IOT for Agriculture: Food Quality and Safety

Gunawan Witjaksono1*, Almur Abdelkreem Saeed Rabih1, Noorhana bt Yahya2, Sagir Alva3

1Department of Electrical and Electronic Engineering, Universiti Teknologi PETRONAS Seri Iskandar, 32610, Perak Darul Ridzuan, Malaysia
2Department of Fundamental Applied Science, Universiti Teknologi PETRONAS Seri Iskandar, 32610, Perak Darul Ridzuan, Malaysia
3Mechanical Engineering Department, Mercu Buana University Jl. Meruya Selatan no.1 Jakarta Barat, Indonesia

gunawan.witjaksono@utp.edu.my

Abstract—Food is the main energy source for the living beings; as such food quality and safety have been in the highest demand throughout the human history. Internet of things (IOT) is a technology with a vision to connect anything at anytime and anywhere. Utilizing IOT in the food supply chain (FSC) is believed to enhance the quality of life by tracing and tracking the food conditions and live-sharing the obtained data with the consumers or the FSC supervisors. Currently, full application of IOT in the FSC is still in the developing stage and there is a big gap for improvements. The purpose of this paper is to explore the possibility of applying IOT for agriculture to trace and track food quality and safety. Mobile application for food freshness investigation was successfully developed and the results showed that consumer mobile camera could be used to test the freshness of food. By applying the IOT technology this information could be shared with all the consumers and also the supervisors.

1. Introduction
For the past few years, food quality and safety has been a major concern and a hot topic in all around the globe, and especially in China for many reasons [1]. For instance, the incident of 2008 Sanlu melamine milk powder scandal has shocked the world due to its effect on thousands of babies, which resulted in death of several of them. Another incident that stunned the Chinese community and the world happened in 2011, when the meat from the Shuanghui Group (the largest meat supplier in China) was discovered to contain a substance (Clenbuterol hydrochloride) that is prohibited to add to food stuffs in China [2]. Food quality and safety gains attentions of both government agencies and consumers due to the major loss to the state revenue, and also the consumers health risks that caused by breaching the food standards. Therefore, there is an imperative need to develop technologies that can guarantee the safety of food along the whole food supply chains (FSCs) that include production, processing, packing, transportation, storage, distribution and sale for the consumers. Many researches have been conducted around the world with the development of some technologies like internet of things (IOT) to help the factories to resolve issues related to food quality and safety. IOT is a vision to
connect to anything at anytime and anywhere, and it is expected to drastically change the status of our life in years to come. It is defined by European commission information society as “Things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts” [3]. IOT technologies are believed to be able to provide potential solutions to resolve issues of traceability, visibility and controllability along the FSCs line [4]. IOT technologies have already been for many years in the pharmaceutical supply chain to enhance the quality and to keep the drugs safe [1]. IOT will play a role in resolving the issues of food quality and safety in term of managing factory staffs, food products and also in term of providing useful information to the customers to make them feel easier and comfortable to track or consume the food with great confidence [5].

Food packaging plays an important role to preserve the quality and safety along the line of the supply chain. Traditional packaging is only meant to protect the food from the environmental changes such as, temperature, humidity, light, gaseous emissions or microbial attacks. On the other hand, active packaging systems are those which have interactive communication between the packed food and the packaging environment to provide protection to extend the shelf life of the food. Active packaging protects the packed food by containing active components that release or absorb substances into/from the food to keep the conditions under control. In contrary intelligent packaging does not contain active components. However, it has intelligent systems that communicate with the supervisors or consumers to provide the current status of the food [6]. Smart packaging devices can be divided into two types. The first type is called data carriers such as barcode labels and radio frequency identification (RFID) tags, while the second type is called package indicators, which are used to monitor environmental changes such as time-temperature indicators and gas indicators. Fadable ink for time-temperature control of food freshness has been widely used in printing labels on food packages for the freshness indication. The working principle is that, as time passes, the ink will disappear and indicating that the food is no longer fresh [7]. The label ink will react to the oxygen which will make the colour to fade with time or temperature change. The rate of colour change is varied by the chemical composition used to make the ink. Figure. 1 shows how the label ink is faded with time. Gas indicators are labels that detect the presence of a gas due to the food condition change inside the package [6]. Polyaniline (PANI) film was used in [8] as a sensing layer to check the spoilage of fish based on reaction of the film with ammonia released as the fish is spoiled. PANI films will react to the ammonia released due to the fish spoilage as a result of bacterial growth. The reaction will lead to the change of the films colour. Another smart packaging indicator was reported in [9], which is a novel sticker sensor based on methyl red immobilized on bacterial cellulose membrane for broiler chicken freshness assessment. The colour of the sticker changes from red to yellow to indicate the chicken spoilage as shown in Figure. 2. As the chicken spoilage progresses, the pH level increases due to increase of spoilage volatile amines, which will occupy the headspace of the food package.
The reaction of the volatile amine with the methyl red/cellulose membrane will cause the color of the membrane to change to yellow. The aim of this paper is to explore the possibility of using the internet of thing technology to provide a solution for the food quality and safety control along the whole food supply chain.

