IoT-Based End-to-End Monitoring of Logistics and Tracking of Truck Vehicles Using Arduino Microcontroller

Charles G. Juarizo, Jayson P. Rogelio, Jessie R. Balbin, Elmer P. Dadios

***Abstract*— This paper describes the design and implementation of a system that monitors end-to-end visibility of the logistics which includes temperature & humidity monitoring, security alerts and truck vehicle location updates. A near real-time monitoring system designed based on the Internet-of-Things platforms. The system has three components: the sensors system, the monitoring system, and the display system. The sensor system has ultrasonic sensors, the temperature & humidity sensors and the Global Positioning System (GPS), which are connected to the internet via the Wi-Fi network to track the location, the status of the truck rear door and the ambiance inside the truck. The monitoring system is used to get the information from the sensors database, then converted into a more significant context and provided data to the admin and the truck driver in the dashboard. The display system is used to show the current data inside the truck and to check all the sensors are all working. Notification alerts are sent to the dashboard with security alert and the truck driver when the rear truck door opened. The results were evaluated using the t-test & variance and obtained no significant difference between the proposed study and the conventional method.**

Index Terms — real-time monitoring system, internet of things (IoT), global positioning system, cloud computing

I. INTRODUCTION

Internet of Thing (IoT) is changing much about the world we live in from the way we drive to make purchases and even how we get energy for our homes. Internet of things has a huge influence on the logistics industry. The Internet of things technology will provide intelligence to the logistics distribution network, agility and intelligence to the supply chain, and transparency and real-time to the item management to the logistics system [4], [9], [12], [19]. An example of this is the transportation of perishable products' increased volume in today's logistics operation that needs to maintain the quality of items by providing a right temperature, humidity, vibration, etc. [14], [16]. Internet of Thing key technologies which include sensing layer technology, transmission technology, application technology and security technology [6], [15]. But how exactly do all these devices share such as large quantities of data and how do we put that information to work? The process starts with these devices which securely communicate with an Internet of Things platform that integrates the data from many devices and applies analytics to share the most valuable data with applications that address logistic industry needs. In the Philippines, logistic industry is facing many problems, such as inadequacy or lack of information and the security in logistics. Today, logistics solutions must be personalized to each customer [13, [18]. Full transparency of orders from transporting of goods, the conditions of shipping truck which included the ambient temperature of truck are not monitored [3] . These lacks information included the status of goods if they could be delivered on time and could be monitored the vehicles' exact locations [1]. Security is growing concern in the logistics industry due to goods that are being passed or shipped from provider to provider. Rear-door status is one of the major concerns for shipment. If the door of the truck is opened during the transportation, security is now a problem.

Mejjaouli & Babiceanu [4] investigated the benefits of implementing an RFID-based monitoring system in the transportation operations of perishable foods. The main contribution of their work is directly related to the transportation operations by providing a solution for re-routing or interrupting the shipment of perishable products based on real time data received from the RFID tags. It consists of RFID sensor tags which is responsible for sensing, collecting and storing data about the monitored transportation conditions. The RFID check points deployed along the transportation path wherein the RFID check points are equipped with RFID readers that retrieve the stored data and check whether the required conditions were maintained or not. A decision module responsible for analyzing the data retrieved by the RFID readers can make operational decisions based on the predefined goals.

This paper will fill in the gap from the previous study that is related to the transportation of perishable foods utilizing Internet-of-Thing (IoT) based on monitoring system. The previous study didn't exhibit the required temperature and humidity needed to maintain inside the truck before transporting the goods in a near real-time monitoring which include the rear-door status of the shipping truck and the exact locations of the shipping truck. Notifications will be displayed in the dash-board on the status of the truck rear-door and alarm notifications is send to the driver if there is a change of state of the door from close to open status and vice versa.

The objective of this study is to develop a near real time end-to-end monitoring of logistic and to track shipping trucks utilizing Arduino Microcontroller. Specifically, (1) to develop a system that monitors the temperature, humidity & the rear door status of the shipping truck vehicles; (2) to develop a GPS system utilizing an Arduino microcontroller for tracking; and (3) to develop Internet of Things (IoT) platform that integrates the data from the microcontroller and

This work was supported by the Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD) in funding this for the IAENG World Congress on Engineering 2019.

