Smart Tyres: An Environmental-Friendly Solution to Road Accidents

C.Y. Hou, H. Alhussian, G. Hayder, S. Basri, S. Jadid

***Abstract:** The absence of the tyres monitoring system on vehicle has caused difficulty for driver to check the pressure and temperature of the tyres in real time. Besides that, due to the large geographical area of rural area where the distribution of petrol station with air pump might not be equally distributed, certain area is hard to access air pump. The abnormal pressure and increases in temperature on tyre lead to longer braking distance, tyre blowouts and related issues. The paper describes the deployment of IoT sensors for monitoring application in tyres and data is accessible on mobile app. This monitoring system consists of two sensors to measure the temperature and pressure of the tyre using ESP32 microcontroller board and uploaded into the cloud platform using Wi-Fi technology. While Blynk the mobile app is designed to collect the informative data from the cloud platform and the data is represented in graphical representation using open source Cloud platform. It is made available for real-time monitoring data. Apart from that, this system also incorporates alert system to provide a scalable monitoring system as well as alerting the user for any abnormal reading of the tyre.*

***Keywords:** Internet of Things (IoT); Cloud Platform; Monitoring System*

I. INTRODUCTION

Internet of Things (IoT) is playing a crucial part in the forth industry revolution (IR 4.0) that we are a witness today by offering the ability to connect different sensors, devices and services and supplying real-time data on demand [1]. These real-time data acquired form IoT sensors can be sent to cloud computing for further analytics and processing bridging the gap between the real world and virtual cloud computing [2]. Thus, total transparency occurs minimizing required human intervention which in turns enhance efficiency and accuracy. IoT are used in diversity of applications nowadays, including but not limited to: health-care, waste management systems, agriculture, transportation, oil and gas, etc… [3]. Tyre monitoring system is one of the IoT applications which includes sensors, microprocessor controller and cloud platform.

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Sensors are usually small devices that have the capability of sensing and wireless sensing whereas actuators are devices equipped with processing abilities [4] which enable them to convert electric signals to physical events accordingly to the surrounding environment. It is known as wireless network deployed in numerous locations that capable to connect big number of low power and low cost and multifunctional actuator nodes and sensors [5-7].

Tyre monitoring systems are used to monitor the status of the tyre. The system can be classified into two categories which are tyre monitoring and upload data into the cloud. The increasing number of vehicles on road has caused number of accidents caused by vehicle parts increased as well. It is very dangerous to drive with low tyre pressure. In 2007, in United States it became mandatory that every car made after 2007 has a tyre pressure monitoring system built in. But most of the current system will only show an illuminating light on the dashboard, which the driver needs to figure out which tyre is low in pressure.

According to Ruiz[3], the number of accidents caused by burst tyres is on the increase. Abu Dhabi Police have log 7,603 offences against motorists for using defective tyres in January and February 2013. Poor-quality tyres have caused 53 accidents in 2012, killing 13 and seriously injuring 28. Apart from that, it is hard for driver to identify the current condition of the tyre and the pressure which is suitable for the tyres. Most over inflated or under inflated their car tyres which caused the tyres to overheat when driving long distance which eventually lead to flat tyre or tyre burst and driver will be losing control of the vehicle and lead to road accident to happens.

Based on the survey conducted in April 2018 among Universiti Teknologi PETRONAS (UTP) students, 8 out of 20 respondents agreed that they do not check their tyre pressure regularly, and 12 out of 20 respondents do not aware of the impact of underinflated and overinflated tyre. These results are very concerning as most of the respondents are highly educated Malaysian youngsters aged between 19 and 25 years, though they are neglecting the importance of tyres in safety driving, and this shows that many accidents caused by vehicle's tyres can be avoided. Besides that, according to The Stars [8], Road accidents cost Malaysia RM9.2bil in 2016. Road accidents not only costing loss of lives but money as well.

II. LITERATURE REVIEW

2.1 Internet of Things

Internet of Things (IoT) was first introduced in 1999 by Kevin Ashton [4]. This IoT concepts has been widely applied in many areas including business, transportation, cities, healthcare, and others. There are many applications that are currently implementing IoT. Basically, the word "Things" in IoT can be referring as sensors, devices or anything that can connected the internet and able to transmit information from it onto cloud server which the information will eventually to be accessible by end user.

IoT offers the extension of Internet which linked all the everyday objects that connected under the same network by deploying the object-object interaction through wireless networks. It connects the physical devices that contain unique identity embedded with actuators, microcontroller, and network connectivity by harnessing the required sensors' information. The information will then be sent to the Internet across the existing network service and infrastructure, which creating a direct integration of the physical world and the virtual systems of computing [6].