2. Architecture of IOT technology
IOT technologies compose of different distributed resources that can be selected depending on the need of the different users and organizations around the globe [1]. By considering the vertical view of the IOT technology which focuses on the technical implementation, the resources of IOT can be categorized under three different layers, which are considered to be the main architecture layers of the IOT [10]. These layers are the sensing layer, the network layer and application layer as shown in Figure 3.
Figure 3. Layers of the IOT architecture from the perspective of technical implementation [10]

2.1 Sensing layer
Sensing layer can be subdivided into two layers based on the functions of the units. They are data acquisition and collaboration layers. In the data acquisition layer the things from the physical world like temperature, humidity, pressure, concentration, multimedia data, etc., are sensed using devices like sensors, Radio Frequency Identification (RFID) tags, Ultra-wide Band (UWB), Near field communication (NFC), WiFi and cameras. On the other hand, collaboration layer focusses on the technologies applied in short distance data transmission, context awareness and massive information processing. For these applications technologies like Wireless sensor network (WSN), Ad-hoc network, coordination treatment technology and middleware technology.

2.2 Network layer
Network systems have been used for many years already, and it is a heterogeneous system that comprises backbone, mobile communication, wireless local area network (WLAN), satellite communication networks, Global positioning system (GPS), Bluetooth etc. The data acquired by the sensing layer is transmitted to the application layer through this network layer.
2.3 Application layer

Application layer is sub-divided into two layers. They are support sub-layer and service sub-layer. Support sub-layer process the data using intelligent processing unit, and then will deliver to the user based on the issued request. Due to the large volume of the data involved the system integrated high processing data technologies such as cloud computing, peer to peer (P2P) middleware technology. Service sub-layer provides the interface and platforms to support the individual public services. Typical applications of this sub-layer will be security monitoring, disaster monitoring, vehicle scheduling monitoring and intelligent household appliances monitoring.

3. IOT technologies application in food supply chain

As shown in Figure 4, the overall view of applying IOT technology in food supply chain comprises of heterogeneous devices, with ubiquitous data exchange, tracking and localization systems [4]. There is well defined connectivity throughout the supply chain between the food producers, transportation bodies and also the food consumers. For instance when the temperature exceeds the desired value inside the food truck, the system will trigger an alarm and send a signal to the refrigeration controls to increase the ventilation to re-adjust the temperature and keep it under control. Same process is applied for other parameters like, humidity, gas concentrations, and ambient pressure and so on.

![Figure 4. Overall picture view of applying IOT in food supply chain [4]](image)

4. Some applications of IOT sensing layer

As was mentioned before, this layer is the first layer that is used to collect the data required for the IOT technology to function. Following are two examples of applications used for food freshness level detection and food authenticity identification.

4.1 Mobile camera app development for food freshness detection

As shown in Figure 3 one of the devices used for data acquisition is camera. For this purpose to take advantage of the mobile camera of the food consumers, a mobile app has been developed as part of the IOT technology used for the food supply chain. This app is to check the freshness of the prawn and displays the results on the screen of consumer’s mobile. More information about the mobile app is presented in our previous published article in [11]. In brief, the mobile app developed is based on
chromatic parameter to display the freshness level of the food directly by reading the RGB colour from the colour changing labels, and correlating it with the colour of pH paper. Then the app will display the freshness of the food by stating whether the food is “fresh, “good” or “spoiled”. Figure 5 shows the results of the app from the screen of the mobile phone.

4.2 Food type authenticity

Another application example of developing sensors for IOT sensing layer is using Fourier transform infrared spectroscopy (FTIR) to differentiate non-halal meat from halal meat which is necessary for the Muslims consumption. The data collected by FTIR sensor could be communicated directly through the communication layer to the application layer, where consumers and also supervisors can directly access the type of the meat source. FTIR was used to differentiate pig fat (lard) from the fats of cow, chicken and lamb in a broad range of mid infrared spectroscopy ranges from 400 – 4000 cm\(^{-1}\). The full description of the results analysis are reported earlier in [12]. Results at wavenumber 2361.05 cm\(^{-1}\) is shown in Figure 6.

