IoT based smart irrigation, control, and monitoring system for chilli plants using NodeMCU-ESP8266

Amirul Amin Abd Halim[1], Roslina Mohamad[1], Farah Yasmin Abdul Rahman[1], Harlisya Harun[2], Nuzli Mohamad Anas[3]
[1]Wireless High Speed Network Research Group (WHiSNet), School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, Shah Alam, Malaysia
[2]Satellite Communication and Avionics System Integration (SCASI) Research Cluster, Universiti Kuala Lumpur Malaysia Institute of Aviation Technology, Subang Jaya, Malaysia
[3]IoT Sytems Lab, MIMOS Berhad, Kuala Lumpur, Malaysia

Article Info

Article history:

Received Nov 17, 2022
Revised Dec 31, 2022
Accepted Feb 3, 2023

Keywords:

Chilli plant
Cultivation system
Internet of things
Irrigation control
Monitoring system

ABSTRACT

Traditionally, chilli plant irrigation relies solely on rainwater, which leads to uncontrolled and excessive water consumption and, in turn, unhealthy growth. Furthermore, existing cultivation systems lack systematic control and monitoring to sustain efficient crop growth. Much effort has been put into developing plant irrigation control and monitoring systems in recent decades, resulting in significant technological advancements in the agricultural sector. This paper describes the development of an internet of things-based irrigation control and monitoring system testbed for a chilli plantation. A DHT11 sensor, comprising of moisture, temperature and humidity sensors, were integrated with a node microcontroller NodeMCU ESP8266 unit interacting via wireless fidelity. A controller system that could remotely control the irrigation system was placed in the plantation area. Users interacted with the system through a user interface platform developed using Blynk and Thinger.io. Hence, real-time sensor data were sent to the user interface platform and represented in an easy-to-interpret manner. The results show that the irrigation system testbed can also control the amount of water used, ensuring efficient plant growth.

Corresponding Author:

Roslina Mohamad
Wireless High Speed Network Research Group (WHiSNet), School of Electrical Engineering
College of Engineering, Universiti Teknologi MARA
40450 Shah Alam, Selangor, Malaysia
Email: roslina780@uitm.edu.my

1. INTRODUCTION

The most significant problem in some regions of Malaysia is a lack of water cultivation due to insufficient precipitation and an abundance of water waste due to improper water storage arrangements. Farmers plan their crop outputs mainly based on precipitation forecasts [1]. According to risk in Malaysian agriculture, severe climate change is a concern confronting Malaysia's agricultural industry [2]. Most of the water supplied to irrigation systems comes from, for example, natural rainfall and drain water, which is disrupted during the dry season, affecting crop output [3]. Most farmers water their plants manually, but this method is inefficient. Thus, automatic irrigation systems are used to resolve this issue [4]-[6], as they reduce the amount of labour needed to run the plantation and the time required to do so [7]. Dust control, trash management, and mining also use irrigation systems [8].

The internet of things (IoT) also plays a significant role in most industries. IoT is a network of connected computing devices, mechanical and digital machines, objects, animals, or people that can exchange data over a network without requiring human-to-human or human-to-computer interaction. The use of the IoT has increased due to its advantageous features. Improvements in the agricultural industry are significant, as this industry meets one of the primary needs of society and the economy of the country [9]-[11]. The IoT is expected to deliver promising solutions to alter the functions and positions of many current industrial structures, such as transportation schemes and development processes. The IoT is also currently used in Malaysia's agriculture industries, especially in irrigation systems.

Several methods are proposed to gather crop information or sensor data with better irrigation [12], [13]. IoT devices such as Arduino, node micro-controller units (NodeMCU) and sensors can also track farms in real-time and gather crop information remotely. The costs of these systems are manageable; the main challenge would be properly using massive amounts of sensors and other instruments. This technology is used to predict a field's irrigation requirements using ground parameter sensing such as soil moisture, soil temperature, and environmental conditions, along with weather forecast data.

Today, irrigation systems are an important part of ensuring high plant productivity in the agricultural industry. The irrigation systems currently used in Malaysia, especially for plantations, are divided into two categories [14]. The first category is manual irrigation systems by which farmers rely solely on rainwater to treat their crops. This technique is still used by many farmers because it is very cheap. However, it creates many problems because rainwater only falls during certain times and seasons. In addition, farmers cannot systematically control the water system, as it depends only on rainwater and reservoirs. Moreover, manual irrigation systems cannot provide accurate information on the condition of crops in terms of temperature, humidity and soil moisture.

