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IOT based smart cold chain temperatur monitoring and alert system for vaccination container

Abstract, *A vaccination is one of primary precautionary source to prevent the severe effects of corona virus. The vaccination has to be maintained in the temperature range of 2^{O}C to 8^{O}C. The proposed system measures and monitors the temperature inside the vaccine container. A thermocouple device and smart controller encapsulated inside the container. The thermocouple senses the temperature in container. The smart WiFi enabled controller measure the temperature using electrical output of thermocouple. The measured temperature is passed to the cloud server and mobile view. The data and time wise maintenance of vaccine temperature, emergency indication, and current vaccine container temperature are displayed in the cloud. The system is useful on maintaining vaccine at prescribed temperature level and effectively protects the human life. The system achieved the accuracy of 99.5%.*

Streszczenie. Szczepienie jest jednym z podstawowych środków ostrożności, aby zapobiec poważnym skutkom koronawirusa. Szczepienie należy prowadzić w zakresie temperatur od 2OC do 8OC. Proponowany system mierzy i monitoruje temperaturę wewnątrz pojemnika na szczepionkę. Termopara i inteligentny sterownik zamknięte w pojemniku. Termopara wyczuwa temperaturę w pojemniku. Inteligentny sterownik obsługujący WiFi mierzy temperaturę za pomocą wyjścia elektrycznego termopary. Zmierzona temperatura jest przekazywana do serwera w chmurze i widoku mobilnego. Dane i czasowe utrzymywanie temperatury szczepionki, wskazanie sytuacji awaryjnej i aktualna temperatura pojemnika na szczepionki są wyświetlane w chmurze. System jest przydatny w utrzymywaniu szczepionki w przepisanym poziomie temperatury i skutecznie chroni ludzkie życie. System osiągnął dokładność 99,5%. (***Inteligentny system monitorowania temperatury w łańcuchu chłodniczym oparty na IOT i system ostrzegania o pojemniku na szczepienia***)

Keywords: COVID, Vaccine, cold chain, NodeMCU, WiFi
.**Słowa kluczowe:** szczepienie, monitorowanie temperatury

Introduction

The COVID'19 (corona virus disease) changes the life style of every human. There are certain protection systems followed to prevent the infection of COVID pneumonia. The external protection systems such as face mask, Personal Protective Equipment (PPE) cloth, hand gloves, eye glass, and sanitizers. The internal protection system developed using vaccine. The vaccination will help to protect the people from severe lung infection. The vaccinations are to be maintained with the temperature of 2^{O}C to 8^{O}C as per the guidelines of World Health Organization (WHO). The effect of lower temperature maintenance on vaccination leads to in effective. The ice cube container is presently used to maintain the temperature. In urban health centers are having freezers. The rural health centers need the transportation of vaccine for longer distance. The transport vehicle is equipped with freezer container. The vaccine storage locations are also having the vaccine freezing facility.

Literature review

Yakum et al. (2015) [1] have analyzed the ineffectiveness in the vaccines due to lack of temperature maintenance. The vaccine container temperature is measured physically at various locations of North western region, Cameroon. The major reason identified for lack in temperature measurement is due to power failures. An importance of supply chain management, temperature maintenance of various vaccines and methodologies to be adopted were discussed by Bajrovic et al. (2020) [2]. Hanson et al. (2017) [3] have given review on the effect of ineffectiveness of vaccine due to loss of temperature. The vaccines are to be maintained with improper temperature conditions leads to makes the severe effects on children. The broad survey was conducted which concluded that the major reason for vaccine improper maintenance is due to lack of concentration of workers. The vaccine cold chain leads to loosing many countries investment. Maglasang et al. (2018) [4] have discussed the requirement of freezer and refrigerator requirement of rural health centers. The requirements of vaccine fertilization at the time of transportation were analyzed. The monitoring of vaccine temperature and power failures were monitored mechanically. The study on nature of vaccine effects get changed due to abnormal temperature was analyzed by Sow et al. (2018) [5]. The refrigeration failure leads to reduces the effectiveness of vaccines and also the color of vaccine also gets changed. Yamoah et al. (2019) [6] have proposed the detailed study on vaccine cold chain maintenance. The effect of vaccine performance at different age group was proposed by Ateudjieu et al. (2020) [7]. The children from the 0 to 59 months age group children vaccination effectiveness were studied. A mobile network based remote level temperature monitoring was proposed by Lutukai et al. (2019) [8]. A cold chain maintenance of vaccine temperature in urban center analogy was made by Ringo et al. (2017) [9]. An electronic controller based breathing level monitoring was proposed by thiyaneswaran et al. (2020) [10]. The causes of breaking cold chain mechanism of medicine were discussed by das (2020) [11]. The cloud based air quality updation were proposed by Thiyaneswaran et al. (2021) [12].

