**International Journal of Informatics and Communication Technology (IJ-ICT)**
Vol. 12, No. 1, April 2023, pp. 54~61
ISSN: 2252-8776, DOI: 10.11591/ijict.v12i1.pp54-61 

# Comparative performance study of HC-12, nRF24L01, and XBee for vehicular communication

**Sumendra Yogarayan[1], Siti Fatimah Abdul Razak[1], Mohd. Fikri Azli Abdullah[1], Afizan Azman[2], Vethanayagi Arultas[1], Suneetha Sri Raman[1]**
[1]Faculty of Information Science and Technology, Multimedia University, Melaka, Malaysia
[2]School of Computing Science, Faculty of Innovation and Technology, Taylors University, Subang Jaya, Malaysia

**Article Info**

***Article history:***

Received May 21, 2021
Revised Jun 10, 2022
Accepted Aug 30, 2022

***Keywords:***

Distance
HC-12
nRF24L01
Vehicle communication
XBee

**ABSTRACT**

In recent times, the volume of traffic congestion has been rapidly growing on roads. These days the necessity of having safe transportation and journey is essential. Thus, vehicle communication could be a possible solution to enhance safe transit. Vehicular communications provide a wide range of applications with different characteristics, namely vehicle and vehicle (V2V) communications. Every year, traffic accidents kill many people worldwide, and many people have been injured. V2V communication enables vehicles to communicate with each other to provide safety and convenience to drivers. Therefore, this paper explores a direction to develop a conceptual approach to V2V communication with HC-12, nRF24L01, and XBee. The study aims to analyze and evaluate the communication range that may contribute to the future road transportation system.



***Corresponding Author:***

Sumendra Yogarayan
Faculty of Information Science and Technology, Multimedia University
Jalan Ayer Keroh Lama, 75450 Melaka, Malaysia
Email: sumendra@mmu.edu.my

## 1. INTRODUCTION

Road crashes kill many people in the world each year, and many more people are injured. The primary reason for these accidents is a limitation due to situations on the road, which may be due to the brake failure, sudden standstill or distance blackness [1], [2]. Furthermore, a delay in the driver's response to events on the roadway could lead to unavoidable consequences [3], [4]. Road safety is often improved to ensure that drivers can see the circumstances coming along the road. Hence, this would be possible if the vehicles were communicating with each other. Vehicle and vehicle (V2V) communication is becoming a reality and will provide various services for safety and efficiency [5], [6]. In addition, V2V has demonstrated that it can be incorporated into current designed automotive applications. The exchange of information on vehicle mobility and the state of the road between vehicles plays a significant role in the safety of drivers and passengers. A driver can receive information about road conditions and vehicle speeds in the surrounding area in a particular context. This helps the vehicle make better decisions about vehicle control and route.

In another context, when vehicles communicate in real-time, the driver can avoid potential crashes by changing the speed based on the speed of the nearby vehicle [7]–[9]. Therefore, this paper explores the communications platform used between vehicles with HC-12, nRF24L01, and XBee. This paper is organised as follows: i) section 2 elaborates on the mechanism of the three modules and related works; ii) the experimental work and outcome are shown in section 3; and iii) in the last section, the conclusion was highlighted.

## 2. RELATED WORKS

The HC-12 is a state-of-the-art semi-duplex wireless mode that provides a frequency spectrum of 433.4 to 473.0 MHz. The module is integrated and would use 100 channels at 400 kHz measurement. The maximum module transmitting power is 100 MW, the receivable sensitivity is at a baud rate of 9,600 in the air with -112 dBm, and the communication distance is less than 1,000 meters through open space. The low data rate makes it possible to reach the most rapid communication ranges. There are three types of operation, such as FU1, FU2, and FU3, which can be customised to the various requirements. For energy-saving modes, FU1 and FU2 apply, while for maximum power mode, FU3 is suitable [10]–[14]. There are several studies of the HC-12 modules for various purposes, as shown in Table 1.

