International journal of science, engineering, and information technology
Volume 07, Issue 01, December 2022
Journal homepage: https://journal.trunojoyo.ac.id/ijseit

INTERNET OF THING BASED CORN TEMPERATURE AND HUMIDITY CONTROL WITH FUZZY METHOD

Kukuh Winarso[a], Faikul Umam[b], Yulia Eka Mawarni[c]

[a]*Industrial Engingeering Departement, Bangkalan, Indonesia*
[b]*Mechatronics Engineering Departement, Bangkalan, Indonesia*
[c]*Department of Mechatronics Engineering, University of Trunojoyo Madura, Bangkalan, Indonesia*

A B S T R A C T

Technological developments that are currently very helpful in work, one of which is in the agricultural sector. Farmers currently do not use technology, even though using technology can help farmers in completing their work. This study used the fuzzy logic method to control the temperature and humidity of corn. Several previous studies have focused more on making corn drying devices so they cannot remotely monitor temperature and humidity in corn. The aim of this research is to create an IoT-based corn temperature and humidity control system with the fuzzy logic method. This research focuses on making tools and systems that can monitor corn temperature and humidity remotely by utilizing a mobile application. The results of this study were two tests, the first experiment used corn with low or wet humidity and normal temperature while the second experiment used corn with high temperature and low humidity. The first experiment in the drying process showed a significant increase from the corn moisture value which was initially 400 to 649 in 15 minutes, while from 649 to 1003 it took 10 minutes. The second experiment took approximately the same time as the first experiment, which was about 15 minutes. When the humidity value has started to rise from 759 to 1005 it only takes approximately 10 minutes.

Keywords: corn, control, temperature, humidity, IoT, fuzzy logic.

Article History
Received 20 September 2022 Received in revised form 20 October 2022 Accepted 2 November 2022

1. Introduction

Technological developments that are currently very helpful in work, one of which is in the agricultural sector. Farmers currently do not use technology, even though using technology can help farmers in completing their work. Technological developments in the agricultural sector have brought significant changes to the process of making farmers' jobs easier [1]–[9].

Corn is one type of plant that is multi-purpose and strategic to develop. Corn plants are currently not only used for food but also for animal feed and industrial raw materials. Corn production based on data from BPS (2022), corn production in (2021) is above 23 million tons of dry shelled corn, an increase of 0.60 million tons. The increase occurred on the island of Java as much as 0.46 million tons [10]–[16].

Research conducted by Ubaidillah M in 2019 involved the design of a plc-based drying device for agricultural products. In this study, manual control was still used so that it could not monitor the condition of corn in real time at a distance [17], [18].

Internet of things (IoT) is a concept that aims to take advantage of continuously connected internet connectivity. The development of IoT is currently very rapid so that it can influence both individuals and groups that can help make human work easier. The benefits of IoT are many, one of which is controlling electronic devices remotely via a computer network [19]–[69].

This study used the fuzzy logic method to control the temperature and humidity of corn. System implementation will be designed in a mobile form so that it is easier to monitor the temperature and humidity of corn by utilizing IoT as a technology that can help maintain the quality of corn after going through the storage process.

2. Methods

2.1. System Design

In terms of the components needed, their respective functions will be explained as follows :

1. DHT11 sensors
   Used as input for monitoring the temperature in the room occupied.
2. Soil sensors
   Used as input to monitor the moisture content of the corn contained in the tool.
3. ESP 8266
   Used to perform processing on the input provided by DHT11 which is then used to activate other components.

* *Corresponding author.* Phone : 081333574112;.
E-mail address: kukuh@trunojoyo.ac.id.

4. WI-FI module
   This section is used as a tool for communication between Android smartphones and the ESP 8266 microcontroller.
5. Android smartphones
   This section is used as a sender of commands on the ESP 8266 microcontroller by utilizing the existing wifi on the smartphone.

After the function of each component is mentioned, it can be seen regarding the system circuit shown in Figure 1.

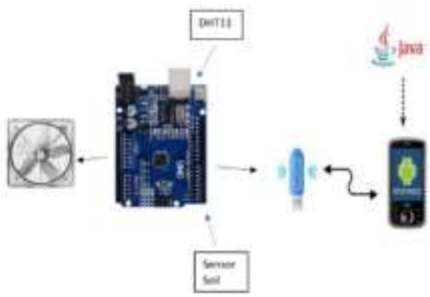

Figure 1. System Chaining

The components used consist of electrical and mechanical components. These components can be combined on the ESP 8266 board with pin initialization which will be shown in the design circuit on the hardware, which will be shown in Figure 7. Before that, you can see about the flowchart travel. The following is the flow of the humidity and temperature monitoring program described in the flowchart of Figure 2.

