate. To achieve this, an automated microclimate management system was developed using cloud architecture. This system comprises six fundamental components: a cloud server, a local object server, a mobile application, a group control device, a device module, and a sensor. The greenhouse complex's dependability is increased, and the possibility of data loss due to network failures is decreased, by replicating data from a local device to the cloud. Based on the test results, the user interface's reaction time can be deemed acceptable when it takes less than two seconds from the time that data packets are received until they are seen on the user's screen. Data availability and system dependability can be increased by duplicating functionality and replicating databases across on-premises object servers and cloud services.

The system designed here [7] is extremely complex, cutting-edge, and capable of measuring six microclimatic parameters in three separate greenhouse sections. A decision-making control system can be activated to adjust required parameter values by providing ventilation or by turning on and off processes of mist foggers in required areas of the greenhouse after comparing the collected data with expected values. In addition to this, the system continuously records to create databases. The system presented demonstrates its utility for measuring and revealing distinctions in the greenhouse microclimate in terms of the temperature, humidity, and soil moisture parameter monitored.

The primary contribution of this study [8] is the development of two-way data transmission based on the Internet of Things (IoT) utilizing Firebase Realtime Database as the platform for handling and tracking the environment of the smart greenhouse. Sensors and micro-controller are present as smart nodes, which may broadcast microclimate readings to a distant firebase to store the dataset. Users will be able to remotely operate the actuators in the smart greenhouse using the data that is provided on the Laravel-based website interface. By measuring the latency and packet loss data values, the architecture of a smart greenhouse-based two-way data communication system was analyzed and tested.

The main goal of the study [9] is to create an IoT-based system capable of producing temperature, humidity, and soil moisture sensors that are location-specific microclimatic characteristics. With the aid of the Cropwat program, which is based on macroclimatic parameters, the data is further examined and verified. By tracking various microclimatic indicators, farmers can assess their irrigation water requirements. This involves using sensors to measure soil moisture and temperature, which are then fed into the LoRA system. The system analyzes this data to estimate evapotranspiration. The Mcguinnes-Bordne formulation is used to evaluate the sensor data, and the results of this study effort open the way for the estimate of evapotranspiration in the microclimate setting.

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3 Parameters of Microclimate in Greenhouse

To create the best climatic conditions for crop development while using the least amount of fuel and energy possible, a variety of factors are used both inside and outside the greenhouse. Solar radiation, air temperature, relative humidity, air flow rate, and carbon dioxide concentration are a few of these variables. Nevertheless, monitoring and climate control are made more difficult by the interaction of the variables that affect one another and by their dependency on the shifting ambient environment.

A. ***Temperature***

Temperature's main function is to ensure that crop leaves develop at a young age. Nelson states in [10] that while greenhouse plants do best at temperatures between 15 and 30 degrees Celsius, most plants grow well at temps between 10 and 24 degrees. Nelson [10] found that the temperature difference needed for crop development between day and night should be around 8 to 10 °C under sunny situations. Depending on the type of plant, different temperatures are required for optimal plant development.

B. ***Humidity***

The appropriate humidity levels for a plant are strongly dependent on water stressors, harsh weather conditions, the risk of pestilence/insects, ripeness, and the crop growth phase [11, 12]. As a consequence, optimal humidity levels are required for plant development, which is expressed in terms of the vapor pressure deficit, which is defined as the difference between the water vapor pressure at saturation and the actual water vapor pressure at the greenhouse temperature [11].

C. ***Air Flowrate***

Poor air circulation inhibits plant activity and might cause humidity and disease control issues. The greenhouse's air circulation should be between 0.2 and 0.7 m per second. Plant development is hampered if carbon dioxide levels are not maintained. The exchange of air is what ventilation is all about. Moving the air breaks down this "stratified" air, reducing heating costs and keeping your plants comfy.

D. ***Light Intensity***

This is the point at which photosynthesis is at its peak and plant growth is at its peak. Growth is slowed when the amount of light is lowered. Light saturation is the point at which an increase in light intensity no longer increases photosynthesis Maps, figures and tables.

E. ***Carbon Dioxide Concentration***
The advantage of CO2 enrichment is mostly seen in increased crop yield due to improved photosynthesis. CO2 enrichment in the greenhouse is an important characteristic because it has a beneficial influence on crop development, provided that other growth parameters, such as water supply, are satisfied. CO2 levels should be provided to greenhouse crops to compensate for the significant drop in CO2 caused by photosynthesis, especially when adequate ventilation is not available.