2.2 Roles of IoT in Today and Future World

According to Peng *et al*[9], wireless sensor networks has drawn much attention as the sensor nodes equipped with various monitoring capabilities have additive advantages over the traditional communication technologies. With the emerge of IoT, the dream of when you are out of home and your computers will notify you to that your medicines or milk have expires or you need more pepper. This soon to be a reality due to the amazing possibilities of the Internet of Things (IoT).

From this we can see with the IoT sensors, owners will be able to use an app to access their cars remotely in order to adjust the temperature, check the mileage or even start the car, like a remote virtual dashboard.

All this are thanks to the IoT technology, IoT devices connecting everything parts of the car and producing masses of data to monitor and improve virtually every aspect of the day to day. The solutions offered by the IoT allow us to envisage a more efficient future in many respects.

2.3 Roles of tyres on road accidents

According to Insurance Institute for Highway Safety[10], in the United States, hundreds of people die in car accidents in every month. There are several causes of fatal car accidents that some led to death which include; speeding, drivers' distraction, and equipment failure are the most obvious causes. As far as safety is concern, several studies have found out that tyre failure has one of the highest impacts on road traffic accident statistics.

Tyre has a tremendous effect on the rate of road traffic accidents. The causes and effects of tyre blowout on road traffic accidents and found out that 89 percent of the drivers surveyed in Metropolis were not familiar with the tyres they are using[11]. That can be many caused that could lead to tyre blowout. These are the main problems that could lead to tyre failure.

The statistics shown in Figure 1 below were taken from the Mechanical Engineering Department of Takoradi Polytechnic[11].From the statistics we can see that the pressure and temperature of a tyre plays an important role of tyre blowout or burst.

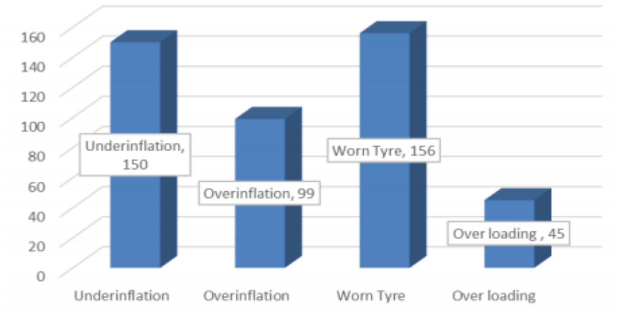


Fig.1 The main causes that lead to tyre failure [11]

Apart from that, worn tyre is the main caused for tyre blowout follows by under inflation or low pressure of the tyre. According to Wetherington[12], vehicle tyres are often given a 4 to 6-year validity period from their Date of Manufacture (DOM) or Date of Production (DOP).

2.4 Accidents Caused by Vehicle Tyres

Since the year 1996 to the year 2002, around 60,397 vehicles were crashed with a totally or partially damaged property and/or injury as being recorded in French motorway with 2000 km. Out of which, 6.7% of the recorded accidents involved tire explosions and blow-outs. Out of the 87% of the accidents, only one vehicle was involved in the accident. Tire blow-outs occurred in 6.5% of cars which represents more than 80% of the vehicles involved in crashes[11].

For small vehicle like car, front tires blowout more frequent while for trucks rear tires occur four times more frequently than for blow-outs of front tires. This because for small cars front tire need to support much heavier load as the car engine are located at the front of the car while for trucks, the rear tires need to bear more heavy lift as the cargo is located above the rear tires. Apart from that, the driver driving style, rate of braking as we are applying the brakes, weight was transfer occurs from rear to front, thus more forces are transferred to the front tires.

2.5 Efforts Make to Reduce Road Accidents Caused by Tyre

Tyres were made to grip on the road surface whenever the vehicle is being steered, accelerated, and especially braked and or negotiating a corner. Because of this the tyre condition plays an important role on the car safety. Under inflated tyre may affect the tyre's ground interaction which is of fundamental importance to every vehicle.

According to European Union commission[13], only 9% of cars on the road have all four tires properly inflated, 83% of car owners do not have the knowledge to properly check their vehicle's tires pressure, 66% of drivers never check the condition of their spare tire and 50% of vehicle owners could not tell if a tire is a bald. European Union Commission combines (different EU legislations and different tyres) it requires a specific approach to assess the possible impacts of different policy options on safety.

