

AN IoT APPLICATION FOR MONITORING THE TEMPERATURE AND HUMIDITY INSIDE COLD CHAIN TRUCK

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Abstract—In today's world, Internet of Things (IoT) is a different development. With the help of IoT, all the physical objects can connect to the internet. And with this we can consider the two layers of the system viz: the sensor devices which gathers data and links to cloud and next is the cloud service which hosts the information from the environment. In the cold chain we need a good environment for the products to be healthy for use. Here we develop a monitoring system with the help of IoT. The Internet of Things entrance is used as a part of this system. In this strategy we use several access methods such as Wifi, GPRS, and so on and also the data can be put in storage locally. The IoT entrance uses ATmega 328 as the MCU, $\mu\text{C}/\text{OS-III}$ as the embedded operating system. The application authenticates that the entrance is reliable. In this paper we try to develop a arrangement encompassing Arduino wireless sensor networks and cloud and then extend our work to develop a method for the transmission of data between them which can be of great use in monitoring the temperature and humidity of cold chain logistics. With the help of this monitoring system, the real time detection of the temperature and humidity of the trucks can be improved and the longevity of the products can be ensured.

Keywords: IoT, WiFi, GPRS, ATmega 328, $\mu\text{C}/\text{OS-III}$, Arduino

1. INTRODUCTION

The transfer of biological, pharmaceutical products in guarded temperature is referred to as Cold Chain logistics. With the development of society, traditional forms for carrying the products with cold chain trucks cannot satisfy human need. Through the monitoring of the temperature and humidity inside cold chain trucks, the goodness of the products can be ensured for a longer time. Recent research has revealed that operations of wireless sensor systems are largely affected by their on-board temperature [1]. In this paper we have designed a gateway which will be the central part of this whole system. The function of the gateway is to gather data, process them, upload them and process user control information. If the network connection is not established then the data will be stored and upon reestablishment of the network it will be uploaded. Fig. 1 depicts the information flow in cold chain.

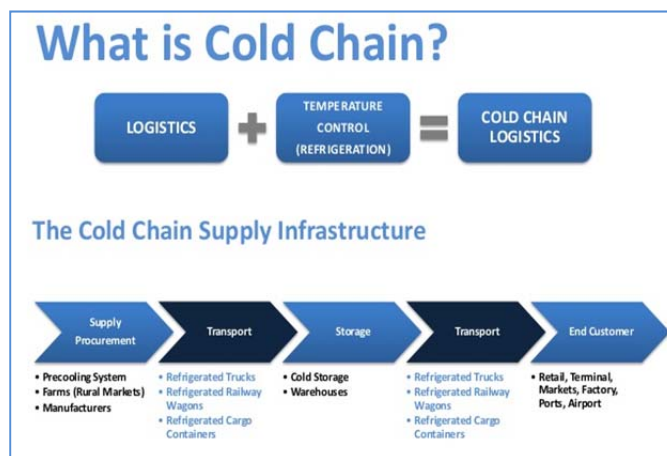


Fig. 1: The structure of cold chain [2]

2. THE STRUCTURE OF THE APPLICATION

This observing system is designed to come up with a solution for protecting dozens of pharmaceuticals inside cold chain truck. As the products enter the truck, the base station reads them. The nodes inside the truck are fitted with sensors for temperature and humidity. Multiple nodes help in reading the temperature in all the parts of the truck. And these nodes constantly send data to the base station. After collection of data from the nodes, the base station with the help of GPRS uploads them to the sensor cloud. Here we will use a gateway for collection of data and sending them to the server as because if we allow each node to communicate with the remote server independently, then the cost will rise up. As given on the Fig. 2 the application is made up of the controller system, the gateway, the server, and the ZigBee coordinator as part of the gateway.