The second category of irrigation systems is based on automated processes. Essentially, current automated irrigation systems in Malaysia fall into two categories: sprinkler irrigation and drip irrigation [15]. Drip irrigation is a water-saving method by which water is supplied by slowly dripping water into the soil or the roots of plants. Meanwhile, in sprinkler irrigation, the water is supplied by sprinkling water around the crop; this type of irrigation is the most commonly used system in Malaysia's agriculture industries [15].

However, both irrigation systems have problems, such as issues related to real-time monitoring, data collection and wasted water. Current sprinkler systems only supply water to the plant without collecting information such as humidity, temperature, and soil moisture from the plants. Furthermore, farmers who wish to manually collect such data would need to examine the soil conditions for each plant, which would require significant time and energy. In addition, water is wasted when there is no control display to notify the farmer when to start and stop an automated irrigation system. This paper describes the development of an irrigation control and monitoring system testbed based on IoT devices and specifically designed for a chilli plantation. The proposed work endeavours to develop a real-time and automated control and monitoring system using relevant crop growth parameters such as temperature, humidity and soil moisture that can be employed to view and interpret growth performance via a user-interface platform.

The testbed of the chilli plant irrigation control and monitoring system was deployed and experimented with at Kampung Paya Rawa, Kedah. Furthermore, the testbed was integrated with planting equipment, including water barrels, pipes and motors. The rest of this paper is organised as follows: section 2 presents the literature review, which investigates previous studies on irrigation and monitoring systems for plantations; the information has been tabulated in a simple form to describe various software packages, databases and other platforms used. Section 3 explains the development of the proposed irrigation and monitoring system and its operation. Section 4 describes the results of the project. All collected data was displayed, including the prototype plan, monitoring display and analysis data related to the objectives of this study. Finally, section 5 provides the conclusions.

2. LITERATURE REVIEW

Farm automation can change agricultural work from manual and static to smart and dynamic, resulting in higher production with less human supervision. Farmers have started using computers and software systems over the last decade to coordinate their financial data, track their transactions with third parties and control their crops more efficiently [16]. Agriculture is increasingly becoming a data-intensive industry in the era of the internet, in which information plays a key role in people's lives. Furthermore, in this age, farmers need to collect and analyse massive amounts of information from various devices like sensors and machinery to be more effective in generating and communicating relevant information [17]. With the advent of open-source Arduino boards and cheap moisture sensors, it is feasible to build equipment that can detect soil moisture and irrigate the fields or the landscape as required.

A remote greenhouse global system for mobile-short message services (GSM-SMS) measurement and control system based on a personal computer were developed by Vimal and Shivaprakasha [18]. The developed system applied a database system linked to the base station. A microcontroller, GSM module, sensors and actuators were used to construct the base station. The central station receives and sent messages through a GSM module during practical service. The criterion values of the parameters to be measured at each base station were determined by the parameters of the central station and then by the parameters of the base station, such as air, temperature and the humidity of the air.

Previous work has primarily focused on assessments in the field of remote monitoring while controlling the technology used and determining its potential benefits. A revolutionary remote-controlled embedded irrigation device based on GSM/Bluetooth was proposed in [19]. Depending on the temperature and humidity read by the sensors, the device determined the irrigation time of the crop and irrigated the field automatically when unattended. The information was shared via SMS on the GSM network between the far end and the planned device. A Bluetooth module, which removed SMS charges when the user was within a few meters of the specified device, was also attached to the main microcontroller chip. The device informed users via SMS on the GSM network or Bluetooth of several conditions, such as electricity status, dry running engine, increased temperature, soil water, and smoke content.

In a previous study, an automated rain gun irrigation system based on a microcontroller was used such that irrigation occurred only when there was a high demand for water, thereby saving a significant quantity of water [20]. Noerhayati *et al.* [21] argued about the design of plant watering equipment with automatic pumps for drip irrigation on dry land. This study aimed to activate automatic watering equipment on dry land, determine the effective and efficient manner and identify more specific performance in the use of electrical power.