Charles G. Juarizo is currently the chairperson of Electronics Engineering Department, Pamantasan ng Lungsod ng Maynila, Intramuros, Manila 1002 Philippines (cgjuarizo@plm.edu.ph).

Jayson P. Rogelio is a senior research specialist at Department of Science & Technology, Metal Industry Research and Development Center, Taguig City 1631 Philippines (rogeliojayson@gmail.com).

Jessie R. Balbin is a faculty member of the ECE Department, Mapua University, Intramuros, Manila 1002 Philippines (jayebalbin@gmail.com).

Elmer P. Dadios is with the Manufacturing Engineering & Mgmt. Department, DLSU , Manila Philippines (elmer.dadios@dlsu.edu.ph).

applies near real time data and share the valuable data with applications to the truck driver and the supplier.

This study would help the company to increase their operational efficiency and by the IoT enables information to be shared at every level – allowing insufficiencies like the fluctuations of the temperatures and the humidity to be identified quickly so that the problems can be immediately rectified or could be even prevented altogether. Companies can see delays, slowdowns or trends that will affect the product and inefficient process that cost them money can be identified and corrected. Moreover, the supplier could also access the information – from up to the minute details on where the item is in transit to accurate alerts notifying them of delivery dates and times. It also includes transparency in operation, increases the value for investment, enhance customer service with up-to-the minute information, service and extra peace of mind through real time ability to track.

II. RELATED LITERATURE

Yin, Feng and Li [20] demonstrated the algorithm for logistics chain in IOT based on provenance information, wherein the RFID tags are used in logistics chain process. Fuzzy linguistic values have been utilized in expressing the reputation of the enterprises and user appraisal. Simulations results shows the performance of this algorithm by taking the account of the vagueness of user appraisals on service chain results and several measures to evaluate reputations of enterprises.

Reference [1] - [2] demonstrate an GSM based vehicle tracking system to transfer the latitude, longitude from GPS and automobile data to end systems and map their exact location in Google Earth using application programming interfaces (API). Researchers have also worked on GSM tracking system with theft identification and lock feature utilizing the fingerprint system and surveillance system to increase the level of security. Also, there are research that has performed Web-based vehicle tracking system [5], where the latitude and longitude are transmitted to the server through HTTP protocols. Kim, Jang & Jung [11] developed a near real-time tracking of IoT Device Users to track the person who is a danger. The GPS system can be integrated with RFID [18] for food transportation. The Radio Frequency Identification (RFID). The RFID sensor tags are responsible for sensing, collecting and storing data about the monitored transportation conditions and investigated the benefits in implementing RFID-monitoring in a logistics [8], [14] ,[17]. The data from the RFID and GPS are transmitted through wireless communications system and can be viewed with the end users.

III. METHODOLOGY

A. Design of the System

Sensors, servers and databases are the key components to drive the IoT infrastructure [5]. The temperature, humidity, door status monitoring system with tracking of truck delivery vehicles is a cloud-based solution utilizing the internet as the gateway.

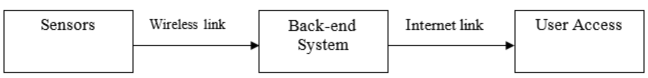

Figure 1 General Block Diagram

In figure 1, the system block diagram has three components: sensors and control, the back-end system and the user access. The sensors and control block are used to measure the temperature, humidity, the status of the door and the location. They send the signal to the Arduino microcontroller to process. The received signal is in the form of analog signal. Computers can only work with digital data and this data form the sesors which will be processed converting into digital signal by the used of analog-to digital converter. The back-end system refers to the server which is physically close to data storage systems. The system is scalable. And, during traffic congestions, the Web server can distribute some of its workload to peer servers that are not busy. The researcher will conduct the following steps to fully demonstrate the usefulness and capabilities of IoT-Based Monitoring of logistics and tracking delivery vehicles on real time. In Figure 1, the conceptual framework of this research is based on the Internet of Things system. The data coming from the delivery truck vehicles which include temperature, humidity, the door status and the location of the vehicle will transmit to the internet of thing platforms. This data will be stored in the cloud storage which will be analyzed, processed, or even interpreted. This information will be sent or notified to the retailer, the distributing center and even the dispatcher or driver.

