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An internet of things enabled framework to monitor the lifecycle of *Cordyceps sinensis* mushrooms

Minakshi Memoria[1], Sanjeev Kumar Shah[1], Harishchander Anandaram[3], Anooja Ali[4], Kapil Joshi[1] Parag Verma[1], Rajesh Singh[2,5], Anita Gehlot[2,5], Shaik Vaseem Akram[2]
[1]Uttaranchal Institute of Technology, Uttaranchal University, Dehradun, India
[2]Division of Research and Innovation, Uttaranchal Institute of Technology, Uttaranchal University, Dehradun, India
[3]Centre for Excellence in Computational Engineering and Networking, Amrita Vishwa Vidyapeetham, Coimbatore, India
[4]Department of Computer Science and Engineering, REVA University, Bangalore, India
[5]Department of Project Management, Universidad Internacional Iberoamericana, Campeche, México

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ABSTRACT

Cordyceps sinensis is an edible mushroom found in high quantities in the regions of the Himalayas and widely considered in traditional systems of medicine. It is a non-toxic remedy mushroom and has a high measure of clinical medical benefits including cancer restraint, high blood pressure, diabetes, asthma, depression, fatigue, immune disorder, and many infections of the upper respiratory tract. The cultivation of this kind of mushroom is limited to the region of the Sikkim and to cultivate in the other regions of the country, they are need of investigation and prediction of cordyceps sinensis mushroom lifecycle. From the studies, it is concluded that the precision-based agriculture techniques are limitedly explored for the prediction and growth of *Cordyceps sinensis* mushrooms. In this study, an internet of things (IoT) inspired framework is proposed to predict the lifecycle of *Cordyceps sinensis* mushrooms and also provide alternate substrate to cultivate *Cordyceps sinensis* mushrooms in other parts of the country. As a part of lifecycle prediction, a framework is proposed in this study. According to the findings, an IoT sensor-based system with the ideal moisture level of the mushroom rack is required for the growth of *Cordyceps sinensis* mushrooms.

Corresponding Author:

Rajesh Singh
Division of Research and Innovation, Uttaranchal Institute of Technology, Uttaranchal University
Dehradun-248007, Uttarakhand, India
Email: drrajeshsingh004@gmail.com

1. INTRODUCTION

Traditionally, Chinese medical and Tibetan medicine prefer *Cordyceps sinensis* as a medication for different diseases [1]. *Cordyceps* is a generic name derived from the Latin word *kordyle* meaning “club” and *ceps* meaning “head”. *Cordyceps sinensis* is the mixture of a caterpillar and a fungus that can only be found in Sikkim at altitudes above 4,500 meters [2]. *Cordyceps sinensis* is typically harvested from April to August in cold, grassy, alpine meadows of the Himalayan mountains [3]. Traditional North Sikkim healers and residents use *Yarsagumba*, *Keerajhar* (*Cordyceps sinensis*) alone or in combination with other herbs to strengthen the immune system, improve renal function in patients with erythematosus, and retard aging [4]. In addition, it is also used to recover from anemia, immune deficiencies, fatigue, low back pain, impotence, night sweats, and for recuperation from chronic disease. The annual ascomycete *Cordyceps sinensis* is closely associated with the mushroom and is not technically a mushroom but is described in traditional Chinese and Tibetan medicine as an exotic therapeutic fungus [5]. Cordyceps comprise distinct nutritional components like amino acids, carbohydrates such as oligosaccharides, monosaccharides, vitamins like K, B12, B2, and B1.

Even though this plant has numerous medicinal benefits, it is only found in Sikkim. It is difficult for people in other parts of the country to benefit from it because it grows at high altitudes and in cold climates [6]. The study of the life cycle of *Cordyceps sinensis* mushrooms must be carried out in order to understand the various parameters that are required to cultivate the same mushroom in a different region [7]. As a part of it, a few studies have proposed frameworks to study the lifecycle of the *Cordyceps sinensis* mushrooms, but those frameworks lack a graphical user interface and are not embedded with internet of things (IoT). Currently IoT gained significant attention in the farming for its real-time sensing, monitoring and provide valuable insights to the farm to cultivate more effectively [8]. In the mushroom gardening field, IoT is used for control and observation, and a significant number of readily available structures, particularly for mushroom development, have yet to be used for general climate screening and control. To overcome these challenges, we have proposed a framework that is based on IoT, where the lifecycle of caterpillar is studied. Based upon the study, we can identify those parameters that can be applied in other climate area of India, to grow this kind of mushroom by studying the lifecycle of caterpillar. The contribution of the study is as a system is proposed with the integration of big data and IoT framework, that IoT inspired framework is proposed to study and predict the lifecycle of *Cordyceps sinensis* and developing dynamic web portal for the real-time visualization of mushroom processing.