Figure 2. System Flow

The flowchart above explains the flow of the system, starting from making a declaration on the variable from the output provided, then the sensor reads the variable used as a comparison input for fuzzification, then the results of the fuzzification are converted into a fuzzy form which is then adjusted to a predetermined rule base. In the rule base, various comparison conditions between sensor inputs have been read; in the rule base, it affects the output to be produced, followed by the defuzzification process, which is a change from the fuzzy result to a real number which is then displayed in the results. If the program has not been exited, the sensor reading is repeated continuously and the results shown will be different. If you exit the loop program that has been running will stop.

After discussing the flowchart, it is continued with reading the block diagram of the flow contained in the ESP 8266 microcontroller shown in Figure 3.

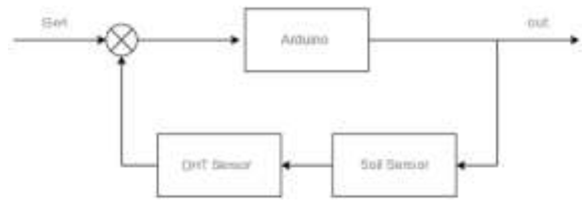

Figure 3. Microcontroller Block Diagram

The block diagram in Figure 3 shows the system flow of the components used. Starting with determining the settings on the input used then processed by the ESP 8266 microcontroller which detects the output of the output will produce feedback because the program detects it continuously. The feedback generated through a comparison between the two sensors, namely the DHT 11 sensor and also the soil moisture sensor from the feedback that has passed through the two sensors, is then re-detected by the ESP8266 microcontroller. The loop in the system flow continues until the program is stopped or changed.

The circuit block diagram for the entire tool process is shown in Figure 4.

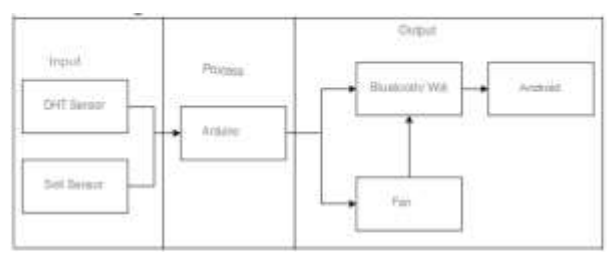

Figure 4. IPO Chart

Figure 4 illustrates the system block I-P-O diagram which explains how the process of running a system is as follows :

1. The input starts from the sensor readings produced by the DHT11 sensor as a temperature sensor and soil moisture as a humidity reading sensor, from the sensor readings a comparison is made.
2. The comparison process of the ESP 8266 microcontroller process which performs several conditions on the sensor reading results, from the sensor reading results is determined the results that affect the output.
3. Output is generated from data processing by arduino sent by sensors. After sending the output is divided into two, namely hardware and software output. The hardware output is also read by the software. Hardware output in the form of rotation on the fan which is sent to the bluetooth module or Wi-Fi module shows how many rotational speeds occur on the fan, and also the software output from sending values by the ESP 8266 microcontroller is sent to the bluetooth module or Wi-Fi module to run or enter results on reading temperature, humidity, and fan rotation data into an android. Android is used to display the results of humidity and temperature readings, peel indicators, and also the rotation state of the fan.

2.2. Data Collection Technique

The data collection used in this study was to use data collection by reviewing previous research and also testing the tools used to see if the data generated were appropriate.

2.3. Software Design

The layout design of the software when it is first run is shown in Figure 5.

Figure 5. Software Design

The application design above is the initial design of an Android-based corn temperature and humidity control application in making this application using Android Studio. In the application there is a "start" button to enter the dashboard page, as shown in Figure 6.

Figure 6. Dashboard Page

In Figure 6 above there is a display or design that has several features, namely the back button, temperature value, humidity value, and also features how the condition of the fan is when the two sensors read the signal.

2.4. Hardware Design

The series of temperature and humidity control systems in corn is shown in Figure 7.