A. System Architecture

The system architecture shown in Figure 2, it can be classified with respect to sensor, monitoring, and the output display. The main pillar of the system is the internet.

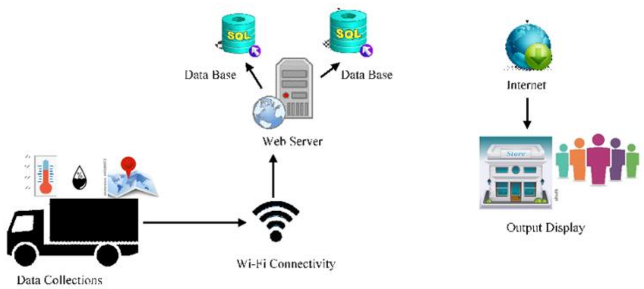

Figure 2 System Architecture

All the data gathered will be stored in the data base which come from the sensors as shown in Figure 3. The sensor data will be processed and to be analyzed by the data analytic system and converted into context form. This data will be displayed to the customers, dispatchers, and the distributors. PHP is what is known as a Server-Side Scripting Language - which means that it is interpreted on the web server before the webpage is sent to a web browser to be displayed. This can be seen in the expanded PHP recursive acronym **P**HP-**H**ypertext **P**re-processor. This diagram outlines the process of how PHP interacts with a MySQL database.

B. Monitoring System

In Figure 3, the researcher will have to place the temperature, humidity and ultrasonic sensor inside a truck or an enclosed area, where the monitoring is to be done. The sensors are interfaced with the Arduino Mega. The Arduino sends a start signal to temperature & humidity sensor, DHT11 module, and then DHT11 gives a response signal containing temperature and humidity data. Arduino collect and extract in two parts one is humidity and second is temperature then displays the output to LCD.

Figure 3 Conceptual Framework

DHT11 temperature and humidity sensor program is divided into two parts: data reading program, temperature and humidity reading program. Data reading program only reads data of temperature and humidity inside the vehicle. Temperature and humidity reading program includes sending the start signal, the data read and data checksum, and the response needed to be judged on the DHT11.

The Ultrasonic sensors are used to detect the status of the rear door of the truck. Whenever the range of the Ultrasonic sensor is out of range, it will display on the LCD that the door is opened, and the same time the Ultrasonic sensor sends the high signal to the buzzer and the buzzer starts beeping to give warning to the truck driver [10]. You can adjust the sensor detection range according to your door.

C. GPS system

The GPS system as shown in figure 4, the modem is installed in the truck vehicles which is going to be tracked. The GPS modem and Wi-Fi modem are interfaced with the microcontroller unit that send the position of vehicle.

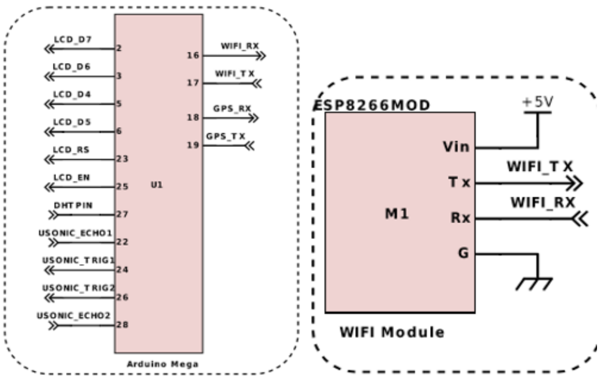

Figure 4 Block Diagram for GPS system

The GPS receiver receives signal from the satellite. This information or signals contain the Latitude and longitude of the GPS receiver or the truck vehicle. This signal will send to the Arduino microcontroller and the output of the microcontroller will be sent to the WiFi module. The microcontroller extracts the desired information and makes a packet out of it that consists of geographical data and other information.