F. ***Solar Radiation***
The first and most important meteorological characteristic for determining a region's eligibility for protected cropping is solar radiation [13]. The primary source of heat gain is direct solar radiation intercepted in the greenhouse, and it contributes the most to the increase in the daytime temperature of the protected cropping environment. Furthermore, significant amounts of solar energy are collected and stored in the soil before being released at night [14].

4 Method and Materials

We utilized advanced technologies to gather crucial indicators for greenhouse growth, such as temperature and humidity levels inside and outside the greenhouse, soil moisture, light intensity, and airflow. These parameters were collected to develop comprehensive databases. Furthermore, we employed remote operation techniques in compliance with recommended procedures and effective technology. This allowed us to remotely operate various devices, including fans, lighting, and irrigation pumps. The primary objective of this study is to optimize the variables that create an ideal environment for plants to thrive in a greenhouse. We evaluated three control subsystems for these variables and provided recommendations for their potential application in an automated or autonomous sustainable greenhouse farming system.

Users can choose between an Android application or a Web application, both of which provide access to the database through a REST API in a Laravel project. The data is delivered and received in JSON (JavaScript Object Notation) format. Additionally, the app includes a user interface that allows for controlling the actuators.

The EPS32 controller, connected to the Wi-Fi network, sends the measured parameters to the local server every five seconds. More detailed design information regarding the built IoT-based data transmission system can be found in "Fig. 1".

The system utilizes an ESP-WROOM-32 controller, which is a dual-core 32-bit microcontroller with built-in Wi-Fi (802.11/b/g/n/e/i) and Bluetooth capabilities. The controller is programmed using the Arduino IDE through an ESP32 Dev Module add-on. It is configured as a client access point, allowing it to obtain an IP address from the gateway, connect to the Wi-Fi network, collect the sensed parameters, and transmit them to the server for storage.

The information sent by the gateway to the API address serves to specify the connection for the MySQL database's data storage. The information is then used on a mobile application interface built using Android Studio and a website-based interface created with Laravel as front-end and back-end. Using a web application framework (Laravel) with expressive and clean syntax, the API resources are specified and set up.

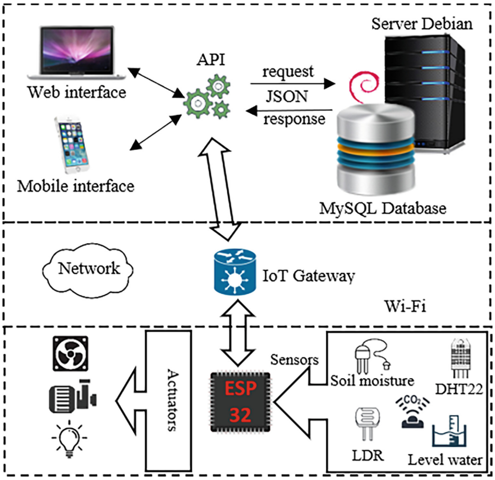


Fig. 1. The constructed IoT-based data transfer infrastructure.

Since the server is a basic device located in the lab with a public IP address. The server has a dual-core CPU, 2 Go of Memory, and 500 Go of hard drive space. We would rather install a Linux operating system, and we choose Debian 11, which is set up as a web server by installing apache2 and phpMyAdmin to build the database.

The "Fig. 2", illustrates the greenhouse model which is built of wood and wrapped in translucent plastic foil. The seedling starter in the center has sensors for measuring the soil moisture humidity. The irrigation system consists of a pump, a water level sensor, and two tanks. Moreover, there are three fans, where two create air and the other withdraws it. The light subsystem is made up of LEDs designed specifically for seedling growth and LDR sensors to gauge light intensity.

Fig. 2. The modal of the greenhouse constructed.

The automated control system is intended to regulate the greenhouse model's microclimate environment. As depicted previously, the model is made up of several autonomous subsystems, including temperature control, irrigation, lighting, remote monitoring and control, and IoT subsystem. The functional wiring diagram for all components of the greenhouse model is shown in "Fig. 3".