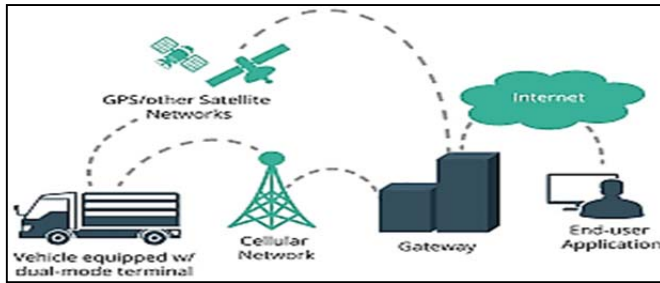


Fig. 2: Data transfer between cold chain truck and the internet [3]

The transfer of data from ZigBee to MCU is done by the acquisition and the data is sent to the server from the MCU through the Wifi/GSM. The job of control system is transmission of data from server to micro control unit. The micro control unit then encapsulates the data in proper format and transfers to the acquisition and control system through ZigBee controller.

3. TECHNOLOGY USED

3.1 Internet of Things

In early days, Internet was used for only accessing websites, to communicate with each other. But with the advancement of technology, Internet is used for connecting devices with higher capabilities and low power consumption to the cloud. Also nowadays huge network of sensors which have the ability to obtain and process information, can be created with these devices. And gradually with this came the idea of 'Internet of Things' with the help of which computer can collect information about any entity.

3.2 Arduino

It is an open source platform. In this board we find a single input/output pin. This input/output pin is used for developing the environment for writing programs for the board. This device creates a platform where according to the needs we can design our gateway with the help of this device's functionality which is directly related to IoT.

4. SYSTEM ARCHITECTURE OF GATEWAY

4.1 IoT gateway-the design of the system

The IoT gateway is made of the the ZigBee module, GPRS, Ethernet and ATmega 328 Microcontroller with an Arduino Uno Boot loader as the microcontroller. Ethernet PHY is being used by DP83848 and also connects the Ethernet MAC of the MCU through the MII. Fig. 3 below shows the system architecture of IOT Gateway.

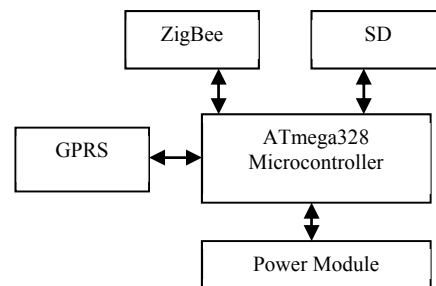


Fig. 3: System Architecture of IOT gateway

4.2 The Schema of ZigBee Coordinator

The generation of the control function, initiation and protection of the network is performed by the ZigBee coordinator. The PAN controller works as ZR as soon as the network initiates. ZC periodically sends beacon frames if the network operates in beacon active mode which is capable of harmonizing the other side of the network. All ZRs send their individual beacons to other nodes and also receive beacons from their parents in cluster topology. CC2530 of TI Company is implemented as the coordinator by the ZigBee module in the gateway and then this is connected with the ATmega328 through serial interface. The ZigBee controller generate different control functions which protects it and starts the network [4].

4.3 The GPRS Module- Design

The function of GPRS is wide coverage, easy to use with high broadcast proficiency and the TCP/IP data broadcast consistency is also high [5]. In this design MG323 is used for introduction of GPRS module. MG323 is composed of RF transceiver, GSM base band control, power module, 26 MHz reference clock, MCP storage, receiving filter and RF front-end module. TTL is the serial port interface level of MG323, so MG323 can join with the serial port interface of ATmega328 [6].

5. THE SOFTWARE DESIGN

5.1 Software- The System Design

As given in Fig. 4 below, development mode of layering is adopted by this system [7]. The development of the application results in the Application Layer. The operating system layer is for the relocation of $\mu\text{C}/\text{OS-III}$ implanted operating system and the hardware layer is for the hardware driver development of each module. The job of the GPRS communication, SD storage and ZigBee communication comprises the whole task of this system.

Application Layer			
Zigbee Protocol		Task management	
Operating System Layer			
Real time Kernel			
Hardware Layer			
Zigbee	SD	Atmega 328	GPRS

Fig. 4: Software system architecture.