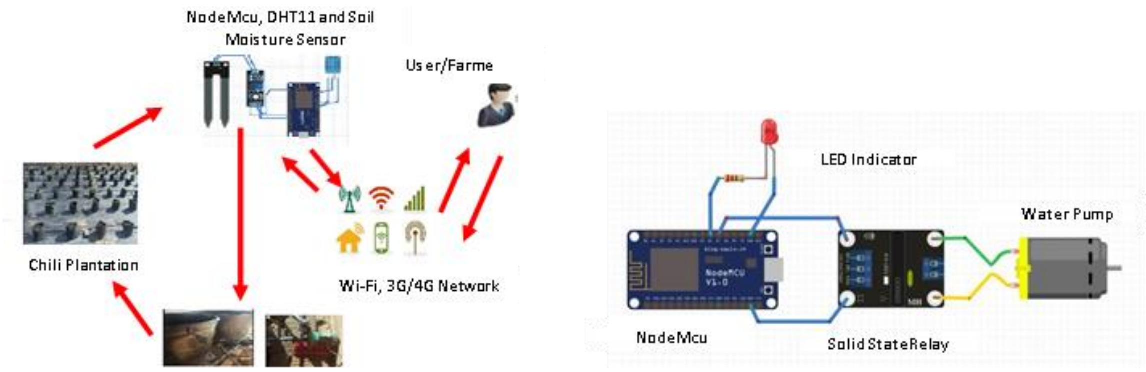
Moreover, Saputra [22] explained soil moisture monitoring through Telegram messages based on the results of watering the plants. The system performance started by detecting plant soil moisture, watering the plants and sending messages about the soil moisture conditions of the plant to the owner’s cellphone. Then, Ren *et al.* [23] described a gardening smart system for web-based orchid plant care. Their prototype was intended to help control plant care systems orchids at the individual level (personal users). Lastly, a horticultural plant growth control and monitoring system in smart gardens has been researched in [24]. This research aimed to create a system capable of controlling the temperature, monitoring the moisture content in the soil and fertilising plants regularly while also providing system reports provided via an easy-to-use interface (namely, smartphones). The synthesis matrix in Table 1 summarises previous studies.

Table 1. Research on irrigation systems based on the IoT

Authors	Research	Contributions	Hardware and Peripherals
Noerhayati *et al.*, 2020 [21]	Design of plant watering equipment with automatic pumps for a drip irrigation system on dry land	– Automated tool that can help overcome the shortage of water in the dry season on dry land. – Scientific knowledge in automation watering drip irrigation systems using pump solar energy as renewable energy.	– Ultrasonic sensor – Soil moisture sensor – MCU V3 node – Water flow sensor – MG996R servo – 10A 5 V power supply – Two-channel relay
Saputra, 2020 [22]	Soil moisture monitoring through the Telegram application based on the results of watering plants	– Measure soil moisture levels of plants. – Send messages about soil moisture conditions in the form of Telegram messages. – Watering plants.	– Arduino UNO – Soil moisture sensor – Water pump – Relay
Ren *et al*., 2020 [23]	Gardening smart system for web-based orchid plant care	– Soil moisture content (pH) can be controlled automatically. – Apart from the automatic mode, users can use the manual mode by turning it on and off pump via online irrigation system.	– STM32F103C8T6 single-chip microcomputer – Wireless fidelity (Wi-Fi) module – Relay – Water pump – Soil Moisture Sensor
Fauziah *et al*., 2022 [24]	Horticultural plant growth control and monitoring system in a smart garden	– Design of a smart garden system based on LoRa. – Design of a smart garden based on LoRa technology for automatic watering of kale plants.	– NodeMCU ESP32 – Lora gateway – Wi-Fi module – Soil moisture sensor – DHT sensor – Smartphone