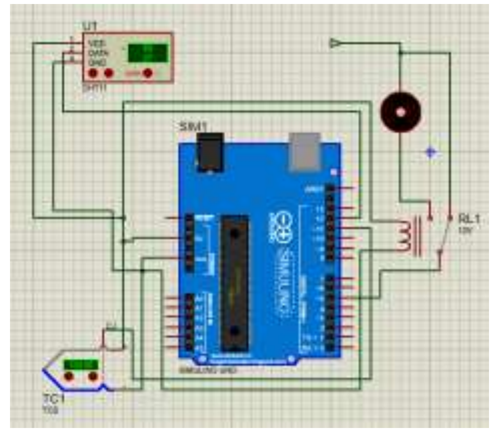

Figure 7. Hardware Design

Figure 7 above shows the hardware design of the design plan that will be carried out on the microcontroller, such as the configuration of the pins used as senders or input readers from the DHT 11 sensor or soil moisture sensor. Pin configuration can also be done at the output for voltage regulation which was originally digital and converted to analog by using analog pins. After doing the wiring, you can enter the available programs.

3. Result

Firebase by entering an account into Android Studio. After entering a Google account, an account from Firebase can be created and connected. How to connect it yourself by creating several variables that can be made in firebase and included in the source code. This application has 3 variables, namely Moist, Temp, and fan, each of which is used to connect from firebase to a TextView that has been given a different id, such as temperature and humidity. The first time the application is run the results of the application will display a value of 0 because the program from the Arduino IDE has not been executed, for the initial appearance and data of these values are shown in Figure 8.

Figure 8. Initial Values From Firebase

The following is a display of the application when the values of the variables in firebase are 0, shown in Figure 9.

Figure 9. Display When Values is 0

After successfully making the application and firebase connected, input the source code into the Arduino IDE application and compile it to run the program, the results of the program above display several conditions, namely the fan is slow, the fan is slow, and the fan turns off depending on the reading of the sensor value. fan condition is determined. Before conducting a circuit experiment on corn, several tests were carried out on the conditions of the circuit to find out whether the circuit was working properly and correctly. The first test was carried out for the "slow fan" condition, shown in Figure 10.

Figure 10. Testing The Condition of The Slow Fan

In testing the conditions of the "alon fan" has several errors in its output. When in this condition the fan can only rotate when the delay from the sensor reading repeats, because the delay is 0.2 seconds, the fan is active when the program has read the temperature and humidity values every 0.2 seconds, in this condition also the output or rotation that occurs the fan becomes slow because the output value has been changed from 1023 to 500 initially, causing the fan rotation to slow down because the voltage is not fully released.

In the next test, testing is carried out with the "medium fan" condition. This condition is a condition where the fan is between fast and slow, for the output value it is given a value of 800. In this condition the fan rotates normally, unlike the "low fan" condition. in the "medium fan" condition, it runs according to the desired destination, the fan does not rotate, waits for the reading of the signal every 0.2 seconds, the fan only changes mode when the humidity value is higher or conditions change, as can be seen in Figure 11.

Figure 11. Testing The Condition of The Fan is Being

In the next test, it was carried out under the "banter fan" condition. In this condition, the fan rotated quickly or normally because the value of the output did not decrease, namely 1023, shown in Figure 12.

Figure 12. Testing The Condition of The Banter Fan

In this first experiment, it showed that the humidity of the corn was 400, so it was very humid and the temperature stated normal with the condition of the fan at best, can be seen in Figure 13.

Figure 13. First Test View

After 15 minutes of the first test, the humidity in the corn has started to decrease, which is worth 687 and the temperature has started to decrease so that the humidity has decreased significantly from before, so the fan starts to reduce its speed. Changes in corn temperature and humidity can be seen in Figure 14.

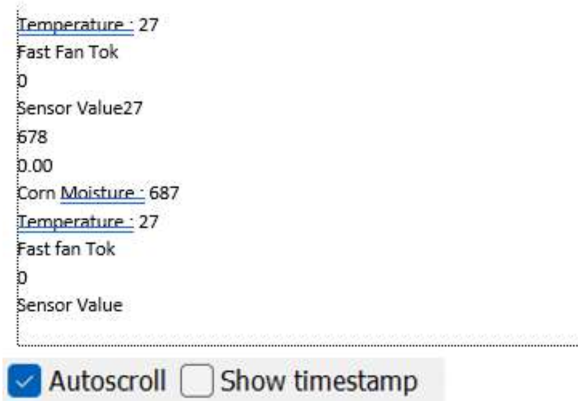

Figure 14. Conditions when humidity Decreases

Testing under fan conditions shows things that are not much different from testing under fan conditions at best, because the data sent via the ESP8266 is data in real time so that it directly matches the speed of data transmission, the display of the application is shown in Figure 15.