D. Internet of Thing (IoT) Platform

In figure 5, Arduino Microcontroller is the brain of the IoT system. The main function is to process the information, or the data sensed by the sensors and process to extract the desired data from all gathered data. The microcontroller works on near real time basis and can be controlled by application. Encryption and decryption of data is also necessary in securing the data. All embedded hardware devices, microcontroller are the ones that process the sensors and GPS data because they have the processor attached to it as input and interfaced to the network gateway.

Figure 5 Block Diagram of the Internet of Thing Platform

Network gateway is responsible for routing the processed data and sends it to the proper locations for its data proper utilization. It helps network connectivity to the data which is essential in IoT system to communicate the system. Server is one of the important components for storing data. There are different servers for different purposes. For our application, we use a web-server. The sensors connect the server through IP address and port number. All the requests and responses happen through HTTP protocol. As the server gets connected, the database is ready to accept values from the sensors.

For this application, we use maximum of two MySQL database for receiving sensors data. One database for location subsystem and the other for Ambience and door-lock status subsystem. The operation of the database is very simple, each sensor information needs to be stored in its respective database. Therefore, we need to design web pages with PHP code that will receive information from the sensor and redirects the values to their respective server database through WI-FI modem. Once the internet is connected, the data such as LP (Location Parameters), DP (Door Status Parameters) and AP (Ambience Parameters) are transferred to the database through http protocol. The process of storing happens between, HTTP client and HTTP server. Below is the HTTP clients request, on which, it first identifies the server with IP address or domain name through DNS. Apart from the server, we need to mention the port number by which it needs to connect with the server.

GET /file.php var HTTP /1.1
Host: www.tomtomker.com

As the server is connected, it looks for the file.php, where the PHP file redirects to a database, where the sensor information is stored. For example, if we want to store the GPS parameters like latitude and longitude, the values are passed to the server and the data are store in the Location DataBase. Similarly, all the sensor information is respectively stored in their corresponding server databases.

E. Cloud Data Network

A typical request goes as follows and seen in figure 6 Apache receives a request for a URL and forwards this request to PHP. PHP sends ‘queries’, in a language called SQL, to the MySQL database, which responds by generating the required information [7]. PHP formats the information

ISBN: 978-988-14048-6-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

into a web page constructed from HTML that is then passed back to Apache. Then, apache sends the web page to the browser which displays it to the user.

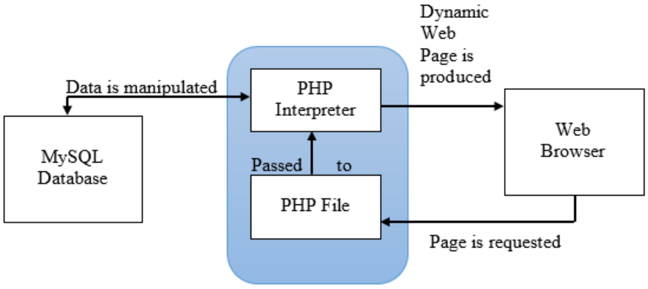

Figure 6 Block diagram of Cloud Data Network

III. RESULTS AND DISCUSSION

Several testing procedures were conducted to evaluate the accuracy and the functionality of the design. One of the most important things to be considered is the design-under-test. This will measure how the device is accurate and reliable that contributes to the benefits of others. This was done by numerous ways until it attains its objectives and purpose. After gathering the data, it was compared to the data of the existing measuring devices. The test was conducted with several trials at different time, date at different locations in Metro Manila. Moreover, testing was done at several transportations such as Light Railway Train, public utility vehicle (PUV) and L300 van in different places. Other factors are considered like the availability of the Wireless Network which could affect the transmission of data on the web portals. This wireless network performance is dependent on the various areas within the network which causes delays in the transmission data. However, data was stored temporarily to the SD memory card until such time connected to the network.

The final testing of the project was simulated using L300 van conducted from Cubao to the Mall of Asia (MOA) areas. Based on the data gathered approximately an average of less than 0.5 difference between the expected and the actual value was obtained. The path travelled of the vehicle was successfully mapped using GPS map and displayed sensors data on the dashboard. Notifications for the status of the door and temperature above the preset value was also successfully sent to the dashboard. Furthermore, Variance and T-test are used for the data analysis of this study. The t-test assesses whether the means of the proposed system and the existing device are statistically different from each other.