The structure of the paper is organized as follows. Section 2 discusses the literature review. Section 3 covers the proposed system in detail. Section 4 covers IoT enabled framework and it is concluded in the final section.

2. PRIOR ART

In these various species of medicinal mushrooms, *Cordyceps* species are highly considered in various positive aspects specially in terms of safety or non-toxic group of medicine [9], to enhance the immune system in terms of human clinical health concern [10], to control neuroprotection based activities [11], [12] effecting medicine for anticancer [13], activities for antimicrobial system [14], and activates for anti-inflammatory system as well [15], [16], and therefore, a significant literature review in concern about the components of medical significances, activities about the pharmacological practices, are hereby covered in Tables 1 and 2 respectively.

Table 1. Constitution for the medical imperative of *Cordyceps sinensis*

Ref	Component	Importance
[17]	Cordycepin	Hostility to tumors, inhibition of RNA/DNA association, concealment (anti-HIV) antimalarial activities of viral replication, regulates homeostatic potential against leukemia action
[18]	Adenosine	Mitigation effect, control of bleeding of cardiovascular arrhythmias
[19]	Amino acids, zinc, vitamins & trace elements	Struggles with sexual drowsiness
[20]	Polysaccharides	Inhibition of lipid peroxidation, pharmacological agitation, inhibition of hemolysis and tumor restraint, anti-oxidation action, immunomodulatory, and antitumor property
[21]	Ergosterol	Hostile to the tumor and immunomodulatory effects
[22]	Cordy glucans	Agitation against tumor

Table 2. Important pharmacological practice of *Cordyceps sinensis*

Ref	Pharmacological Activity
[23]	Hostility to the effects of asthma and against malignant growth specialist
[24]	Activities for possess hypotensive and vasorelaxant
[25]	Hostile to oxidation action
[26]	Fasting reduces hyperglycemia and immune-regulatory movement
[27]	Implementing hostile and invincible modalities for tumor action

This specific species of medicinal mushroom are parasites, essentially on creepy crawlies and other arthropods. Some species from these are also in parasitic categories on other kind of fungi like additionally subterranean, truffle-like *Elaphomyces* and spiders as well [28]. There is an incompatible Sacc., which means *entomophagous* parasitic growth of the family of *Clavicipitaceae*. Caterpillar fungus *Cordyceps sinensis* (Berk.) Sacc., is a very well alleged medicinal mushroom species [29]. Like the part, the cutting edge can be seen jutting slightly above the insect like a tiny horn. This horn-like structure continues to be built even further [30].

The *Cordyceps sinensis* medicinal mushroom is seasonally produced in India with specific regions like Sikkim or other high mountain regions, plus it can very well be filled in environmental-controlled crop produce houses [31]. As of late, *Cordyceps* species in brown rice were effectively compromised towards developing and have been responsible for many examinations refined in brown rice using *Cordyceps* species [32], [33]. By and large, the ecological conditions for the growth of *Cordyceps sinensis* mushrooms can be expressed in terms of temperature, humidity, light intensity, fresh air and the soil moisture [34]. In the mushroom growing/cultivation room, the airflow is an important part of mushroom development because it legitimately affects the carbon dioxide (CO_2) content of the room.

The growth pattern of *Cordyceps sinensis* mushrooms can be divided into two phases; the first phase is vegetative phase, which includes mycelia expansion and development, and the second phase is the regenerative phase [35]. To grow *Cordyceps sinensis* mushrooms, a mycelium culture is allowed to grow on cleaned cereal grains, which bring forming spawn. The produce spawn is inoculated into a disinfected substrate and allowed to uproot the substrate [36]. During brooding, mycelium develops all through the substrate and uses supplements in it. This cycle is called the spawn or production run. During the production run, the ideal temperature is about 25 °C and the high carbon dioxide concentrate is positive. From that point on, the mycelium arrives at the regenerative stage and is fitted to deliver mushrooms. The main variables that induce the formation of *Cordyceps sinensis* mushrooms are an unexpected decrease in temperature (temperature of 5 to 10 °C) and a sudden decrease in carbon dioxide fixation [37]. After that, the ideal temperature for growth is around 10 to 25 °C, 85% to 92% RH (relative humidity), 600 ppm (million per million), and carbon dioxide fixation under 500 lux, 2,000 lux for 12 hours. Since dissimilar phases required a specific senescence, temperature, carbon dioxide, and the concentration of carbon dioxide, a framework with pre-determined conditions for different phases simplifies it to a *Cordyceps sinensis* mushroom farmers [38]. All these referenced functions do not allow checking and control through the graphical user interface. Similarly, IoT can be easily used for control and observation in the mushroom gardening field. Similarly, a significant number of accessible structures in the market, especially for mushroom development, are not yet employed for general climate screening and control.