5.2 Relocation of μ C/OS-III

In this design ATmega328 is selected as the microcontroller unit. Thus the design implements the embedded operating system μ C/OS-III. Relocation of μ C/OS-III [8] contains OS, CPU and BSP as given below:

- a. We need to include the necessary headers to build the application like app_cfg.h header file that configures the application, bsp.h for the Board Support Package (BSP), includes macros and different categories of function, such as BSP_Start(), BSP_LEDLT_On(), OS_TS_READ() and more. os.h is the main header file for μ C/OS-III, and includes the following header files: os_cfg.h, cpu.h, cpu_core.h, lib_def.h.
- b. The next task is to create a process control box (OS_PCB) to allocate different resources.
- c. A stack method is used to store such task using the CPU_STK user defined datatype where the data can be allocated from heap using malloc().

5.3 Protocol Conversion

By using the Zigbee protocol the data is transferred to acquisition and control system by the gateway and then with the help of GPRS or Ethernet the data is transferred to the upper computer. Fig. 5 is the protocol conversion diagram [9].

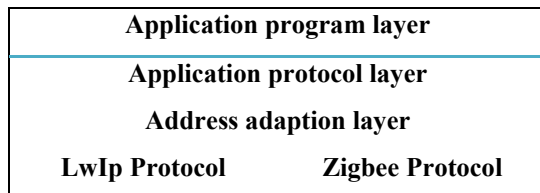


Fig. 5: Diagram for protocol conversion

In TCP/IP, the transfer of Ethernet data is caused by the MAC and the conversion between IP and MAC of DLL is completed by ARP. For the transfer of data Zigbee nodes also needs some way. In the address adaption layer the plotting relation is built amid Mac of Zigbee and IP. And then in the application protocol layer by using application protocol the data format conversion is done.

5.4 The Communication via Ethernet

Ethernet communication is comprehended in this design via LwIP protocol. There are 4 layers in LwIP viz: physical layer, interface layer, network layer and transport layer. The physical

layer controls the driver of Ethernet controller, the purpose of interface layer is to widespread the acknowledgement of MAC by ARP protocol. Network layer comprises of IP, ICMP protocol and so on. Also the network data transfer to certain standard formats is ensured by the network transport layer. Below Fig. 6 shows how the Ethernet sends data.

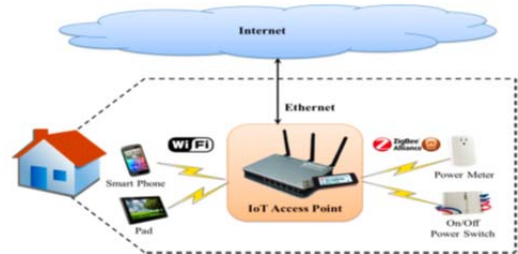


Fig. 6: Ethernet communication

5.5 GPRS Communication

The various steps are:

- Step 1: Start GPRS Task
- Step 2: Repeat Step 3 to Step 5 until module registration is unsuccessful
- Step 3: Module connects to the server successful?
- Step 4: If No, Goto Step 2.
- If Yes, Send data to the Server.
- Step 5: Store data.

Now, we define the device details to send our sensor data to cloud. The details include Device_No "WKSP-01", Client, Device_Type, Device_Key, Node_No, APN.

GSM Response

Start a "DisplayGSMResponse" function and check for Serial Available. Initialize a String "gsm_input" to store GSM response available on Serial. And print the output on LCD and on serial.

GSM Connectioncheck

Start a "GSM_Check" function using "GSM_Serial.println" function, send the command "AT" then initialize the string to read the data from the GSM Response and use "find_String" to search GSM response with "OK". Then use "find_Char_loc" to find the location of response.

HTTP initialization

Start a "httpinit" function using "GSM_Serial.println" function, send the command "AT+SAPBR=3,1,CONTTYPE,GPRS". Write 2 seconds delay for each GSM AT command and print to LCD. Using "GSM_Serial.println" function, send the command

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“AT+SAPBR=3,1, APN,INTERNET, “AT+SAPBR=1,1,
;“AT+SAPBR=2,1,”, “AT+HTTPIPINIT”,
“AT+HTTTPARA=CID,1”,
“AT+HTTTPARA=URL, Using “GSM_Serial.println”
function, send the command
“AT+HTTTPARA=Content,application/json”
    
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HTTP Post

Start a“**httppost**” function. Initialize a String “data” and arrange data from sensors and cloud details in JSON format. Using “GSM_Serial.println” function, send the command “AT+HTTPDATA=JSON Count, 40000” also send the JSON data with fields of device key, node number, Temperature, Humidity. Connect to the server before posting the data using HTTP. Using “GSM_Serial.println” function, send the command “AT+HTTPACTION=1”. Initialize a string “RES_input” and read all the data available on serial from “AT+HTTPACTION” response and use the “**find_string**” and “**find_char_loc**”to search the response with “200”.