3. SYSTEM DESIGN AND IMPLEMENTATION

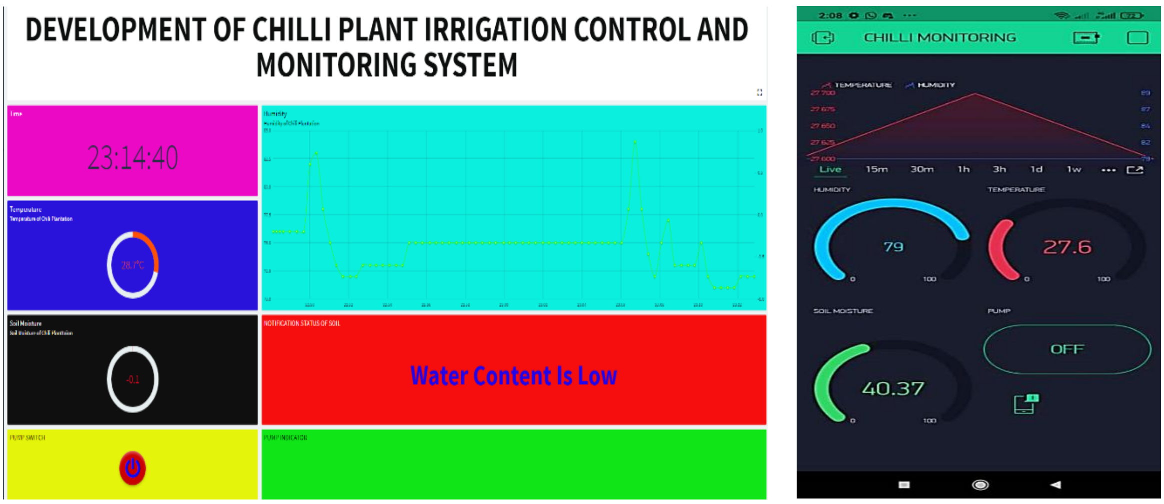
The architectural system design of the chilli plant irrigation control and monitoring system is shown in Figure 1(a). A NodeMCU ESP8266 was connected with a DHT11 humidity and temperature sensor and an FC-28 soil moisture sensor (referred to as a sensor box). ESP8266 [25], developed by espressif systems, is a low-cost open-source IoT platform that runs on an ESP12 RF module and other necessary components such as an antenna, universal serial bus (USB) connector and analogue and digital input/output pins. In this work, the chilli irrigation control and monitoring system was developed using Arduino IDE since it is easy to use. The system testbed was connected to the water pump (see Figure 1(b)) through a solid-state relay of FOTEK SSR-25 DA that applied a photocoupler as the switching motor. Thus, the plant irrigation system could be controlled via NodeMCU, which was connected wirelessly via Wi-Fi or a 4G network.



(a) (b)

Figure 1. IoT based smart irrigation for chilli plants, (a) chilli plantation irrigation control and monitoring system and (b) irrigation control connection diagram

A mobile application and a desktop application were developed using Blynk and Thinger.io (see Figures 2(a) and 2(b)), respectively. Thus, users could monitor the temperature, humidity, and soil moisture of the chilli plantation and then control its irrigation system accordingly. Gauges were used to show the relative humidity, soil moisture, and air temperature. The super chart was also used to plot humidity levels versus temperature readings. When the temperature rises, humidity falls, and vice versa. Switches in the form of on/off button gadgets were used to activate and deactivate the pump. In addition, a notification widget detailing the current soil moisture level was developed. Table 2 categorises the soil condition of the chilli plantation based on the humidity, temperature and soil condition readings.



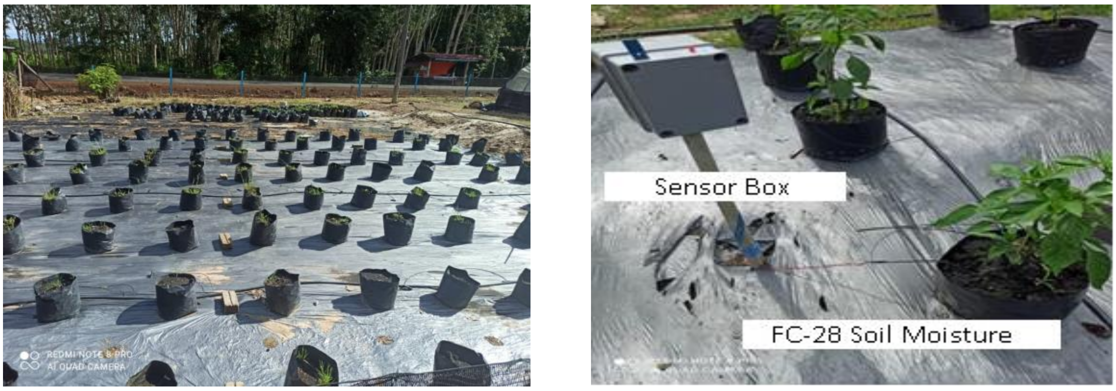
(a) (b)

Figure 2. Graphical user interfaces development based on, (a) Thinger.io and (b) Blynk

The chilli cultivation system comprising water pumps, 900-gallon water tanks, filters, valves, and poly tubes was set up on 0.5 hectares located in Kampung Paya Rawa, Kedah. However, the chilli plant monitoring and control system testbed was deployed in an area of 10×10 metres, as shown in Figure 3(a). Crop management was facilitated by spacing rows four feet apart and polybags two feet apart in rows. Each crop bag contained micro-tubes containing nutritional solutions. Figure 3(b) shows the location of the sensor box within the chilli plantation area.