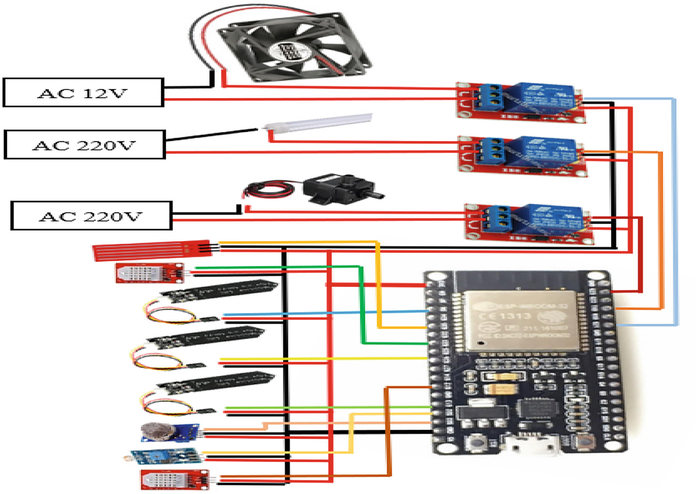


Fig. 3. Wiring diagram of the hardware used in the model.

The watering subsystem in "Fig. 4" is implemented with a water pump submerged in a large tank beneath the greenhouse to collect excess water droplets, which has a level sensor to detect when there is insufficient water and alert the user. A second tank is placed at a steeper angle to ensure that the automatic micro-irrigation (drip) will be filled by the needs of plants as determined by the tree soil moisture planted in a different pot. The slope will automatically give watering to the crops when the second tank is full or as needed. Experience has taught us that it takes a certain amount of time to fill the tank since the pump must be stopped so that there isn't an excess of water.

When conditions are darker than during the day, the lighting subsystem is used. That is made possible using a special LED meant to promote rapid development and larger yields (ultra-purple light due to the short wavelength), linked to the controller, and it will turn on when the intensity sensor notices that there is no daylight left. To give greenhouse plants the appropriate light during the day, the user can interact with the interface of the light subsystem at night if there is a need for light.

A group of fans was utilized to create another subsystem with a DHT22 and MQ2 gas sensor to regulate the indoor temperature and monitor the quality of the air. Cooling fans are activated to pull or generate air when the temperature, humidity, or air quality is below or upper the average required value.

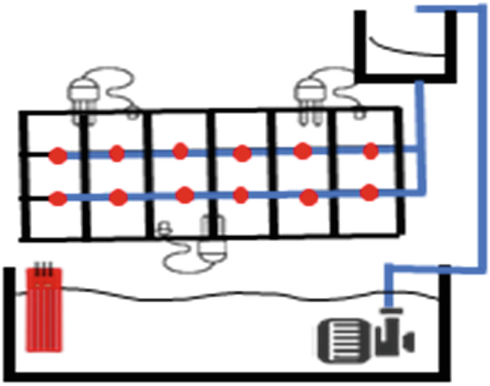


Fig. 4. The structural irrigation subsystem.

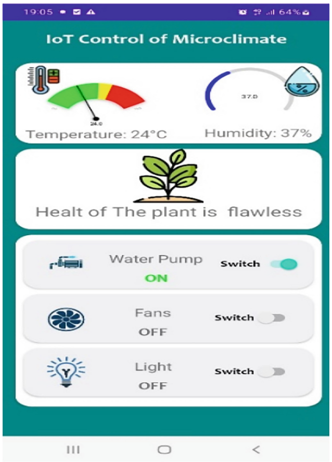
5 Results and Discussions

The model performs well with the relatively easy interactive user interface of the mobile and web-based applications shown in "Fig. 5", where the user can find a variety of make-up that aid them in keeping track of the greenhouse's internal microclimate and provide them with some information about the condition of the plants in the form of sweet notifications, as seen in "Fig. 5". If necessary, a system can automatically perform a single action or a set of actions, such as turning on a pump for irrigation when the soil moisture senses a need for it or turning on a fan to remove air.

For the dataset's development, it is quick and simple since every 5 s, a new record of the humidity (internal and external), temperature (internal and external), airflow, the amount of water in the tank, and the status of actuators (on/off) are recorded. All of these measurements are time and date stamped.

The use of APIs and JSON format (Requests/Responses) demonstrates our application's ability to co-use several programming languages and platforms for the collection and manipulation of data. Thus, our system is not limited by most of the software or hardware compatibility issues and can be supported by any device available to users. For example, we use the Java programming language in Android Studio to create mobile applications, and JavaScript on the web to access this JSON format (Fig. 6).