![Figure 5. Testing of Apps on pH papers of (a) pH 6, (b) pH 7 and (c) pH 8](image)

![Figure 6. FTIR peaks of lard, cow, chicken and lamb fats at 2361.05 cm\(^{-1}\)](image)
5. Conclusion
This paper presented an idea of utilizing internet of things (IOT) for agriculture, food quality and safety. A mobile application (app) for the sensing layer of the IOT technology was developed and the app shows that the freshness of food could be investigated by studying the picture of the food and comparing it to the reference picture. The condition of the food whether it is fresh, good or spoiled could be shared with all consumers and food supervisors through the network and application layers of the IOT technology.

Acknowledgment
The authors of this paper acknowledge the financial support by UTP under STIRF-UTP, project code: 0153AA-F71 and by Petronas Research Fund (PRF) under by 0153AB-A32.

References
[1] Y. Gu, W. Han, L. Zheng, and B. Jin, "Using IoT Technologies to Resolve the Food Safety Problem – An Analysis Based on Chinese Food Standards," in Web Information Systems and Mining: International Conference, WISM 2012, Chengdu, China, October 26-28, 2012. Proceedings, F. L. Wang, J. Lei, Z. Gong, and X. Luo, Eds., ed Berlin, Heidelberg: Springer Berlin Heidelberg, 2012, pp. 380-392.
[2] Y. Liu, W. Han, Y. Zhang, Li, J. Wang, and L. Zheng, "An Internet-of-Things solution for food safety and quality control: A pilot project in China," Journal of Industrial Information Integration, vol. 3, pp. 1-7, 2016.
[3] Z. Pang, Q. Chen, W. Han, and L. Zheng, "Value-centric design of the internet-of-things solution for food supply chain: Value creation, sensor portfolio and information fusion," Information Systems Frontiers, vol. 17, pp. 289-319, 2015.
[4] X. Zhao, H. Fan, H. Zhu, and H. Fu, "The Design of the Internet of Things Solution for Food Supply Chain," presented at the 2015 International Conference on Education, Management, Information and Medicine, 2015.
[5] B. Song and Q. Xing, "On security detecting architecture of food industry based on Internet of Things," in 2011 IEEE International Conference on Automation and Logistics (ICAL), 2011, pp. 81-85.
[6] K. B. Biji, C. N. Ravishankar, C. O. Mohan, and T. K. S. Gopal, "Smart packaging systems for food applications: a review," J Food Sci Technol, vol. 52, pp. 6125–6135, 2015.
[7] Y. Galagan and W. F. Su, "Fadable ink for time–temperature control of food freshness: Novel new time–temperature indicator," Food Research International, vol. 41, pp. 653-657, 7// 2008.
[8] B. Kuswandi, Jayus, A. Restyana, A. Abdullah, L. Y. Heng, and M. Ahmad, "A novel colorimetric food package label for fish spoilage based on polyaniline film," Food Control, vol. 25, pp. 184-189, 5// 2012.
[9] B. Kuswandi, R. O. Jayus, A. Abdullah, and L. Y. Heng, "A Novel On-Package Sticker Sensor Based on Methyl Red for Real-Time Monitoring of Broiler Chicken Cut Freshness," Packag. Technol. Sci, vol. 27, pp. 69–81, 2014.
[10] L. Zheng, H. Zhang, W. Han, X. Zhou, J. He, Z. Zhang, et al., "Technologies, applications, and governance in the internet of things," Internet of things-Global technological and societal trends. From smart environments and spaces to green ICT, 2011.
[11] G. Witjaksono, N. H. F. B. M. Hussin, A. A. S. Rabih, and S. Alfa, "Real Time Chromametry Measurement for Food Quality Detection using Mobile Device," presented at the Nommensen International Conference on Technology and Engineering Nommensen HKBP University, Medan Indonesia, 2017.
[12] G. Witjaksono, I. Saputra, M. Latief, I. Jaswir, R. Akhmeliawati, and A. A. S. Rabih, "Non-Halal biomarkers identification based on Fourier Transform Infrared Spectroscopy (FTIR) and Gas Chromatography-Time of Flight Mass Spectroscopy (GC-TOF MS) techniques," presented at the The International Conference on Applied Photonics and Electronics, Avillion Port Dickson, Malaysia, 2017.