Proposed cold chain monitoring

There is system required to monitor the storage temperature of vaccine. The block diagram of proposed system is shown in the Fig.1. The proposed system has the measurement unit along with the Internet of Things (IOT) facility. The nodeMCU has facility of inbuilt WiFi module. The temperature is measured using the PT100 thermistor sensor device notified in the Fig.1. It has able to sense the temperature in range of -150^{O} to $+150^{O}$. A rechargeable battery backup is made with the capacity of 1000 mAH. The proposed system will come up to backup time of 3 days (72 hours). The complete setup is packed in plastic non-interference container. The steel part of sensor module is projected in cooling container which consists of vaccines. The sensor senses the temperature and converts into equivalent analog electrical signal. The analog electrical signal is converted into digital quantity by the controller. The temperature is computed in terms of degree Celsius. The temperature measured is passed to cloud server through the WiFi module.

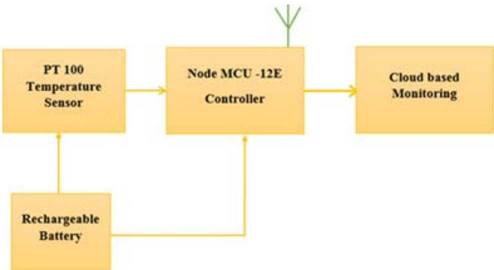

Fig.1 Block diagram of proposed system

Temperature sensor

The proposed system uses the PT100 temperature sensor. The PT100 used in the proposed implementation is shown in the Fig.2. It has the Stainless-Steel (SS) lead which is encapsulated by the vibrant heat insulation. In the proposed system SS leads are dipped inside the vaccine container. The proposed sensor is having the capability of measuring -50^{o} degree Celsius to +250^{o} degree Celsius. The resistance offered at 0^{o}C is about 99.9`Ω. It consists of 3 leads. Two leads are used for power supply and 3rd lead is used to take the temperature in terms of electrical voltage. The sensor gives out the heat equivalent of analog voltage.

NodeMCU

The proposed system uses the centralized controller NodeMCU-12E shown in the Fig.2. It requires +5V power supply. It consists of digital I/O lines namely D0, D1, D2, D3, D4, D5, D6, D7, D8, D9, D10, and D11. It has one analog input A0. It has +3.3 V source in on board. It consists of ESP8266 inbuilt WiFi module with patch antenna. It will be useful for transferring the data into cloud. The PT100 temperature output is connected with the A0 analog pin.

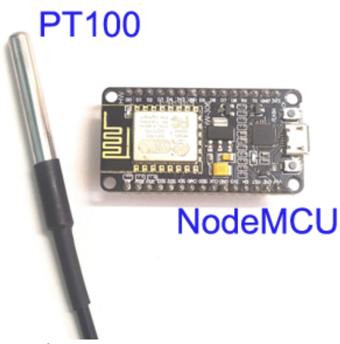

Fig. 2 Hardware requirement

Software microcode

The microcode is generated using Arduino IDE plat form. The nodeMCU is configured as webserver. It measures the temperature. The NodeMCU WiFi is connected with the internet enabled local hotspot using Service Set Identifier (SSID) and Password. The hotspot device also the part of system. A separate provision is provided to hold the system and hotspot. The thingspeak cloud environment provides the 4 channels and 14 fields in each channel for the purpose of non-commercial and research work. The proposed system uses single channel and 12 fields. Each field is used to represent one container temperature. The thingspeak provides the Application Program Interface (API) key for each channel. The nodeMCU is initially connected with WiFi module using the fused SSID and password. The hotspot device is having the built in GSM which holds the SIM card to enable the internet access. The Write API key is used to configure nodeMCU as webserver. The nodeMCU reads the temperature value from the sensor with the interval of 5 seconds as refresher period. The measured temperature data is written in the thingspeak server in corresponding channel and field.

Results and discussion

The proposed system is tested using the 25 number of IOT enabled proposed units. 15 number of units are fixed in the vaccine container and 10 units are fixed storage refrigeration. The containers are used inside the PHC and rural camp locations. The vaccine container temperature is updated in the cloud in corresponding field is shown in Fig.3. Every 5 seconds data will be updated in the cloud field. The temperature can be monitored even in remote location. The sample of tested output shows the container temperature of 4.81^{O}C on 28-06-2021 at the time of 20:43:20. The temperature indications are helps to refrigerate the vaccination system in effective manner.