Our main objective is to help farmers achieve higher crop yields while conserving energy and resources, especially reducing water loss, by controlling the internal microclimate using this technology. In addition, we aim to collect and prepare the dataset for future research by integrating a deep-learning algorithm to predict microclimate parameters.



Temperature: 24°C

Humidity: 37%

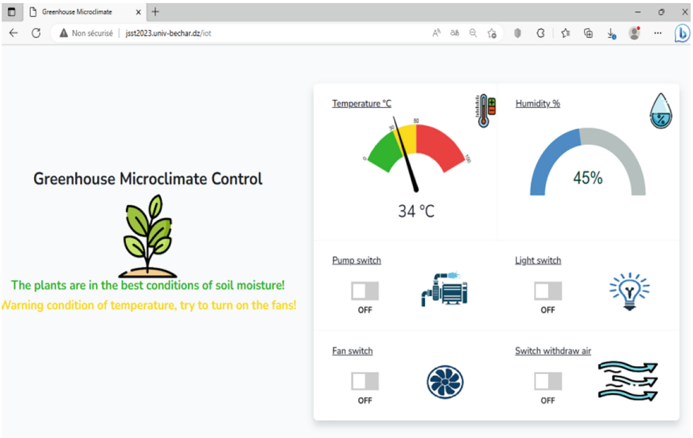
Healt of The plant is flawless

Water Pump ON

Fans OFF

Light OFF

Fig. 5. control page



The plants are in the best conditions of soil moisture!

Warning condition of temperature, try to turn on the fans!

Pump switch OFF

Light switch OFF

Fan switch OFF

Switch withdraw air OFF

Fig. 6. The mobile and Web-based interface of the application

6 Conclusion

The use of digital devices and computer techniques is expected to rapidly expand the field of smart agriculture. Our system for tracking and managing various factors that affect the microclimate within a greenhouse has successfully achieved our goals of collecting data for characterizing these aspects. However, future work in this field must involve additional validation of the gathered data. Traditional methods for processing and organizing such vast amounts of data are impractical, so the adoption of modern tools and technologies such as cloud platforms, edge computing, and fog computing has become a standard practice to save costs and time.

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A Review on Network Layer Attacks in Wireless Sensor Network and Defensive Mechanisms

Sana Touhami[1,3](✉), Mohamed Belghachi[1], and Achouak Touhami[2,4]

[1] Department of Mathematics and Computer Science, Tahri Mohammed University,
Bechar, Algeria
touhamisana@gmail.com
[2] Department of Mathematics and Computer Science, Ali Kafi University Center,
Tindouf, Algeria
[3] Information and Telecommunication Laboratory, Tahri Mohamed University, Bechar, Algeria
[4] Energetic in Arid Zones Laboratory, Tahri Mohamed University, Bechar, Algeria

Abstract. Wireless sensor networks (WSN) are considered as one of the most widely used networks for all-inclusive applications. They are organized into many sensor nodes. The deployment of nodes in these networks is not secure, and this may lead to security attacks. In this paper we are deliberating different types of attacks in network layer and defensive mechanisms against those attacks.

Keywords: Wireless Sensor Networks · Attacks · Defensive mechanisms · Network layer

1 Introduction

Wireless sensor networks represent novel decentralized wireless systems characterized by their low energy consumption, affordability, and compact dimensions [1, 2]. These networks find applications across a wide spectrum of domains, including healthcare, habitat monitoring, civilian and military use, traffic management, and environmental tracking [1, 3]. Within the environmental context, WSNs play a role in gauging parameters like temperature, pressure, noise, humidity, and others (Fig. 1).

The WSN (Wireless Sensor Network) [2, 4] functions through an extensive array of nodes, with each node being linked to one or more sensors. A typical sensor node comprises a radio transmitter, an interface circuit, a microcontroller, and a battery, with an antenna attached to the radio transmitter. These nodes operate under several constraints like restricted storage capacity, low power availability, minimal latency, narrow bandwidth, compact physical dimensions, and limited energy resources. These constraints on sensor nodes represent significant obstacles to ensuring security within the sensor network. Various forms of attacks have been documented during inter-node communication, whether they occur within the communication range or beyond it (i.e., insider attacks or outsider attacks). Consequently, security challenges arise in routing processes, such as data aggregation, route discovery, and data dissemination [1, 5].