Figure 15. Display When Humidity Decreases

10 minutes after the test is finished, the corn moisture value has reached more than 1000, the corn moisture is getting smaller so the fan will decrease again, then the application will display the fan condition as "slow fan", as shown in Figure 16.

Figure 16. The Humidity Display is Decreasing

In the second experiment this was carried out using wet corn with a higher corn temperature or you could say it was hot, this was done to get different results and goals from the first experiment. At the time of the experiment the corn conditions were wet and had a high temperature, the resulting output was a "blow fan" this happened because the desired result was that the temperature of the corn could drop significantly, shown in Figure 17.

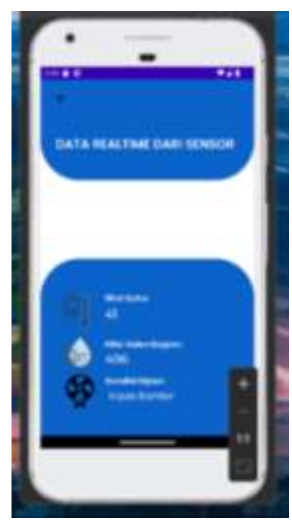

Figure 17. The Second tes tis at High corn Temperatures

Within 10 minutes after carrying out the test, the temperature and humidity of the corn decreased but not as significantly as the first experiment. This is because the fan tries to lower the temperature first. The display of the application after the temperature drops can be seen in Figure 18.

Figure 18. Results When The Temperature Start To Drop Under Fan Conditions at Best

The figure above shows that the condition of the fan is still "low speed fan".

Within 15 minutes the humidity has started to decrease again, so the fan condition will change to "medium fan" or the fan will start to reduce speed because the humidity has started to decrease to 759, shown in Figure 19.

Figure 19. Results When The Fan Starts to Decrease in Speed

Within 10 minutes the humidity value has decreased again, namely to a value of 1005 so that the humidity has decreased, then the fan condition will become "slow fan", the display of the "slow fan" condition. In this second experiment, the time needed to reach the desired dryness point with a total time needed is 35 minutes, the time also depends on the temperature in the corn, shown in Figure 20.

Figure 20. The Results of Temperature and Humidity Have Decreased

Data on the time needed to make corn conditions from moist conditions to dry corn conditions are shown in Table 1.

Table 1. Time Span

No	First try		Second Try	
	Time required	Temperature and Humidity	Time required	Temperature and Humidity
1	-	27° & 400	-	41° & 496
2	10 minute	27° & 649	10 minute	28° & 497
3	15 minute	27° & 1003	15 minute	28° & 759
4	-	-	10 minute	28° & 1005
Total	25 minute		35 minute	

The test data that has been carried out in the first experiment and the second experiment are shown in Table 2.

Table 2. Test Results Data

No	First Try		Second Try	
	Fan Condition	Temperature and Humidity	Fan Condition	Temperature and Humidity
1	Fast Fan	27° & 400	Fast Fan	41° & 496

No	First Try		Second Try	
2	Medium Fan	27º & 649	Fast Fan	28º & 497
3	Low Fan	27º & 1003	Medium Fan	28º & 759
4	-	-	Low Fan	28º & 1005

4. Conclusion

The results of this study refer to the first experiment using corn with low or wet humidity and normal temperature while the second experiment used corn with high temperature and low humidity. The first experiment during the drying process showed a significant increase from the corn moisture value which was initially 400 to 649 in 15 minutes, while from 649 to 1003 it took 10 minutes.

In the second experiment using corn with high temperature and humidity values. After 10 minutes the fan can only reduce the temperature, while the humidity decreases but not too significantly, while when the decrease in the value of the "fast fan" and "medium fan" conditions, the time needed is approximately the same as the first experiment, which is around 15 minutes. When the humidity value has started to rise from 759 to 1005 it only takes approximately 10 minutes.

In the first and second experiments, the time difference was quite long, which was 10 minutes.

REFERENCES

[1] M. R. Waluyo, Nurfajriah, F. R. I. Mariati, and Q. A. H. H. Rohman, “Pemanfaatan Hidroponik Sebagai Sarana Pemanfaatan Lahan Terbatas Bagi Karang Taruna Desa Limo,” Ikraith-Abdimas, vol. 4, no. 1, 2021.