Table 1. HC-12 related studies

| Author | Purpose | Contribution |
|---|---|---|
| [15] | Intelligent lane clearance and collision avoidance system | Analyse on warning system to a vehicle when the vehicle crossed the permitted limits |
| [16] | Automatic vehicle overtaking system | Analyse the phase delay of a propagating wave between two receiver antennas |
| [17] | Safety and security of coal mine workers | Analyse different parameters and take actions to mitigate all hazards |
| [18] | Collision detection robot car model | Analyse collision avoidance and maintain a safe distance between cars |
| [19] | Vehicle platooning prototype car model | Analyse predictive controller and navigation algorithms in longitudinal and path control |
| [20] | Vehicle to vehicle communication | Analyse to attenuate vehicle noise to some degree and reduce vehicle horn |
| [21] | Traffic signal control system | Analyse an efficient route with a traffic light for emergency vehicles |
| [22] | Vehicle speed proposition system | Analyse to reduce accidents and warn drivers of the speed limit at high accident zones |
| [23] | Collision prevention and warning system | Analyse to reduce collision and damage in circumstances of accidents |
| [24] | Motorcyclist intelligent helmet | Analyse to decrease violation by riders of traffic rules and cause accidents |
| [25] | Smart motorcyclists protection system | Analyse to reduce road accidents by riders under the influence of alcohol |
| [26] | Toll gate system | Analyse to apply contactless transaction overcoming the queue. |
| [27] | Electric vehicle telemetry data system | Analyse to monitor and acquire onboard telemetry data of the electric vehicle. |
| [28] | Street light energy-saving tool | Analyse to minimise energy consumption and reduce maintenance of street lights |
| [29] | Accident location and traffic management system | Analyse to convey a message to the rescue team in the circumstance of road accidents |

Generally, nRF24L01is a transmitter-receiver module that transmits and receives data on a specific channel frequency. In addition, they should be on the same channel for two or more transmitter-receiver modules to communicate. This channel can vary from 2.4 to 2.525 GHz within the 2.4 GHz (2,400-2,525 MHz) industrial, scientific and medical (ISM) band. Each channel has a bandwidth of less than 1 MHz and 125 available channels. For instance, the nRF24L01 module also can use 125 different channels and has a network of 125 independent modules in a location [30]–[34]. Several studies of the nRF24L01 modules are used for various purposes, as shown in Table 2.

Table 2. nRF24L01 related studies

| Author | Purpose | Contribution |
|---|---|---|
| [35] | Temperature measuring system | Analyse transmitting temperature information in the event of exceeded set value |
| [36] | Multipurpose radio-controlled car | Analyse a transmitter unit in terms of reception accuracy and transmission exactness |
| [37] | Vehicle to V2V to infrastructure communication system | Analyse to alert of potential hazards or violate action made by drivers |
| [38] | Temperature and humidity sensing | Analyse to evaluate the power efficiency and reliability of communication |
| [39] | Multipurpose wireless sensing | Analyse different approach contexts for possible long operation |
| [40] | Wireless control car movement | Analyse to improve the efficiency of transportation through wireless communication |
| [41] | Data collection box tool | Analyse temperature values at different environments and alarm abnormal temperatures |
| [42] | Quaternion based wireless data transfer | Analyse real-time transmission and acquisition of sensor data |
| [43] | Automatic gate control system | Analyse to avoid the head-on and collision that occur by human negligence |
| [44] | Automatic street light control system | Analyse to reduce the energy consumption of transmitting information to a base station |
| [45] | Inter vehicle collision avoidance system | Analyse prototype cars to avoid a collision at road accidents areas |
| [46] | Inter vehicle alert system | Analyse vehicle communication for reducing accidents due to drivers negligence |
| [47] | An autonomous vehicle surveillance system | Analyse transmitting data at different road conditions and speeds |
| [48] | Motorcyclist smart helmet and blind-spot detection | Analyse on warning motorcyclists of potential hazards that can decrease the probability of road accidents |
| [49] | Motorcyclist smart helmet accident detection | Analyse sending messages to immediate family members if accidents have occurred. |