Table 2. Categorisation of soil conditions of a chilli plantation

Category	Soil moisture reading	Soil moisture percentage (%)	Conditions/notification status
1	712.7-1023	0-30	Dry/water is needed
2	307-713	31-69	Humid/soil is humid
3	0-306.4	70-100	Good/soil is good

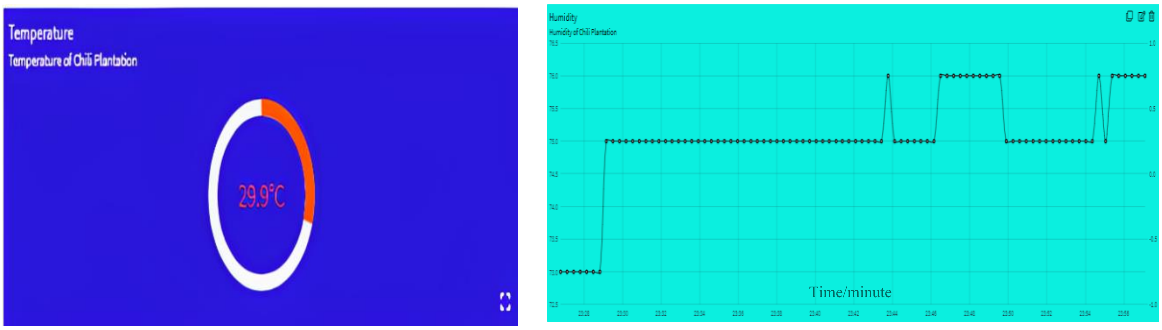


(a) (b)

Figure 3. Deployment of IoT based smart irrigation for chilli plants, (a) chilli plantation area and (b) sensor box and soil moisture sensor

4. RESULTS OF THE CONTROL AND MONITORING SYSTEM

A desktop application for the chilli plant irrigation control and monitoring system was developed using Thinger.io. The interface comprises temperature and humidity readings received from the sensors. The received data were represented in doughnut-shaped gauges with values ranging from 1-60 ℃ depicting instant temperatures (Figure 4(a)). Meanwhile, humidity readings were represented by a time series chart (Figure 4(b)).



(a) (b)

Figure 4. Graphical user interfaces using Thinger.io, (a) temperature reading and (b) humidity reading

Table 3 presents the hourly temperature and humidity readings transmitted by the DHT11 sensor over 12 hours. Temperature changes in the chilli crop influenced the humidity value of the crop area. When the temperature rose, the humidity decreased and vice versa. Variations in temperature in the chilli crop area affected changes in the crop region's relative humidity. When the temperature increased, the relative humidity dropped and vice versa. Meanwhile, Table 4 shows the percentage of soil moisture changed to derive its condition status based on the rules set in Table 2.

For instance, Figure 5 depicts the notification statuses that appeared in the mobile application developed using Thinger.io. In Figure 5(a), the moisture sensor value of 29.11 provided a notification when the water content was low, while in Figure 5(b), the notification indicated that the soil was humid. These indicators assisted users in monitoring their chilli plantation and controlling the irrigation system. In addition to the Thinger.io application, a mobile application was developed using Blynk, a platform used to manage device provisioning and sensor data visualisation.

Table 3. Average temperature and humidity readings

Time	Temperature (°C)	Humidity (°C)
8.00 am	26.7	83
9.00 am	27.2	78
10.00 am	29.4	73
11.00 am	30.1	70
12.00 pm	32.3	65
1.00 pm	35.4	51
2.00 pm	34.8	55
3.00 pm	31.2	74
4.00 pm	29.8	79
5.00 pm	27.5	80
6.00 pm	27.3	82
7.00 pm	26.7	83
8.00 pm	26.7	83

Table 4. Changes in moisture values

Sensor value of soil moisture	Sensor value of soil moisture in percentage (%)
1023	0
1020	0.30
1012.75	1
930.65	10.35
810.5	20.52
712.7	30
613.48	39.62
513.5	48.76
409.2	60
306.4	71.23
205.8	82.45
103.3	90
0	100

(a) (b)

Figure 5. The notification provided by the Thinger.io mobile application, (a) the moisture sensor current indication and (b) the humidity sensor indication