For now, this analysis is built around the following elements[13]:

a) The identification of accidents under these relevant conditions. Relevant meteorological conditions (based on the analysis of the EFSA and DWD databases) and current tires usage statistics are used to enrich the database and identify those accidents where different policies options may have an influence on the statistics.

b) The assessment of the possible effects linked to different policy options is based on the analysis of information presented in the GIDAS database. As a result of the comparison of grip-related accidents between two vehicle categories (those with and those without the appropriate tire use conditions), it is possible to identify risk reduction rates for changed tire use behavior. This is then extrapolated to the overall fatality statistics [13].

2.6 Comparison between Mobile Application and Website

Research on the platform to display collected data and information to the user was carried out and both webpage and mobile app has been carefully evaluated to identify the suitable platform to display collected information.

Due to the fact that there are significantly more mobile devices than the number of computers connected to the Internet, mobile applications represent a high potential for services in today information society. Research shows that in today world there are more mobile user compares to PC user as smartphone is more portable. Figure 3 shows the data released by StatCounter [14], in which 51.3% of all web visits on October 2016 were came from mobile devices while compared to 48.7% of visits from traditional computing platforms such as laptop and PC.

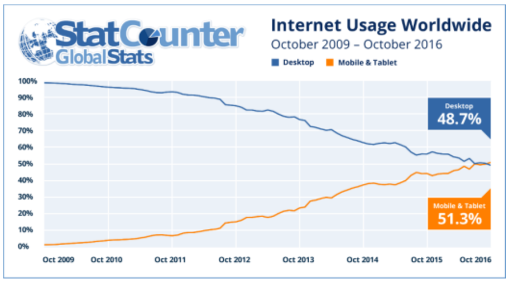


Fig.2 Chart shown mobile device internet usage exceeds traditional desktop and laptop for the first time on worldwide[14]

According to research of Rebekah [15], she discovered that her project team members prefer to use mobile application more than traditional websites on mobile device. They pointed out that applications are more aesthetically and responsive than mobile websites, since "apps provide one-click access, unlike a mobile website that take several clicks and scrolling and text entry, to access every time".

Mobile application trump website in several ways [16]. First of all, mobile app can push live notifications whereas website cannot. Some mobile application even allow user to have offline access where it is impossible for website cannot as website need to access internet. The performance of mobile application can be better the website due to its easy engagement with the user. Apart from that, with a mobile application, user can just search for the mobile application icon and access it from there. Furthermore, a mobile website normally has cluttered design whereby user cannot read some of the text and view the pictures fully from the websites [16]. Figure 4 shows the percentage of time spent by users on mobile apps vs mobile web.

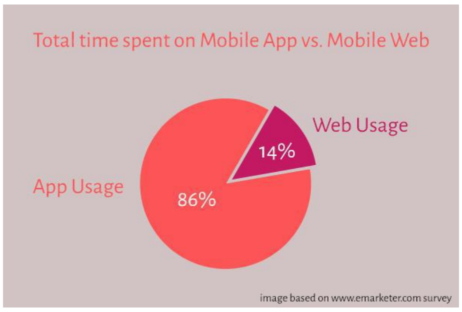


Fig.3 Total time spent on Mobile App vs MobileWeb[16]

2.7 Comparative Study between Microcontroller Board

There are many different types of microcontroller unit with different price range available in the market today. In order to choose the most suitable microcontroller board to be used in this project, comparison between CT Uno, ESP32, Raspberry Pi 3 Model B and Intel Edison has been conducted. The specifications of the above microcontroller board are available in [17-20] and these are the summarization has been done in Table 1 as shown below.

Table. 1 Comparison of Microcontroller Unit [18-20]

Specifications	CT Uno	ESP32	Raspberry Pi 3 Model B	Intel Edison
Microprocessor	ATmega 328	Xtensa Dual-Core 32-bit LX6	Broadcom BCM2836	Intel© ATOM ™
Clock Speed	16MHz	160MHz	900MHz	500MHz
Current Consumption at 5V	50mA – 1A	300-400mA	2.5A	1A
RAM	32kB	512kB	1GB	1GB
Network	Via external modules	- Wi-Fi LAN (802.11b/g/n) - Bluetooth 4.1 (802.15)	- Wi-Fi LAN (802.11b/g/n) - Bluetooth 4.1 (802.15)	- Wi-Fi dual-band (802.11a/b/g/n) - Bluetooth Low Energy
Programming Language	Arduino IDE	Arduino IDE, Python	Python, C language	Arduino IDE, Python
Estimated Cost	RM62	RM79	RM191	RM498

III. METHODOLOGY

The development of smart tyres system is divided into four parts:

1. Study the board and sensors voltage and signaling.
2. Linking the ESP32 board, temperature sensor and pressure sensor on the breadboard with certain resistor. For example, 4.7k Ohm resistor is installed.
3. Programmed and setting up using Arduino IDE.
4. Access and validate data received from the sensor through mobile apps called Blynk.