3. PROPOSED SYSTEM

The advancement in technology in the area of farming has transformed the monitoring of farming in real-time environment from any location through internet connectivity. As limited real-time technology was used, this encouraged the implementation of IoT to predict the growth of *Cordyceps sinensis* mushrooms in this study. The proposed framework is based on the growth of *Cordyceps sinensis* mushrooms using the tail of a caterpillar, and it will pave the way for the recommended substrate for *Cordyceps sinensis* mushrooms. The proposed framework is illustrated in Figure 1, and it comprises of five components such as substrate model, big data warehousing, cloud IoT module, IoT enabled framework, and mobile app. Despite the fact that much work has been done on alternate substrate for yield of *Cordyceps sinensis* Mushrooms, there is limited data on the alternate substrate for growth of *Cordyceps sinensis* mushrooms. An alternative substrate for the cultivation of *Cordyceps sinensis* Mushrooms other than the lab variants is suggested with the assistance of proposed framework.

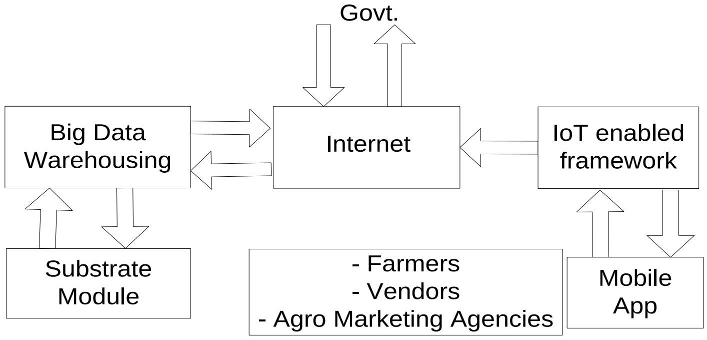

Figure 1. Proposed framework on between big data and IoT framework

IoT enabled framework is portable IoT device with soil and environment sensors. Mobile app module provides interface to the users, and it will also notify the users or farmers through text messages. Storage, big-data mining, analysis, and knowledge building engines, as well as an application module to interface with users, make up the cloud IoT module. Big data warehousing is generally used to store and mine the data which is relevant to the users and knowledge building module is used to take the decision based on the prediction. Since the inherent benefits of cultivation of *Cordyceps sinensis* mushrooms are high, the suggested module saves data collected on a regular basis from soil and environmental samples. The cloud IoT model is sandwiched between the big data warehousing engine. This module is critical in making decisions based on current weather conditions, crop yield predictions, best crop sequence analysis based on data accumulated over time, best crop for corresponding soil attributes, and watering requirements based on soil moisture level. This database makes recommendations to farmers for crops to plant on acreage with unusual soil features based on prior mushroom stock and current market demand. Big data analysis can be used to predict future output of each product based on existing knowledge.

4. IoT ENABLED FRAMEWORK

The IoT-enabled framework is a critical component in the proposed system as it is in charge of soil sampling at regular intervals to obtain soil property data. Figure 2 illustrates the proposed IoT framework in which it comprises of multiple sensing nodes to sense and monitor the environmental parameters of structure rack of mushroom. Temperature, humidity, and CO_2 convergence are the environmental parameters that are required to be continuously monitored through the sensing node. Based on these parameters, the water supply through solenoid valve is controlled by sensing node through relay. The sensing node is connected to the structure rack through wireless communication protocol.