[2] R. Nandika and E. Amrina, “SISTEM HIDROPONIK BERBASIS INTERNET of THINGS (IoT),” SIGMA TEKNIKA, vol. 4, no. 1, 2021, doi: 10.33373/sigmateknika.v4i1.3253.

[3] D. Setiadi and M. N. A. Muhaemin, “Penerapatn Internet of Things (IoT) pada sistem Monitoring Irigasi,” Jurnal Infrontonik, vol. 03, no. 2, 2018.

[4] D. Setiadi and M. N. Abdul Muhaemin, “Penerapan Internet of Things (IoT) pada Sistem Monitoring Irigasi (Smart Irigasi),” Infotronik : Jurnal Teknologi Informasi dan Elektronika, vol. 3, no. 2, 2018, doi: 10.32897/infotronik.2018.3.2.108.

[5] S. Wahyudi, E. Noerhayati, and A. Rachmawati, “Sistem Kinerja Alat Irigasi Curah (Sprinkler) Berbasis Mikrokontroler IoT (Internet Of Things),” Jurnal Rekayasa Sipil, 2020.

[6] D. A. H. Kevin, “Rancang bangun sistem monitoring dan kendali irigasi berbasis internet of things (iot),” Institut Teknologi Telkom Purwokerto, vol. 1, no. 69, 2019.

[7] Shofiyun, M. Humam, and A. Basit, “Sistem Irigasi Otomatis Pada Sawah Bawang Merah Berbasis IoT (Internet of Things),” Journal Cyber Resilience of Systems and Networks, vol. 1, no. 1, 2021.

[8] Miftahul Walid, H. Hoiriyah, and A. Fikri, “Pengembangan Sistem Irigasi Pertanian Berbasis Internet of Things (IoT),” Jurnal Mnemonic, vol. 5, no. 1, 2022, doi: 10.36040/mnemonic.v5i1.4452.

[9] F. R. Hadi, M. Fikriadin, T. R. T. W. Cahya, and A. F. Rahmasari, “Pemanfaatan Lahan dengan Sistem Aquaponik sebagai Pemulihan Ekonomi Masa Pandemi bagi Pemuda Karang Taruna di Desa Selopuro Ngawi,” Jurnal Abdimas Indonesia, vol. 1, no. 3, 2021, doi: 10.53769/jai.v1i3.113.

[10] R. Ramdani, S. P. Sutisna, and E. Sutoyo, “Rancang Bangun Prototipe Kontrol Suhu Dan Kipas Pada Box Dryer Pengeringan Biji Jagung Berbasis Arduino Uno At328,” Almikanika, vol. 2, no. 2, 2021.

[11] A. A. N. Lubis et al., “Serangan Ulat Grayak Jagung (Spodoptera Frugiperda) pada Tanaman Jagung di Desa Petir , Kecamatan Daramaga , Kabupatem Bogor,” Jurnal Pusat Inovasi Masyarkat, vol. 2, no. 6, 2020.

[12] Y. Maharani, V. K. Dewi, L. T. Puspasari, L. Rizkie, Y. Hidayat, and D. Dono, “Kasus Serangan Ulat Grayak Jagung Spodoptera frugiperda J. E. Smith (Lepidoptera: Noctuidae) pada Tanaman Jagung di Kabupaten Bandung, Garut dan Sumedang, Jawa Barat,” CROPSAVER - Journal of Plant Protection, vol. 2, no. 1, 2019.

[13] B. Silap and C. S. Rante, “Serangan Hama Ulat Grayak (Spodoptera frugiperda) Pada Tanaman Jagung (Zea mays L.),” Jurnal Agroekoteknologi Terapan, vol. 1, no. 2, 2020.

[14] B. Widhayasa and E. S. Darma, “Peranan faktor cuaca terhadap serangan Ulat Grayak Spodoptera frugiperda (Lepidoptera : Noctuidae) pada Tanaman Jagung di Kabupaten Berau, Kalimantan Timur,” Jurnal Agroekoteknologi Tropika Lembab, vol. 4, 2022.

[15] B. Widhayasa and E. Suryadarma, “Peranan Faktor Cuaca terhadap Serangan Ulat Grayak Spodoptera frugiperda (Lepidoptera: Noctuidae) Pada Tanaman Jagung di Kabupaten Berau, Kalimantan Timur,” Journal of Tropical AgriFood, 2021, doi: 10.35941/jatl.4.2.2022.6999.93-98.