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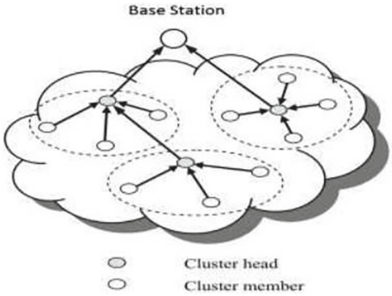

Fig. 1. Wireless Sensor Network.

Wireless Sensor Networks [1, 5] also fall under the category of ad hoc networks. The security objectives of such networks encompass both traditional network security concerns and the unique constraints posed by ad hoc networks [4, 6]. Security goals are categorized into primary and secondary objectives. Primary objectives, also known as standard security goals, encompass privacy, integrity, authentication, and availability. Secondary objectives include data freshness and self-organization [3]. Privacy pertains to the ability to shield messages from unauthorized listeners, while integrity ensures that incoming messages remain unaltered by potential attackers. Authentication verifies the identities of senders and receivers, preventing packet modification and injection of spurious packets. Availability ensures that resources are accessible for message transmission. Data freshness involves maintaining the recency of data, preventing the replay of previous messages.

2 Architecture of WSN

A Wireless Sensor Network (WSN) is constituted by an array of energy-efficient devices referred to as sensor nodes (SNs), strategically placed across a designated area for the purpose of monitoring atmospheric fluctuations. Interactions among these SNs establish a network, with certain SNs, known as sinks, serving as points of direct communication with end users. At the core of the WSN lies the sensor, responsible for gathering physical data related to environmental conditions, including but not limited to sound, moisture, intensity, and pressure, across diverse domains.

The sensor nodes possess several functions, encompassing data processing, communication, and managing network operations alongside multiple other SNs. This network's architectural depiction, as shown in Fig. 2, involves integral components such as the processing unit, sensing unit, power source, and communication module [7].

The sensing component comprises an arrangement of multiple sensors along with an analog-to-digital converter (ADC). By utilizing this combination, the sensors collect information and convey it in the form of sensed data.

The ADC's role involves conveying the data gathered by the sensor nodes (SNs) and recommending subsequent actions based on the sensed data. The communication module's purpose revolves around receiving requests or commands from the central processing unit (CPU). The CPU's primary function is to interpret these queries or

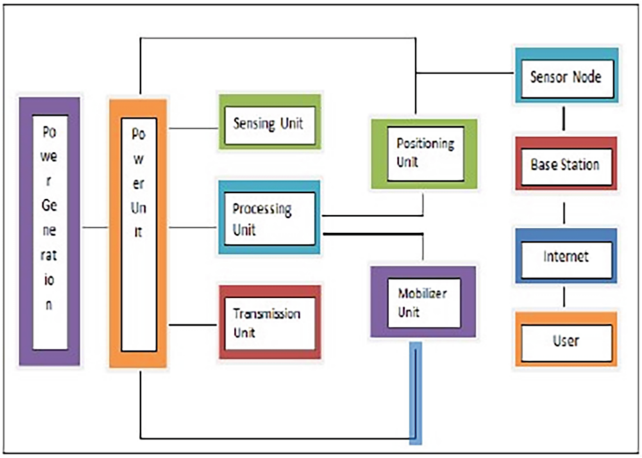

Fig. 2. Architectural diagram of WSN.

commands for the ADC, while also overseeing and controlling power distribution for the received data and calculating routes toward the sink.

The Power Distribution Unit's function is to supply power to all units within the WSN. Each SN unit comprises mechanisms for location identification (for locating purposes) and unit mobility (for sensor movement). The SNs carry out computations and transmit essential data across the network. In this scenario, SNs serve as routers, connecting with the battery-powered wireless network. WSNs are characterized by low energy consumption, scalability, fault tolerance, cost-effectiveness, and minimal maintenance requirements. These networks possess a limited bandwidth capacity and are programmable through software means.

3 Applications of WSN

Below are some WSN application fields [8]:

A. *Military Applications*
Sensor nodes play a role in conducting surveillance in military battlegrounds and are also involved in equipping smart missiles with guidance systems and identifying instances of weapons of mass destruction attacks.

B. *Medical Application*
The patient has the option to wear sensors, which proves highly beneficial for diagnosing and keeping track of the patient's condition. These sensors oversee the patient's physiological information, encompassing metrics like heart rate and body temperature.