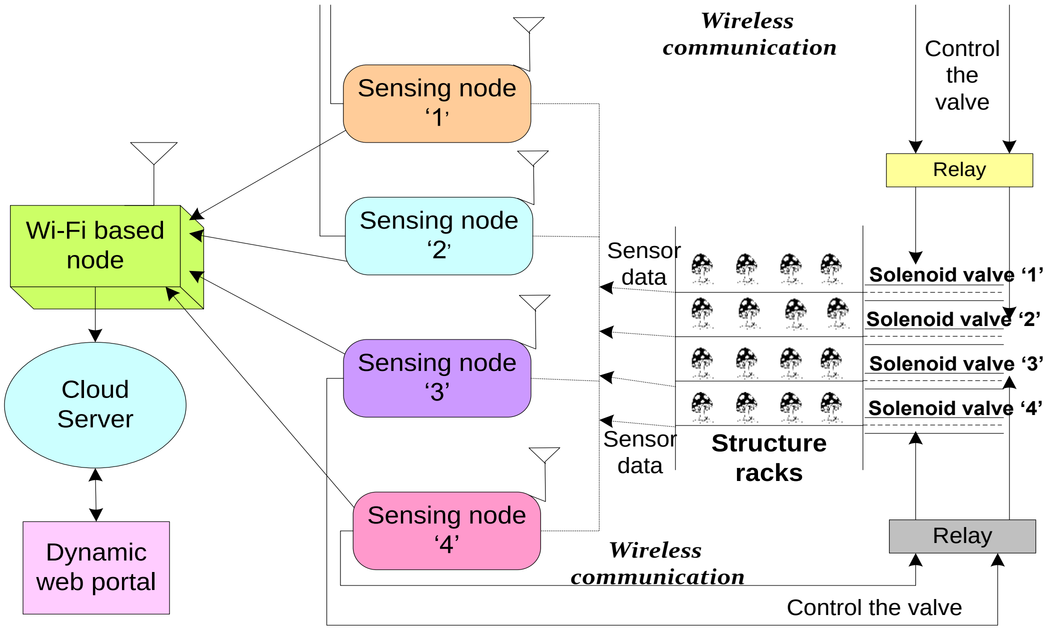

Figure 2. IoT enabled framework

The conveyer line framework is used to reduce human differences with the goal that it can computerize to measure mushroom growth. The user interface connected to the fundamental regulator is the dynamic site intended to automate the cycle. The system of conveyer line will be used for laying fertilizer; these are the fraction or racks on which mushrooms have been developed. These fertilizers are coming from purification rooms and should be kept in rooms where mushrooms should grow. On the off chance that the wet matter of the bed is replaced by the ideal requirement, an intricate water system framework is used flexibly for watering at that point. The information of sensing node is updated to the cloud server through Wi-Fi based node that is based on internet connectivity. Information running in the cloud will be refreshed at regular intervals. As indicated by continuous information, temperature activation, humidity, CO_2 focus, and bed moisture content (if necessary) are carried out, which suggests that it reports to the regulator about the continuous information and orders. A dynamic web portal is designed using Django as our production tool to automate the entire cycle. Additionally, a conveyer belt framework is planned to minimize human arbitrage for this entire cycle.

4.1. Sensing node with sub-controller

The sensing node is critical because it is the primary reason for the IoT-based framework to collect soil samples at regular intervals in order to obtain soil property data. It is an IoT enabled device with memory and computing capabilities, as well as a GPS sensor to detect positional data. The soil nutrient sensor devices that are attached to it are the main components of this kit. The soil pH sensor, soil moisture sensor, phosphorus (P), potassium (K), and nitrate (N) sensors are interfaced to the sub-controller. The sensing node performs two different tasks such as monitoring and control. In the monitoring, the sensing of the information begins with the distinct sensors like temperature and humidity sensor, CO_2 sensor, light-dependent resistor (light dependent resistors (LDR) sensor), and soil moisture sensor. This sensing node detects clock-like information and updates the same as par with the cloud and sends similar information to the cloud regularly and updates the information running at regular intervals as the signal cycle completes and automation is done in similar manner. The electrical characteristics of the MG-811 gas sensor suggest that the more predominantly predicted CO_2 focus will create a more modest output voltage. Table 3 illustrates the Environmental conditions in different operating modes

Table 3. Environmental conditions in different operating modes

Parameter	Mode of Spawn-run	Initialization mode of Pin head	Mode of Cropping
Temperature	25 °C	19 °C	20 to 25 °C
Humidity	90.0% RH	95.0% RH	85.0% RH
Carbon dioxide	$20{,}000\ ppm$	$600\ ppm$	$< 600\ ppm$
Soil Moisture	48%	52%	68%
Light intensity	Off	2,000 lux per 12 Hrs.	Above 500 lux per 12 Hrs.