5.6 The Software Design of ZigBee Module

ZigBee is a low-cost, low-power, wireless mesh network standard. As a result of which it is extensively used in wireless and monitoring applications. The Low power-practice permits longer lifespan with smaller batteries. The ZigBee coordinator is run by the ZigBee Protocol. ZigBee defines two layers of the OSI (Open Systems Interconnection) model: the Application Layer (APL) and the Network Layer (NWL). A precise set of facilities is performed by each layer . Service Access Points (SAP’s) is used by the different layers for communication. These SAPs enfold two forms of articles:

- (1) A data entity (NLDE-SAP) to provide data transmission service
- (2) A management entity (NLME-SAP) providing all the management services between layers.

For the establishment of the ZigBee network and the monitoring of the ZigBee nodes the gateway is in charge. After the μC/OS-III startup, the first will be the initialization of the ZigBee and then the MAC and network address are managed by the upper computer. The ZigBee protocol is based on 802.15.4 and composed of application layer, network layer, data link layer and medium access layer [10]. Also the protocol is running in ZigBee coordinator. The establishment of the ZigBee network and the monitor of the ZigBee nodes is performed by the gateway.

6. RESULTS AND DISCUSSION

With the help of arduino UNO-R3 board and GSM (800) & wifi module (shown in Fig. 7), after collecting the details of the temperature and humidity we post this data to the

server. Table 1 depicts the results that are coming out from experiment.

We have taken the temperature in three times of the day viz: morning, afternoon and evening as we get different values at different times based on the formula [11], Relative humidity, $RH = 100 * (EXP((17.625 * TD) / (243.04 + TD))) / (EXP((17.625 * T) / (243.04 + T)))$, TD = DEWPOINT, T = Temperature in K, so we can carry those products at those times which are suitable according to the temperature.

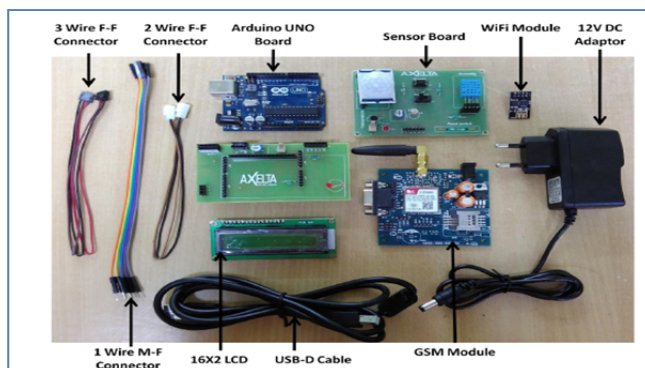


Fig. 7: Arduino UNO-R3 board, sensor & GSM module

Table 1

Monitoring System	
Temperature	Humidity
14	76.84
15	72.03
12	87.57
14.2	86.62
15.5	96.84

Table 2

Types	Transport Temperature	Relative Humidity
Pineapple, bananas, mangoes, melons, lemons	10.0-12.0	85-90
Oranges	4.5	89-90
Apples, apricots, pears, strawberries, cherries, peaches, grapes	-0.5- 1.5	85-90

After verifying the result with Table 2 [12], the system automatically send the confirmation that the temperature and humidity details are suitable for the products inside the truck and the products will be in good quality. This kind of management ensures that the products inside the truck are in the best environment.

7. CONCLUSION

The wireless sensor networks are connected with the internet with the help of the IoT gateway and also ensure the monitoring of the products inside cold chain truck. Also this type of application helps in checking the temperature and humidity on a continuous basis and then resulting instructions are sent to the server. Based on which the environment inside the truck can be monitored. So, this type of application has certain type of advantage.

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