Linking the ESP32 board, temperature sensor and pressure sensor on the breadboard. Try to link the ESP32 Board with the IoT sensor like temperature and pressure sensors using breadboard. Some soldering is involved in the process. Research were done for the current and data transmission.

A resistor is needed to install for the temperature sensors. A proper programming code needed to be coded into the board in order for the board to receive and analyses the raw data received from the sensors. After that, Access and validate data received from the sensor through mobile apps called Blynk.

In this section, the subsystems will undergo various testing to determine its functionalities and capabilities. To validate the subsystems are working perfectly, each subsystem will be tested separately. To ensure the data transmitted from the sensor to mobile apps is accurate, double measure of the temperature and pressure is needed. In both static and dynamic condition, which mean the when the tyre is spinning or stationary.

The app will have following requirements:

1. Real time synchronize of the data: Temperature and pressure reading.
2. Alert beeping for underinflated or overinflated pressure of the tyre.
3. Alert beeping for abnormal temperature of the tyre.
4. The data is transferred wirelessly through Wi-Fi.

3.1 System Architecture

The proposed IoT architecture of the system contains 3 main subsystems. The environment is made intelligent enough by incorporating the sensor boards, microcontroller, as well as communication modules which will capture and disseminate the sensors' information to the cloud platform.

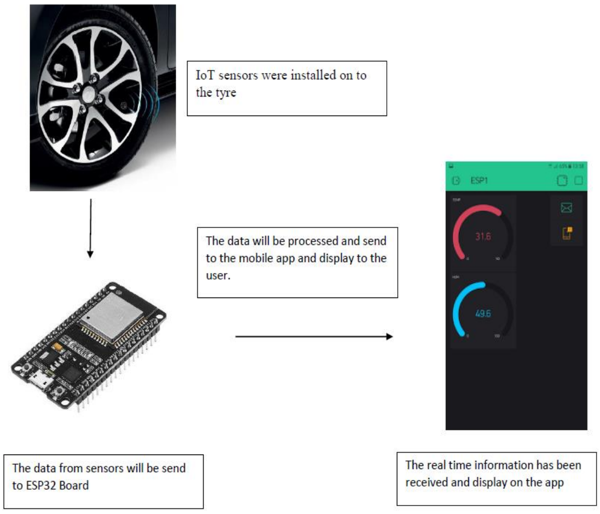
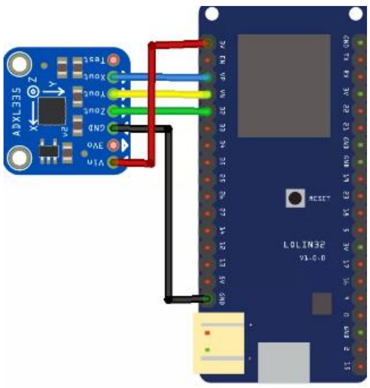


Figure 4: Overall System Architecture



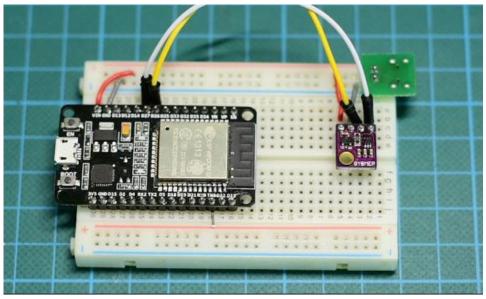


Fig.5 Connection between ESP32 Board & BMP280 Sensor (left), and Connection between ESP32 Board & BMP280 Sensor (right)

IV. RESULTS AND DISCUSSION

4.1 Temperature and Pressure Index Sensing

The results of the BMP280 temperature as well as pressure sensors are measured using Celsius (°C) and pascal (pa) respectively.