4.2. Main controller

The fundamental controller is our Raspberry Pi 3B+ regulator module, with ESP8266 fitted to prod all sensing nodes. The continuous information state of each dark room where mushrooms grow is brought to the main controller, for example, the central processing unit or brain of morphology by the cloud. For solenoid valves in each room, associations are made for dripline irrigation systems.

Dripline irrigation system structures are used on the basis that mushrooms require exceptionally low amounts of water. The solenoid works so that the control relay to turn on the valve comes from the module. The solenoid opens and water is given flexibly, similarly, it should be noted that bed moist matter is detected at regular intervals and is reported to the regulator. Assuming the water required for the mushroom racks is measurable, it should be noted that the solenoid is modified in this exploration to kill the solenoid when the bedwetting material approximates Y-2 must be given so that no one is inauspicious. Mushroom beds are being provided with a measurement of water that can damage yields.

4.3. Dynamic web portal

Figure 3 represents the dynamic web portal work employed in the research work. The dynamic web portal intended for the framework will go as the user interface for the framework. Likewise, it will be the official site for a mushroom processing plant or association that will have various interfaces, for example, client interface, employee interface, and administrator interface.

This dynamic website page is planned to be used in the front end of web planning progress, for example, HTML, CSS, and JS. In the backend, the database is planned to use My SQL innovation. The front end and back end have been combined with the use of the Python web structure Django. The front-end framework for user interface is designed through the use of HTML, CSS, and Java Script. All progress in the framework will be finished by the interface on this page. A login option on the site page which that has three major system whereas customer login, employee login, and administrator login user interface. Customer login is for buyers to request this medicinal mushroom, if they need to enroll first in another customer's signature, they can play the activities they need. On the off chance that an old customer signs up, they can see the status of their request, the history of the request, and so forth, similar to an e-business site. At this point when a worker signs up, he can see the subtleties of his work, asking a representative of a business board to enter a new request, income status, a number of new customers joined, account status, and after this, a similar location when a person signs in from a particular office, they can see the status of ecological boundaries, for example, temperature, viscosity, carbon dioxide determination, of every dim room. The moist material of the bed develops independently and now feels that the moisture content of the bed is low, and it switches water flexibly on the information.