[16] H. D. Pebrianti and H. M. Siregar, “Serangan ulat grayak jagung Spodoptera frugiperda (Lepidoptera: Noctuidae) pada tanaman jagung di Kabupaten Muaro Jambi, Jambi,” Agrohita, vol. 6, no. 1, 2021.

[17] M. K. L. Ubaidillah, “Rancang Bangung Alat Pengering Hasil Pertanian Berbasis Plc (Studi Kasus : Pengering Jagung),” J Chem Inf Model, vol. 53, no. 9, pp. 1689–1699, 2019.

[18] A. Nurbaeti, M. Kusumawardani, and H. Darmono, “Rancang Bangun Alat Pengering Biji Kopi Berbasis Internet Of Things,” Jurnal Jartel: Jurnal Jaringan Telekomunikasi, vol. 11, no. 2, 2021, doi: 10.33795/jartel.v11i2.60.

[19] R. Septian and S. Mufti Prasetiyo, “Sistem Keamanan Menggunakan Kamera dan Sensor Gerak Berbasiskan Internet of Things (IoT),” OKTAL : Jurnal Ilmu Komputer dan Science, vol. 1, no. 9, 2022.

[20] M. A. Febriantono, “Tantangan Keamanan pada IoT (Internet of Things),” Binus.Ac.Id, 2020.

[21] Y. F. Andriani, M. F. Noor, A. S. Salim, and Hanafi, “Internet Of Things (Iot) – Tantangan Dan Keamanan Iot Menggunakan Enkripsi AES,” Jurnal INFORMA Politeknik Indonusa Surakarta, vol. 5, no. 1, pp. 76–83, 2019, [Online]. Available: http://download.garuda.ristekdikti.go.id/article.php?article=1706002&val=18526&title=INTERNET OF THINGS IOT TANTANGAN DAN KEAMANAN IOT MENGGUNAKAN ENKRIPSI AES

[22] M. Wimala and K. Imanuela, “Perkembangan Internet of Things di Industri Konstruksi,” Journal of Sustainable Construction, vol. 1, no. 2, 2022, doi: 10.26593/josc.v2i1.5701.

[23] M. Gunturi, H. D. Kotha, and M. Srinivasa Reddy, “An overview of internet of things,” Journal of Advanced Research in Dynamical and Control Systems, vol. 10, no. 9, 2018.

[24] International Telecommunication Union, “Overview of the Internet of things,” Series Y: Global information infrastructure, internet protocol aspects and next-generation networks - Frameworks and functional architecture models, 2012.

[25] ITU, “Overview of the Internet of things,” 2012.

[26] S. Villamil, C. Hernández, and G. Tarazona, “An overview of internet of things,” Telkomnika (Telecommunication Computing Electronics and Control), vol. 18, no. 5, 2020, doi: 10.12928/TELKOMNIKA.v18i5.15911.

[27] P.P. Ray, "A survey on Internet of Things architectures - ScienceDirect," Journal of King Saud University - Computer and Information Sciences. 2018.

[28] C. Hasiholan, R. Primananda, and K. Amron, "Implementasi Konsep Internet of Things pada Sistem Monitoring Banjir menggunakan Protokol MQTT," Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer, vol. 2, no. 12, pp. 6128–6135, 2018, [Online]. Available: http://j-ptiik.ub.ac.id

[29] S. Ray et al., "A Survey paper on architecture of internet of things," in 2018 IEEE 9th Annual Information Technology, Electronics and Mobile Communication Conference, IEMCON 2018, 2019. doi: 10.1109/IEMCON.2018.8614931.

[30] M. Atzori, "Blockchain-Based Architectures for the Internet of Things: A Survey," SSRN Electronic Journal, 2018, doi: 10.2139/ssrn.2846810.

[31] V. W. Mahyastuty, H. Hendrawan, I. Iskandar, and M. S. Arifianto, "Survey of clustering techniques in internet of things architecture," in Proceeding of 14th International Conference on Telecommunication Systems, Services, and Applications, TSSA 2020, 2020. doi: 10.1109/TSSA51342.2020.9310807.

[32] S. Yerpude, "SMART Warehouse with Internet of Things supported Inventory Management System," International Journal of Pure and Applied Mathematics, vol. 118, no. 24, 2018.

[33] S. Keivanpour and D. A. Kadi, "The effect of 'Internet of things' on aircraft spare parts inventory management," in IFAC-PapersOnLine, 2019. doi: 10.1016/j.ifacol.2019.11.556.