C. *Environmental Applications*
This involves tasks such as identifying floods, enhancing agriculture precision, managing traffic, and detecting wildfires, among other things.

D. *Industrial applications*
This encompasses the identification and analysis of industries, covering items like household devices, manufacturing plants, and supply networks, among others.

E. *Infrastructure Protection Application*
This involves overseeing electricity grids, observing the distribution of water, and so on. The arrangement of sensor networks relies on protocols that are not interconnected, making it an inherent aspect (Fig. 3).

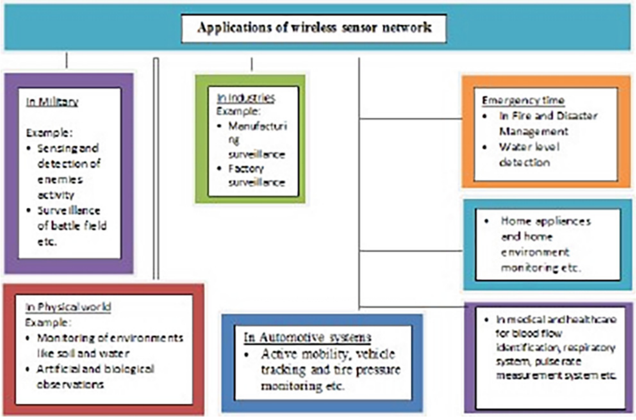

Fig. 3. Applications diagram of WSN.

4 The Internet of Things

The CERP-IoT, which stands for "Cluster of European research projects on the Internet of Things," provides a definition for the Internet of Things (IoT) as follows: It is a dynamic global network infrastructure that possesses self-configuration capabilities based on standardized and interoperable communication protocols. Within this network, both physical and virtual objects possess distinct identities, physical attributes, virtual personas, and intelligent interfaces. These elements are seamlessly integrated into the network [9].

This description illustrates the dual dimensions of IoT: time and space, enabling individuals to connect from anywhere at any time through interconnected devices like smartphones, tablets, sensors, CCTV cameras, and more [10] (Fig. 4). A connected object attains significance when it interacts with other objects and software components. For instance, a connected wristwatch gains value within a health and well-being focused ecosystem, transcending its mere timekeeping function.

The rise of the Internet of Things, which aims to blend the distinctions between computers and everyday items, can be attributed to two key factors: the widespread availability of computer resources and the acceptance of web services by users [11].

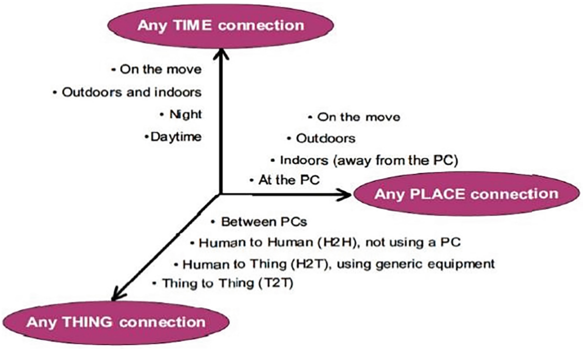

Fig. 4. A new dimension for the IoT [10].

5 Architecture of the IoT

From an architectural standpoint, the Internet of Things is structured into three primary tiers [12]: the data perception layer, the network layer, and ultimately the application layer.

A. *The Perception Layer*
The lowermost tier in the hierarchy, known as the perception layer, assumes the role of gathering data and recognizing it within its surroundings. This layer encompasses the physical components required for collecting contextual information from interconnected objects, which consist of sensors, RFID tags, cameras, GPS (Global Positioning System), and similar technologies.

B. *The Network Layer*
This layer ensures the reliable transmission of data produced within the perception layer and establishes connectivity between interconnected objects as well as between intelligent objects and other servers on the Internet. Conversely, the substantial growth in the number of Internet-connected objects anticipates a significant volume of data within the perception layer. Consequently, it has become essential to implement mechanisms and infrastructure for storing and processing this data efficiently and affordably on the Internet. This necessity is effectively fulfilled by cloud services [13], which offer flexible management of storage and processing resources through vast data centers situated on the Internet. These data centers are adept at handling the data load stemming from the Internet of Things.

It's important to highlight that the cloud employs a contemporary concept called Software Defined Networking (SDN). This concept aims to establish an abstract method of managing networks by separating decision-making and operational functionalities of network equipment. This approach facilitates the deployment of control tasks on platforms that are considerably more efficient than conventional switches, thereby reducing network latency and enabling the automation and self-configuration of extensive arrays of cloud servers.