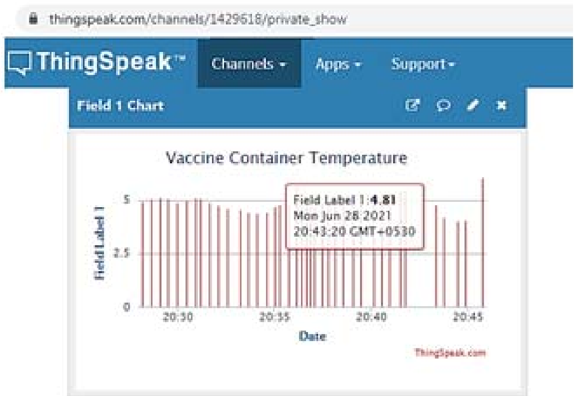

Fig.3 Cloud View of vaccine container temperature

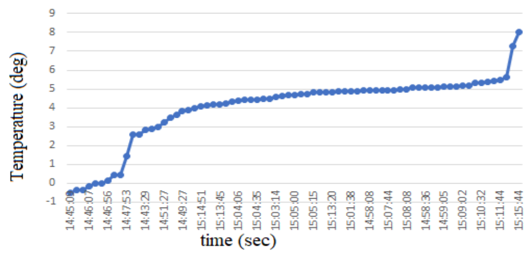

Fig.4 Vaccine container temperature at various time

The temperature variation of container over the specific period is graphically mentioned using the Fig.4. The system is tested with container temperature from -0.5^{o}C to 8^{o}C at various time intervals. The weight of the proposed system is 170 Grams including hotspot device. The temperature at the instant of 14:45:09 is -0.5^{o}C. The temperature at the instant of 14:51:27 is 3^{o}C. The requirements for vaccine container are the range of 2^{o}C to 8^{o}C. The developed system is tested beyond the temperature requirements.

The Table-1 shows the sample of results observed in various locations. The temperature is measured using proposed method and standard calibrated instrument. The results show that the temperature in all proposed systems are equal with calibrated instrument. The temperature at PHC-04 is carried out camp area (outdoor of PHC). The device is fixed in the container. The standard instrument gives the temperature of 2.5^{o}C and same will be given by the proposed method. Another example, at PHC-06 temperature monitoring is processed in cold chain refrigerator. It shows the temperature value as 2.3^{o}C.

Table 1. Measurement of temperature at various locations

S.No	Location	Type of container	Temperature measurement using standard meter	Temperature measurement using proposed system
1	PHC-01	Container	1.5°C	1.5°C
2	PHC-02	Cold chain refrigerator	1°C	1.1°C
3	PHC-03	Cold chain refrigerator	2°C	2.1°C
4	PHC-04	Container	2.5°C	2.5°C
5	PHC-05	Container	3°C	3°C
6	PHC-06	Cold chain refrigerator	2.3°C	2.3°C
7	PHC-07	Container	4°C	4°C
8	PHC-08	Container	3.5°C	3.5°C
9	PHC-09	Cold chain refrigerator	2°C	2°C
10	PHC-10	Container	2.8°C	2.8°C

Table 2: Comparison of accuracy with existing system

S.No	System Description	Refrigeration Maintenance Percentage
1	Proposed system (2022)	99.5%
2	Bajrovic et.al (2020)	97.3%
3	RTM, Lutukai et al (2019)	97%
4	Automated Recording System, Sow et al (2018)	98%

The proposed system accuracy is compared with the existing temperature monitoring system shown in the Table-2. The proposed system accuracy is about 99.5%. The drop in accuracy is due to drop in rural area mobile signals. The accuracy of the proposed system is 1.5% to 2.5% greater than the existing methods.

Conclusion

The cold chain system is very important on maintaining the vaccine. The system is required at the time of transporting vaccines from one country to other country, one state to another state, state to districts, district to urban, and rural centers. In the transportation period vaccines temperature has to be maintained under the limit. The vaccines are made in remote area in establishment of smaller campus and under these situations also the temperature of vaccines to be maintained. At level storage points, urban and rural centers temperature is maintained using refrigerators or freezers. In case of small camp areas vaccine cooling system is maintained using ice cubes or ice bag containers. The temperature of refrigeration, freezers, smaller ice cube containers are to be monitored periodically. The proposed system consists of compact hardware concealed in the non-inference container. The container is placed inside the cooling system. A thermostat lead is dipped in container used to sense the temperature. The temperature is effectively measured and computed using the NodeMCU smart WiFi enabled controller. The temperature is updated in cloud for every 5 seconds. The alert system is useful to turn on refrigeration or used to find the failure of refrigeration system. The system will helpful on protecting vaccination from abnormal temperature and help the society to safe guard from COVID and other associated virus infection.

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