[34] N. R. Atyam, R. P. Babu, P. Ponmurugan, L. S. Senthamil, P. John Augustine, and A. Govindarajan, "Integrated Internet of Things with Blockchains for Vendor-Management Inventory System," in Proceedings - 6th International Conference on Computing Methodologies and Communication, ICCMC 2022, 2022. doi: 10.1109/ICCMC53470.2022.9753843.

[35] Y. Mashayekhy, A. Babaei, X. M. Yuan, and A. Xue, "Impact of Internet of Things (IoT) on Inventory Management: A Literature Survey," Logistics, vol. 6, no. 2. 2022. doi: 10.3390/logistics6020033.

[36] M. Dachyar and R. Yolanda, "Hospital pharmaceutical vendor managed inventory supported by internet of things," in Proceedings of the International Conference on Industrial Engineering and Operations Management, 2020.

[37] D. M. K. Bader, N. Innab, I. Atoum, and F. F. Alathamneh, "The influence of the Internet of things on pharmaceutical inventory management," International Journal of Data and Network Science, vol. 7, no. 1, 2023, doi: 10.5267/j.ijdns.2022.9.009.

[38] C. Team, "Decentralized Infrastructure for Next Generation Internet of Things," Cyber-Physical Chain, 2018.

[39] G. Pau, C. Chaudet, D. Zhao, and M. Collotta, "Next generation wireless technologies for internet of things," Sensors (Switzerland), vol. 18, no. 1. 2018. doi: 10.3390/s18010221.

[40] M. Carnie, K. Seunarine, S. Thomas, G. Thomas, and Z. Haymoor, "Will Next Generation Photovoltaics Power the Internet of Things?," 2022. doi: 10.29363/nanoge.nfm.2022.211.

[41] N. N. Thilakarathne, M. K. Kagita, and W. D. M. Priyashan, "Green Internet of Things: The Next Generation Energy Efficient Internet of Things," 2022. doi: 10.1007/978-981-16-2008-9_38.

[42] S. Kautish and G. Kaur, AI-Enabled agile internet of things for sustainable fintech ecosystems. 2022. doi: 10.4018/978-1-6684-4176-3.

[43] W. C. Wu and H. T. Liaw, "The next generation of internet of things: Internet of vehicles," in Lecture Notes in Electrical Engineering, 2018. doi: 10.1007/978-981-10-7398-4_29.

[44] [44] Shruti and S. Rani, "Internet of Things: The Next Generation Internet," 2023. doi: 10.1007/978-981-19-2065-3_18.

[45] M. Maiti and U. Ghosh, "Next-Generation Internet of Things in Fintech Ecosystem," IEEE Internet Things J, vol. 10, no. 3, 2023, doi: 10.1109/JIOT.2021.3063494.

[46] P. Li, J. Ryu, and S. Hong, "Piezoelectric/Triboelectric Nanogenerators for Biomedical Applications," in Nanogenerators, 2020. doi: 10.5772/intechopen.90265.

[47] L. Parrett and W. Liao, "Internet of Intelligent Things and Applications," Proc W Va Acad Sci, vol. 90, no. 1, 2018, doi: 10.55632/pwvas.v90i1.402.

[48] X. Zhao, H. Askari, and J. Chen, "Nanogenerators for smart cities in the era of 5G and Internet of Things," Joule, vol. 5, no. 6. 2021. doi: 10.1016/j.joule.2021.03.013.

[49] Z. L. Wang, "(Invited) Triboelectric Nanogenerators for Internet of Things and Self-Powered Systems," ECS Meeting Abstracts, vol. MA2019-02, no. 30, 2019, doi: 10.1149/ma2019-02/30/1291.

[50] K. Vinoth Kumar, M. Omer, S. S. Singh, and M. A. Nayrah, "A Review on Triboelectric Nanogenerators (TENGs) using Internet of Things," in 2021 International Conference on Forensics, Analytics, Big Data, Security, FABS 2021, 2021. doi: 10.1109/FABS52071.2021.9702612.

[51] J. Li et al., "Triboelectric nanogenerators enabled internet of things: A survey," Intelligent and Converged Networks, vol. 1, no. 2, 2020, doi: 10.23919/ICN.2020.0008.

[52] A. Ahmed et al., "Integrated Triboelectric Nanogenerators in the Era of the Internet of Things," Advanced Science, vol. 6, no. 24. 2019. doi: 10.1002/advs.201802230.