5. CONCLUSION

This paper described the construction and assessment of a system designed to regulate and monitor the watering of chilli plants. The chilli plantation in Kedah, Malaysia, served as a testbed for incorporating the system's sensors to track environmental variables such as temperature, humidity, and soil moisture. Additionally, plantation tools and equipment such as water pumps, water barrels, and motors were integrated into the system so that they could be used to manage the watering of the plants. The sensor data were collected and processed by a NodeMCU microcontroller, which also operated as the node's central processing unit. Mobile and desktop apps were built utilising Blynk and Thinger.io to facilitate irrigation system monitoring and analysis. Thus, an IoT based smart irrigation, control and monitoring system for chilli plants using NodeMCU-ESP8266 has been discussed to help farmers on their daily routine. In order to enhance existing setup, integrating additional sensors into the system box and incorporating power supply technologies such as a solar supply system enabled the sensor box to run continuously without requiring rechargeable batteries per future recommendations. Long-ranged network modules are worth considering when the goal is to cover a large area to replace the existing limited coverage of Wi-Fi setup.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of the Universiti Teknologi MARA (UiTM) for this study, which was funded by grant 600-RMC/MYRA 5/3/LESTARI (039/2020).

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BIOGRAPHIES OF AUTHORS

Amirul Amin Abd Halim obtained the Engineer degree in Electronic Engineering from Universiti Teknologi MARA, Shah Alam in 2021. From 2022 until now he is with manufacturing and services company at UST Global (M) Sdn. Bhd as Software Validation/Tester Engineer. He is involved in computer operating system, computing services, hardware setup, programming and testing. In 2021, his research interests include wireless monitoring technology, advanced agriculture technology, and healthy ecosystem. He can be contacted at email: amirul.amin9587@gmail.com.

Roslina Mohamad obtained a B. Eng. degree in Electrical Engineering and M. Eng. Science degree from Universiti Malaya, Kuala Lumpur, in 2003 and 2008. She later received a Ph.D in Aerospace Engineering (Deep Space and Wireless Communications Algorithms) from Universiti Putra Malaysia in 2016. Since 2006, she has worked at the School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, as a senior lecturer. She is the head of wireless high speed network (WHiSNet) research group. Her research interests include computing algorithms and digital signal processing for deep space communication, channel coding, information-theoretic security, computation theory, internet of things, and wireless communication. She can be contacted at email: roslina780@uitm.edu.my.

Farah Yasmin Abdul Rahman received B. Eng (Hons) in Electrical Engineering from Universiti Teknologi MARA, Malaysia in 2003. Next, she further her study in Universiti Kebangsaan Malaysia and been awarded with M. Eng, in Communication and Computer. She is a lecturer in Universiti Teknologi MARA, Shah Alam, Malaysia at Department of Computer Engineering, Electrical Engineering Study, College of Engineering. Her research interests are image processing, machine learning, database systems, and embedded systems. She can be contacted at email: farahy@uitm.edu.my.

Harlisya Harun is an Associate Professor in the Avionics Section at UniKL MIAT. She is also the head of Satellite Communication and Avionics System Integration (SCASI) research cluster. She earned her Ph.D at the University of Malaya in Mobile Satellite Communication. She had her M.Sc in Satellite Communication at Aberdeen University, United Kingdom and her bachelor degree in Sheffield Hallam University, United Kingdom. SCASI has been chosen by Malaysian Government through Ministry of Higher Education (MoHE) as one of the TVET Collaboration Hubs (TCH). TCH is one of the Malaysian government initiatives to realise TVET agenda in producing highly skilled human resources in line with the requirement of Industry 4.0. She is also actively involved with professional and learned bodies. She is the chair for Young Professional Group, Malaysian Society for Engineering and Technology (MySET). Her research interests are satellite communication, avionics, wireless communication systems, MIMO radar, and telecommunication. She can be contacted at email: harlisya@unikl.edu.my.

Nuzli Mohamad Anas graduated from Universiti Teknologi Malaysia with a B.Eng. in Electrical Engineering in 2000 and an M.Eng. in Electrical Engineering in 2013. Since 2008, he has worked as a senior researcher at the wireless communication lab at MIMOS Berhad. His research interests include wireless mobile communications and signal processing, especially as it relates to cognitive radio and physical-MAC layer communication design. He can be contacted at email: nuzli.anas@gmail.com.