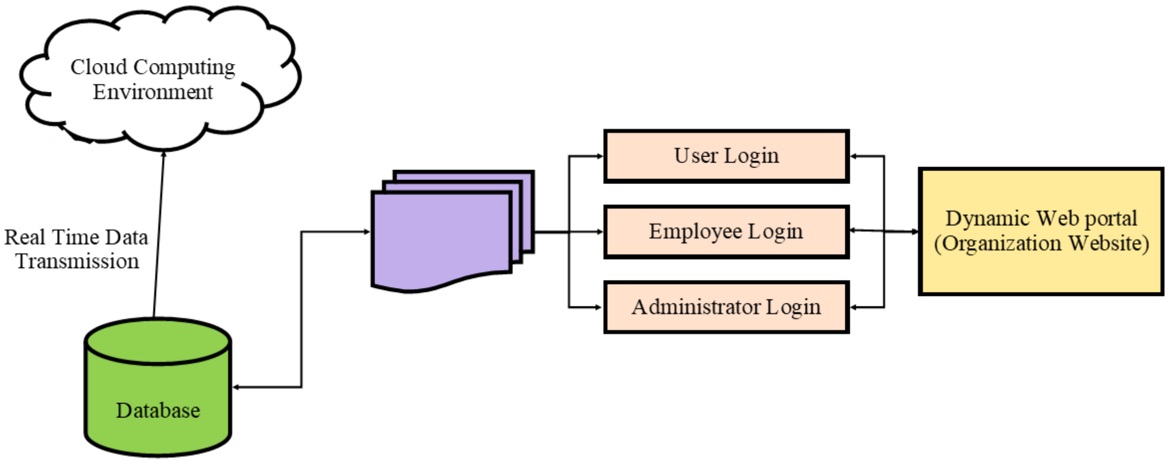

Figure 3. Dynamic web portal of the system

5. HARDWARE DESCRIPTION

In this section, we discuss the hardware description of the sensing node. As discussed above, the sensing node comprises of a controller unit, distinct sensors, wireless communication protocol, relay, and battery power supply. In the sensing node as shown in Figure 4, ATmega 328P controller is selected for processing the sensory data and based on sensory data, the components like solenoid valve are controlled through relay. DHT11 sensor interfaced to the controller act as input, and it sense the temperature and humidity of the structure racks of the mushroom. Soil moisture sensor and BH1750 light intensity sensor are also interfaced to the controller to provide the soil moisture content and light intensity as input data. The sensor data is communicated through the wireless communication protocol to Wi-Fi based node. The wireless communication protocol is selected on the basis of the transmission range. In case if the data needs to be transmitted to the short range, then the Zigbee and Wi-Fi module can be embedded in sensing node for data transmission. In case if the data needs to be transmitted to the long-range, then LoRa communication protocol can be embedded in sensing node for data transmission. In the power supply, there will be different voltage converters to match the operating voltage of the components integrated in the sensing node for proper functioning.

Figure 5 illustrates the Wi-Fi based node enables the sensing node to transmit the data on the cloud server through internet connectivity. Zigbee/LoRa connected to the sensing node act as transmitter and in the same way, the Zigbee/LoRa will be embedded in Wi-Fi based node as receiver to receive the data. ESP 8266 Wi-Fi module embedded in this node enables the transmitting data on the cloud server through internet connectivity. External power supply supplied to Wi-Fi based node is +12 V, but the operating voltage for the Zigbee/LoRa and ESP8266 Wi-Fi module is +3.3 V, so there is requirement of two different +3.3 V voltage converters for proper functioning of the communication module.

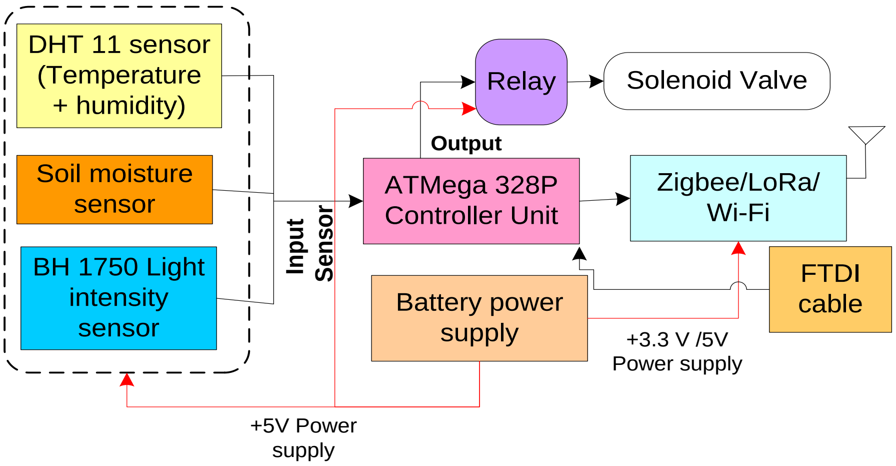

Figure 4. Hardware description of sensing node

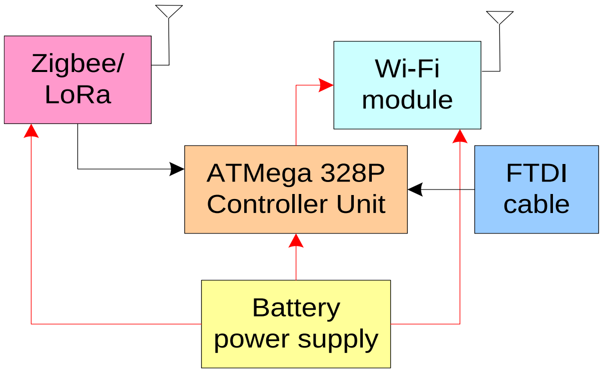

Figure 5. Hardware description of Wi-Fi based node

The sensing node and Wi-Fi based node of the proposed system comprises the ATmega 328P controller. The ATmega 328P controller will be programmed through Arduino IDE that is based on the C++ language. FTDI port interfaced to the ATmega 328P controller in sensing node and Wi-Fi based node enabled to program with necessary instructions based on application. Moreover, the node mapping feature can be embedded in the sensing node to transmit the data if the previous value is more or less than present value. Symmetric encryption enables encrypting the data and same encryption in Wi-Fi based node enables to decrypt the data.