[53] X. Cao, Y. Xiong, J. Sun, X. Xie, Q. Sun, and Z. L. Wang, "Multidiscipline Applications of Triboelectric Nanogenerators for the Intelligent Era of Internet of Things," Nano-Micro Letters, vol. 15, no. 1. 2023. doi: 10.1007/s40820-022-00981-8.

[54] Y. C. Manie, C. K. Yao, T. Y. Yeh, Y. C. Teng, and P. C. Peng, "Laser-Based Optical Wireless Communications for Internet of Things (IoT) Application," IEEE Internet Things J, vol. 9, no. 23, 2022, doi: 10.1109/JIOT.2022.3190619.

[55] A. Čolaković, A. Hasković Džubur, and B. Karahodža, "Wireless communication technologies for the Internet of Things," Science, Engineering and Technology, vol. 1, no. 1, 2021, doi: 10.54327/set2021/v1.i1.3.

[56] U. D. Ulusar, F. Al-Turjman, and G. Celik, "An overview of Internet of Things and wireless communications," in 2nd International Conference on Computer Science and Engineering, UBMK 2017, 2017. doi: 10.1109/UBMK.2017.8093446.

[57] A. S. Hamza, T. Tripp, and S. Member, "Optical Wireless Communication for the Internet of Things : Advances , Challenges , and Opportunities," Techrxiv, no. November, 2020.

[58] J. Jagannath, N. Polosky, A. Jagannath, F. Restuccia, and T. Melodia, "Machine learning for wireless communications in the Internet of Things: A comprehensive survey," Ad Hoc Networks, vol. 93, 2019, doi: 10.1016/j.adhoc.2019.101913.

[59] X. C. Yang, Z. Y. Yan, Z. J. Chun, and L. L. Zou, "Optical Fiber Communication and Wireless Communication Technology Oriented to Internet of Things," in Lecture Notes in Electrical Engineering, 2021. doi: 10.1007/978-981-16-3456-7_31.

[60] D. E. Kouicem, A. Bouabdallah, H. Lakhlef, D. E. Kouicem, A. Bouabdallah, and H. Lakhlef, "Internet of things security : A top-down survey To cite this version : HAL Id : hal-01780365 Internet of Things Security : a top-down survey," Computer Networks, no. 141, 2018.

[61] M. Avatade, M. Lal, and A. Jain, "A Survey of Wireless Communication Technologies in Internet of Things," International Journal of Computer Sciences and Engineering, vol. 6, no. 8, 2018, doi: 10.26438/ijcse/v6i8.823826.

[62] Z. Zhang et al., "Optical wireless communication and internet of things," Chinese Journal on Internet of Things, vol. 6, no. 3, 2022, doi: 10.11959/j.issn.2096-3750.2022.00278.

[63] A. Celik, I. Romdhane, G. Kaddoum, and A. M. Eltawil, "A Top-Down Survey on Optical Wireless Communications for the Internet of Things," IEEE Communications Surveys and Tutorials, vol. 25, no. 1, 2023, doi: 10.1109/COMST.2022.3220504.

[64] R. Wang, C. Yu, and J. Wang, "Construction of Supply Chain Financial Risk Management Mode Based on Internet of Things," IEEE Access, vol. 7, 2019, doi: 10.1109/ACCESS.2019.2932475.

[65] H. S. Birkel and E. Hartmann, "Internet of Things – the future of managing supply chain risks," Supply Chain Management, vol. 25, no. 5, 2020, doi: 10.1108/SCM-09-2019-0356.

[66] D. Satpathy, "Internet of Things : A Boon for Supply Chain Management," Indian Journal of Computer Science, vol. 4, no. 2, 2019, doi: 10.17010/ijcs/2019/v4/i2/144273.

[67] G. N. Montoya, J. B. S. Santos Junior, A. G. N. Novaes, and O. F. Lima, "Internet of Things and the Risk Management Approach in the Pharmaceutical Supply Chain," in Lecture Notes in Logistics, 2018. doi: 10.1007/978-3-319-74225-0_38.

[68] V. Ünal, M. Ömürgönülşen, S. Belbağ, and M. Soyasal, "The Internet of Things in Supply Chain Management," in Logistics 4.0, 2020. doi: 10.1201/9780429327636-5.

[69] S. I. Al-Ayed and A. A. Al-Tit, "The effect of supply chain risk management on supply chain resilience: The intervening part of Internet-of-Things," Uncertain Supply Chain Management, vol. 11, no. 1, 2023, doi: 10.5267/j.uscm.2022.10.009.