The accuracy measurements of the BMP280 sensor are tested and compared with temperature measurement readings from an actual thermometer. Table 2reveals the obtained results from the IoT sensor against the results from the thermometer during different time intervals as well as different locations. The percentage are calculated based on equation 1.

$$Percentage\ Difference\ (\%) = \frac{Actual\ Value\ (°C) - Measured\ Value\ (°C)}{Actual\ Value\ (°C)} \times 100\% \ \ldots\ldots\ldots\ldots.. (1)$$

Table.2 Temperature Measurements Comparison

Location	Thermometer Actual Value (°C)	BMP280 Measured Value (°C)	Difference (%)
Inside the Lab	25.00	25.30	1.20
Openedplace (Normal temperature)	29.50	28.70	2.71
Under sunny place	34.50	35.20	2.03
Café of V5	29.00	29.70	2.41
Room Temperature	27.50	28.20	2.55
Outside of IRC	27.00	27.30	1.11

The relative pressure measured values of the BMP280 sensor are validated by comparing them using an application. Nevertheless, the measured values seem to be a little different as the application measures the relative pressure values based on the whole location. The variation is around ±5% in which the differences are still within the acceptable range.

Transmission of Data to the Cloud

The temperature and pressure sensor data of the BMP280 are sent to over the internet to the cloud using open source cloud platform (Blynk) for storage and real-time monitoring of tyre status using their smartphones.

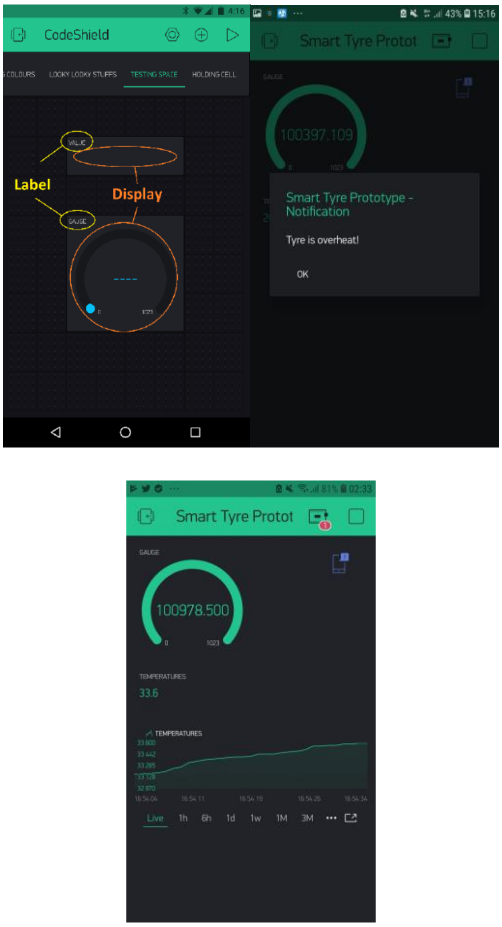


Fig.6Blynk Dashboard, Blynk Alert Notification and Average Temperature Reading

The dashboard created in Blynk consists of all the sensor data from the sensor. The dashboards of Blynkare is shown in Figure 6.

4.3 Data Collection Analysis

The IoT sensors are placed in several locations around the campus of Universiti Teknologi PETRONAS (UTP) to validate their measurements. The selected locations are known to be the hotspot places around the campus such as the football field, café area, Residential Village 5. The collection of the data was carried out for two weeks. The data analysis was done graphically to benchmark the temperature recorded by the sensor nodes and the sensor placed on a moving car tyre rim. The results showed that temperature reading from the sensor is slightly higher than thermometer by less than 3%.

4.4 Final Prototype

Figure 7 illustrates the final prototype of the overall Smart Tyre Monitoring System.

Fig.7 Final Prototype

V. CONCLUSION

In conclusion, the proposed IoT-based tyre monitoring system brings many advantages to the societies. The system has multi-sensing capability that can monitor the tyre surroundings together with mobile apps to display to the user and provide alerts notification when the tyre condition exceeds the optimum range to prevent accidents from happening due to tyre temperature and pressure related issues. With such monitoring application, tyre blowout rate of vehicle can be reduced tremendously, and enable the driver and passenger to check the tyre pressure and temperature and obtain the real-time data that is accessible via the mobile application. Results obtained based on the field deployment has shown that the temperature reading from the sensor is slightly higher than thermometer by less than 3%. Finally, the implementation of this tyre monitoring system embedded with wireless communication can save lives and government spending.