C. *The Application Layer*

Concerning the application layer, it establishes intelligent service configurations and methods for managing various kinds of data originating from diverse sources, represented by different object types.

The architecture has the potential for expansion into a fourth layer, known as the middleware layer [14], positioned between the application layer and the two other tiers. This intermediary layer serves as the bridge connecting the hardware layer with the applications. It encompasses intricate functions for device management, along with responsibilities like data aggregation, analysis, filtration, and the regulation of service access. The middleware layer additionally conceals the intricacies of network operational mechanisms, simplifying the application development process for programmers.

6 Attacks on Network Layer

A. *Blackhole Attack*

The assault is referred to as a routing layer attack [6], wherein packets are transmitted through multiple nodes within the routing layer (Fig. 5).

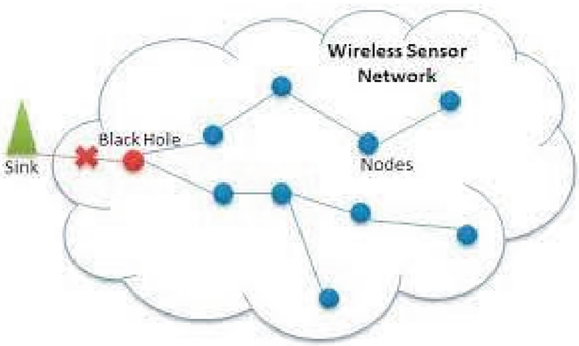

Fig. 5. Blackhole attack.

This attack primarily focuses on causing harm. It presents a challenge to prevention or quick reduction [15]. It can cause temporary disruptions in networks. There are two categories: 1) Internal Black Hole Attack, where the attack originates within the network and involves a deceptive node creating a false route between sender and receiver nodes. 2) External Black Hole Attack, which emerges from outside the network and is akin to Denial of Service (DOS) attacks. Such attacks can lead to network congestion and inflict harm on the entire network.

B. *Sinkhole Attack*

A sinkhole attack [16] is more intricate compared to a black hole attack. Drawing from some understanding of the employed routing protocol, the attacker endeavors to divert traffic from a particular region through their own node. For instance, the attacker might publicize a misleadingly optimal path by promoting factors like power, bandwidth, or high-quality routes to a specific area. As a consequence, other nodes might perceive this attacker node as a better route than their current one and consequently reroute their traffic through it. Given that the affected nodes rely on the attacker for their communication, a sinkhole attack can amplify the impact of other attacks by positioning the attacker within the congested data flow. Numerous other attacks, including eavesdropping, selective forwarding, and black holes, can be exacerbated by sinkhole attacks (Fig. 6).

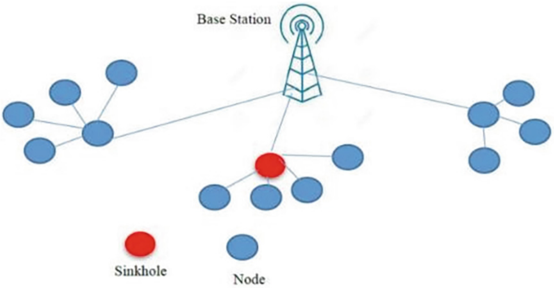

Fig. 6. Sinkhole attack.

C. *Wormhole Attack*

A wormhole attack [17] necessitates the involvement of two or more adversaries. These adversaries possess superior communication resources, such as increased power and bandwidth, compared to regular nodes. They can establish enhanced communication channels, referred to as "tunnels," between one another. Differing from various other attacks that occur within the network layer, these tunnels are physically established. As a result, other sensors are likely to inadvertently include these tunnels in their communication routes, effectively exiting the network under the surveillance of these adversaries (Fig. 7).

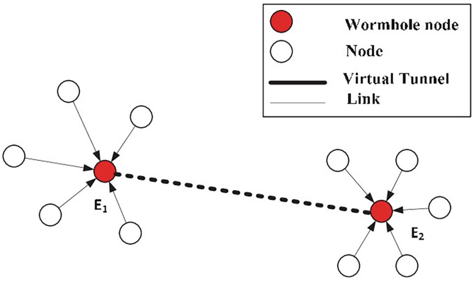

Fig. 7. Wormhole attack.