Table 1 t – Test table for temperature paired two sample for Means

	Variable 1	*Variable 2*
Mean	32.1	31.59275
Variance	0.0979411	0.097152
Observations	69	69
Pearson Correlation	0.2819180	
Hypothesized Mean Difference	0	
df	68	
t Stat	11.257295	
P(T<=t) one-tail	1.7294E-17	
t Critical one-tail	1.6675722	
P(T<=t) two-tail	3.4588E-17	
t Critical two-tail	1.9954689	

Ho: There is no significant difference between the proposed device and the conventional measuring device for temperature monitoring $(\mu_1 = \mu_2)$ *(1)*
Ha: There is significant difference between the proposed device and the conventional measuring device for temperature monitoring $(\mu_1 \neq \mu_2)$*. (2)*
where μ_1 = proposed method; μ_2= conventional method
Decision: Accept Ha, since t-stat (11.2573) > t-critical (1.995469)

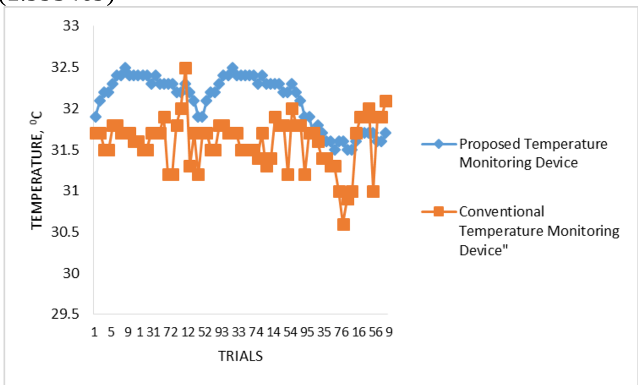

Figure 7 Statistical Graph of Temperature from Recto to Anonas Station (Conventional vs. Propose Device)

At 5% level of significance, it can be concluded that there is no significant difference between the two. The proposed device can therefore determine the value as accurately the same as the existing one.

Table 2 t – Test table for Humidity paired two sample for Means

	Variable 1	*Variable 2*
Mean	65.363768	65.27101
Variance	1.0876385	0.996206
Observations	69	69
Pearson Correlation	0.7652674	
Hypothesized Mean Difference	0	
Df	68	
t Stat	1.0999054	
P(T<=t) one-tail	0.1376260	
t Critical one-tail	1.6675722	
P(T<=t) two-tail	0.2752520	
t Critical two-tail	1.9954689	

Ho: There is no significant difference between the proposed device and the conventional measuring device for temperature monitoring $(\mu_1 = \mu_2)$ *(3)*
Ha: There is significant difference between the proposed device and the conventional measuring device for humidity monitoring

$(\mu_1 \neq \mu_2)$ (4)

where μ_1 = proposed method; μ_2= conventional method
Decision: Accept Ho, since t-stat (1.099905) < t-critica (1.995468)

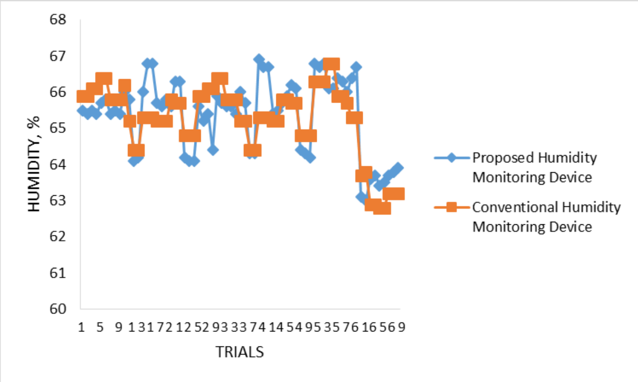

Figure 8 Statistical Graph of Humidity from Recto to Anonas Station (Conventional vs. Propose Device)

At 5% level of significance, it can be concluded that there is no statistically significant different between the two. The proposed device can therefore determine the value as accurately the same as the existing one. Likewise, to check the accuracy of the location latitude and longitude coordinates are also conducted and tested. It shows that the proposed device can therefore determine the latitude and longitude as accurately the same as the existing one as shown in Figure 3.42 and Figure 3.43 respectively.