6. CONCLUSION

Mushrooms from the *Cordyceps sinensis* have been proven to improve immune function, reduce the effects of ageing, promote longer life, and improve liver function in people. The cultivation and growth of this kind of mushrooms are limited to Sikkim in India and it is difficult to many people to gets its medicinal benefits. The investigation and prediction of *Cordyceps sinensis* life cycle is limitedly carried out in previous studies with IoT enabled framework. To overcome these challenges, this study proposed to implement an IoT framework to predict life cycle and provide alternate substrate to cultivate *Cordyceps sinensis* mushrooms in other parts of the country. As part of predicting lifecycle, the framework is proposed. From the study it is conclude with IoT sensor-based system with ideal moisture level in mushroom rack is required to grow this kind of mushroom.

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BIOGRAPHIES OF AUTHORS

Minakshi Memoria is currently working as HOD-CSE in Uttaranchal Institute of Technology, Uttaranchal University, Dehradun. She has done her Ph.D. in Computer Science and Engineering from Gyan Vihar Univeristy, Jaipur, Rajasthan. She has more than 16 years of teaching experience and also has various patents in international and national government patents and published various papers in various national and international journals and conferences. Her area of research includes grid computing, cloud computing, automata, advanced algorithms, artificial intelligence, and distributed computing. She can be contacted at minakshimemoria@gmail.com.

Sanjeev Kumar Shah is currently working as a professor. His area of research is microwave, artificial intelligence, and machine learning. He is also an associate member of the Institution of Electronics and Telecommunication Engineers. He has published 25 scientific papers and 35 patents. He can be contacted at sanjeevkshah19@gmail.com.

Harishchander Anandaram is currently working as assistant professor, Center for Computational Engineering and Networking (CEN), Coimbatore Campus. His research area is metabolic engineering, bioinformatics, functional genomics. He can be contacted at a_harishchander@cb.amrita.edu.

Anooja Ali currently working as assistant professor at REVA University, Bangalore with 14 years of experience in teaching. He has completed Ph.D. from REVA University in algorithms for analysis of protein sequences in cervical cancer. To her credit, she has 16 journal publications, 7 conference papers, 5 copyrights, and 3 Indian patent. Her areas of interest include machine learning and bioinformatics. She can be contacted at Anooja.ali@reva.edu.in.

Kapil Joshi currently working as an assistant professor in the Department of Computer Science & Engineering (CSE) at Uttaranchal Institute of Technology (UIT), Uttaranchal University, Dehradun, India. He has around 8 years of academic experience in different institutions/companies. His areas of interest include operating system, computer networks, web technology, data structure, and Java. He can be contacted at email: Kapilengg0509@gmail.com.

Parag Verma currently working as an assistant professor in the Department of Computer Science & Engineering (CSE) at Uttaranchal Institute of Technology (UIT), Uttaranchal University, Dehradun with more than nine years in the field of industry and academics. He has more than 25 international papers in reputed conferences and journals. His research interests include IoT, healthcare, and image processing-based analysis using distributed computing platforms. He can be contacted at parag_verma@yahoo.com.

Rajesh Singh is currently associated with Uttaranchal University as a professor and director of R&I and post doc fellow at Department of Project Management, Universidad Internacional Iberoamericana, Campeche, C.P. 24560, México with more than seventeen years of experience in academics. He has been featured among top ten inventors for ten years 2010-2020, by Clarivate Analytics in "India's Innovation Synopsis" in March 2021 for filing three hundred and fifty-eight patents. He has twelve patents grant (8 Australian and 4 Indian patents), 5 PCT and published more than hundred research papers in SCI/Scopus journals. He can be contacted at drrajeshsingh004@gmail.com.

Anita Gehlot is currently associated with Uttaranchal University as a professor & head (R&D) with more than fifteen years of experience in academics. She has been featured among top ten inventors for ten years 2010-2020, by Clarivate Analytics in "India's Innovation Synopsis" in March 2021 for filing two hundred and sixty-three patents. She has published more than 80 research papers in SCI/Scopus journals. She has twelve patents grant (8 Australian and 4 Indian patents), 5 PCT. She can be contacted at email: dranitagehlot@gmail.com.

Shaik Vaseem Akram is currently working as an assistant professor at Uttaranchal University, Dehradun. He has published 26 articles in SCI/Scopus. He has published more than 160 patents in which 5 technology transfer. He can be contacted at vaseemakram5491@gmail.com.