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REFERENCES

1. C. RICHES, "Young drivers of today have a shocking lack of car knowledge | Express.co.uk," 2016. [Online]. Available: https://www.express.co.uk/life-style/cars/712956/revealed-shocking-lack-car-knowledge-young-drivers-today-study. [Last Accessed: 02-Aug-2018].
2. M. D. Abagale, J. Akazili, P. Welaga, M. Dalaba, Y. Luu, S. A. Abagale, and R. A. Oduro, "The effects of road traffic accidents on society. The case of the Kassena Nankana districts, Ghana: a quantitative survey," Lancet, vol. 381, p. S3, Jun. 2013.
3. R. Ruiz, "Poor tyre care causes increase in road accidents - The National," 2014. [Online]. Available: https://www.thenational.ae/uae/transport/poor-tyre-care-causes-increase-in-road-accidents-1.464111. [Last Accessed: 02-Aug-2018].
4. N. P. Sastra and D. M. Wiharta, "Environmental monitoring as an IoT application in building smart campus of Universitas Udayana," in 2016 International Conference on Smart Green Technology in Electrical and Information Systems (ICSGTEIS), 2016, pp. 85–88.
5. N. Ohe, M. Ishihara, H. Yonemori, and S. Kitagami, "A Method of Prototype Construction for the Active Creation of IoT Application Ideas and Its Evaluations," vol. 5, no. 1, pp. 1–8, 2016.
6. A. Rao Jaladi, K. Khithani, P. Pawar, K. Malvi, and G. Sahoo, "Environmental Monitoring Using Wireless Sensor Networks(WSN) based on IOT," Int. Res. J. Eng. Technol., 2017.

7. "M2M remote access, industrial internet of things." [Online]. Available: https://www.neratec.com/en/m2m-internet-of-things. [Last Accessed: 03-Aug-2018].
8. The Stars online, "Road Accidents Cost Malaysia RM9.2bil in 2016", [online]. Avialable: https://www.thestar.com.my/news/nation/2017/02/02/road-accidents-cost-malaysia-rm9dot2bil-in-2016. [Accessed: 03-Aug-2018].
9. Y. Peng, U. He, and J. Choi, "Wireless sensing and propagation characterization for smart greenhouses," in Communications in Computer and Information Science, 2012.
10. I. Edunyah, "Causes of Tyre failure on Road Traffic Accident; A case study of Takoradi Township," Int. J. Sci. Res. Publ., vol. 6, no. 2, p. 30, 2016.
11. J.-L. MARTIN and B. LAUMON, "Tire Blow-Outs and Motorway Accidents," Traffic Inj. Prev., vol. 6, no. 1, pp. 53–55, Feb. 2005.
12. M. Wetherington, "Tires Expire in Six Years - Tire Safety Group." [Online]. Available: http://www.tiresafetygroup.com/tires-expire-in-six-years/. [Accessed: 03-Aug-2018].
13. C. Sven Jansen, Antoine Schmeitz, Sander Maas and Rodarius, "Study on some safety-related aspects of tyre use."
14. "Mobile and tablet internet usage exceeds desktop for first time worldwide | StatCounter Global Stats," 2016. [Online]. Available: http://gs.statcounter.com/press/mobile-and-tablet-internet-usage-exceeds-desktop-for-first-time-worldwide. [Accessed: 03-Aug-2018].
15. S. Han and R. Wong, "Which platform do our users prefer: website or mobile app? Which Platform Do Our Users Prefer-Website or Mobile App?," 2012.
16. Nahida Nana, "Mobile Website vs. Mobile App: Which is Best for Your Organization? | BestWeb Technologies." [Online]. Available: https://bestweb.com.my/mobile-website-vs-mobile-app-best-organization/. [Accessed: 03-Aug-2018].
17. "Raspberry Pi 3 Model B." [Online]. Available: http://wiki.seeedstudio.com/Raspberry_Pi_3_Model_B/. [Accessed: 03-Aug-2018].
18. "ESP32 Series Datasheet Including," 2018. [Online]. Available: https://www.espressif.com/. [Accessed: 03-Aug-2018].
19. "CT UNO - Cytron Technologies." [Online]. Available: https://www.cytron.io/p-ct-uno. [Accessed: 03-Aug-2018].
20. "Intel Edison Breakout Board Kit - Cytron Technologies." [Online]. Available: https://www.cytron.io/p-bb-edison-kit. [Accessed: 03-Aug-2018].
21. Hussain A., Mkpojiogu E.O.C., Kamal F.M. (2016). Mobile video streaming applications: A systematic review of test metrics in usability evaluation. Journal of Telecommunication, Electronic and Computer Engineering. Vol 8 Issue 10. Page 35-39

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