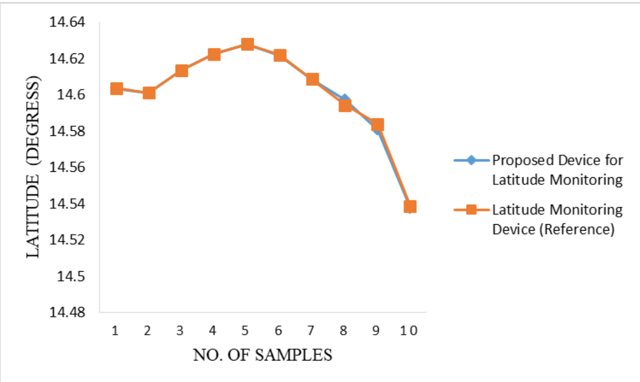

Figure 9 Statistical Graph of sample Latitude coordinates (Conventional vs. Propose Device)

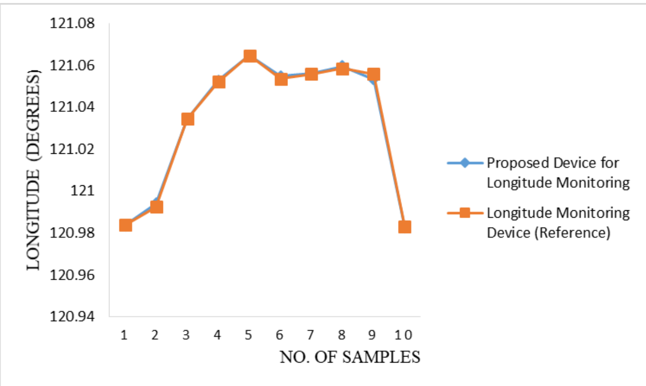

Figure 10 Statistical Graph of sample Longitude coordinates (Conventional vs. Propose Device)

IV. CONCLUSION

In this study, a series of testing conducted proved that this study was able to develop a system that monitored logistics end-to-end and tracking delivery truck vehicles utilizing the Internet-of-Things. A web-based data acquisition and monitoring system for the ambient parameter which include temperature and humidity, the GPS location updates parameter and the security alert for the status of the truck door was successfully incorporated in the truck monitoring system. Parameters such as the ambient temperature and the door status can be illustrated on LCD; all of these were sent to the webpage dashboard on a near-real time including the GPS coordinate parameters such as latitude and longitude coordinates. Data are updated on near-real time for humidity, temperature, rear door status of the truck and truck locations by an interval of 10 to 15 seconds transmission. Truck locations updates are mapped to the webpage dashboard using the GPS coordinates through the application programming interface (API). Notifications were successfully sent to the distributer's webpage dashboard for ambient parameters and door status of the truck and with the implementation of the Arduino microcontroller, a set of sensors, GPS receivers, Wi-Fi module and the application software developed. Security alert was also integrated using buzzer to alarm the truck driver that the rear door is opened.

Furthermore, the device design functionality has been evaluated properly. The results of the test were evaluated using the variance and the T-test which was used to validate the null hypothesis if the mean values of the two sets of data are significantly different. The t-stat value were taken into account which was lower than the absolute of the critical value and/or the P-value was greater than the alpha value of 0.05, therefore indicates no significant difference and the difference in results was due to other design factors, the null hypothesis was accepted, thus proved that the proposed device had a high reliability with high security by tracking delivery vehicles when they were transported from one place to another. The power consumed by Arduino required a DC voltage of 5V. Moreover, the connected USB broadband pocket Wi-Fi also consume additional power. Therefore, an analysis of the power consumption of Arduino-based device should consider the power losses resulting from the operation of the power bank.

ACKNOWLEDGEMENT

The authors would like to thank Alejandro H. Ballado Jr., as well as to Pamantasan ng Lungsod ng Maynila, Mapua University and Metals Industry Research and Development Center for extending their profound knowledge towards the realization of this project.

REFERENCES

[1] H. Abdalsalam, A. Dafallah, "Design and implementation of an accurate real time GPS tracking system," *IEEE, 2014.*

[2] V. Ashok, T. Priyadarshini, N. Raghavi , B. Rajashree, & S. Sanjana, "A secure freight tracking system in rails using GPS technology," 2016 2nd International Conference on Science Technology Engineering and Management, ICONSTEM, 2016, pp. 47–50.

[3] Atabekov, A., Starosielsky, M., Lo, D. C. T., & He, J. S., “Internet of things-based temperature tracking system,” Proceedings - International Computer Software and Applications Conference, 2015, vol. 3, pp. 493–498.

[4] Bailey, Gavin, T. Cherrett, and B. Waterson, “The internet of things for efficient medical logistics: a best practice review,” 16th Annual Logistics Network (LRN) Conference, 2011, pp. 7-10.

[5] Bojan, T., Kumar, U., & Bojan, V. (2014), “An internet of things based intelligent transportation system,” IEEE International Conference on Vehicular Electronics and Safety, 2014, 174–179.

[6] Chen, X.-Y., & Jin, Z.-G., “Research on Key Technology and Applications for Internet of Things,” Physics Procedia, 2012, vol. 33, 561–566.

[7] Das, Arpit, S. Devgan, “Implementation of streaming audio and video for online web-based courses using MySQL database server ang php,” IEEE, 2002, pp. 523 – 526.

[8] Duroc, Yvan and D. Kaddour, “RFID potential impacts and future evolution for green projects. Energy Procedia,” 2012, vol. 18, pp. 91-92.

[9] Feng, Wang, L. Wenzhong, P. Liu, et al., “Visualization of real-time logistics monitoring microsystem based on MEMS sensors,” IEEE NEMS, 2015, pp. 438-440.

[10] P. Hosur, R. Shettar, M. Potdar, “Environmental awareness around vehicle using ultrasonic sensors. IEEE ICACCI, 2016, pp. 1154-1159.

[11] Kim, Jinseong, J. Jang and I.Y. Jung, “Near real-time tracking of IoT device users,” IEEE DOI, 2016, pp. 1085-1088.

[12] R-H Ma, Y-H Wang, C-Y Lee, “Wireless remote weather monitoring system based on MEMS technologies,” Sensors - Open Access Journal, 2011, vol. 11, Issue 3.

[13] J. Macaulay, L. Buckalew and G. Chung (2015). Internet of things in logistics : A collaborative report by DHL and cisco on implications and use cases for the logistics industry. 1st edition, 2015, Troisdorf, Germany

[14] S. Mejjaouli, I. Nisanci, R. Babiceanu, “The use of rfid sensor tags for perishables products monitoring in logistics operations,” IEEE Winter Simulation Conference, 2014, pp. 2001 – 2012.

[15] E. Oriwoh, P. Sant and G. Epiphaniou, “Guidelines for internet of things deployment approaches – the thing commandments,” Procedia Computer Science, 2013, vol. 21, pp. 122 – 131.

[16] N. Raghunathan, & X. Jiang, “Wireless Low-power Temperature Probes for Food / Pharmaceutical Process Monitoring,” 2015, pp. 3–6.

[17] C. Sun, “Application of rfid technology for logistics on internet of things,” AASRI Procedia, 2012, vol. 1, pp. 106-111.

[18] P. Tadejko, “Application of Internet of Things in Logistics – Current Challenges 1, Development of the IoT, 2015, vol. 7(4), pp. 54–64.

[19] F. Xia, LT. Yang, L. Wang and A. Vinel, “Internet of things,” International Journal of Communications, 2012, Volume 25, pp. 1101-1102.

[20] T. Yin, W. Feng, and Z. Li, “Temperature and humidity wireless sensing and monitoring systems applied in greenhouse,” IEEE International Conference on Computer Science and Network Technology, 2011, pp. 857 – 861.

[21] R. Yu, “Discussion on Internet of Things Technology Based Internet Marketing,” (Iccse), 2012, pp. 893–895.

ISBN: 978-988-14048-6-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)