XBee modules are wireless communication modules that are constructed following the Zigbee standard. XBee is an RF module transceiver that uses the IEEE 802.15.4 protocol. The XBee is a modular product design that makes rolling out wireless technology simple and cost-effective. It can be used as a serial replacement or placed in a control mode and configured for various broadcast and mesh network options. The module provides connectivity solutions to wireless endpoints of built-in devices. Xbee has a 2 dBm beam with a sensitivity minimum of -96 dBm. The XBee and XBee-pro radio frequency (RF) modules are built-in solutions providing wireless connectivity solutions. The 3-pin RF modules can be connected directly to the controller, which does not need an encoder or decoder [50]–[54]. Several studies have used XBee for various purposes, as shown in Table 3.

Table 3. XBee related studies

| Author | Purpose | Contribution |
|---|---|---|
| [55] | Wireless sensor network for environmental monitoring | Analyse the transmission of data in real-time deployment |
| [56] | Wireless sensor network for aquaculture monitoring | Analyse temperature and manage automatic turn on a fan for shrimp pool |
| [57] | Early detection system for fire disaster | Analyse on transmitting data in real-time to a specific place |
| [58] | Patients heart monitoring system | Analyse monitoring patient health data in real-time |
| [59] | Real-time vehicle communication tool | Analyse the communication range of vehicles to transmit data |
| [60] | Wireless sensor network for environmental monitoring | Analyse on monitoring real-time data and display through multiple platforms |
| [61] | Wireless environmental control for smart mushroom house | Analyse the dampness of the air and the level of $CO^2$ inside the area |
| [62] | Wireless control robot for multiple sensors | Analyse the measurement and display on a human interaction machine |
| [63] | Cost-effective vehicle tracking system | Analyse tracking vehicles in various environments regardless of obstacles. |
| [64] | Wireless sensor network for environmental monitoring | Analyse transmitting data in real-time and observe the power consumption |
| [65] | Smart parking infrastructure system | Analyse on detecting the presence of a vehicle and transmit data to the gateway |
| [66] | Driver assistance system | Analyse on automation process of the driving system to avoid drivers' negligence |
| [67] | Automatic traffic control for an ambulance | Analyse on determining the traffic congestion and provide smooth route direction |
| [68] | Intelligent traffic light system for ambulance clearance | Analyse ambulance vehicle movement that can control traffic light flow |
| [69] | Traffic management system for emergency vehicle | Analyse controlling traffic lights for smooth flow of emergency vehicles |

## 3. EXPERIMENT AND DISCUSSION

As illustrated in the following subsection, several hardware components were required to interface with the modules in this experiment.

### 3.1. Hardware

The prototype is designed using Arduino Uno integrated separately with three modules such as HC-12, nRF24L01 and XBee. The ultrasonic sensor works along with the modules to detect the range of vehicles for a potential collision. Any alert is indicated in the form of an audible buzzer and visible light emitting diode (LED). The equipment component specifications are presented in Table 4.

Table 4. Equipment/components specifications

| Components | Units |
|---|---|
| Arduino Uno | 9 |
| HC-12 | 3 |
| nRF24L01 | 3 |
| XBee | 3 |
| Ultrasonic sensor HC-SR04 | 9 |
| Buzzer | 9 |
| LED | 9 |

### 3.2. Settings and implementation

The performance analysis of three modules is restricted to a controlled environment, as shown in Figure 1. In accordance with the information presented in the preceding section, each testing setting has been established appropriately with the modules. The initial configurations would use HC-12, then nRF24L01, and finally XBee. Figure 2 shows the initial prototype designed to be tested in the given controlled environment settings.

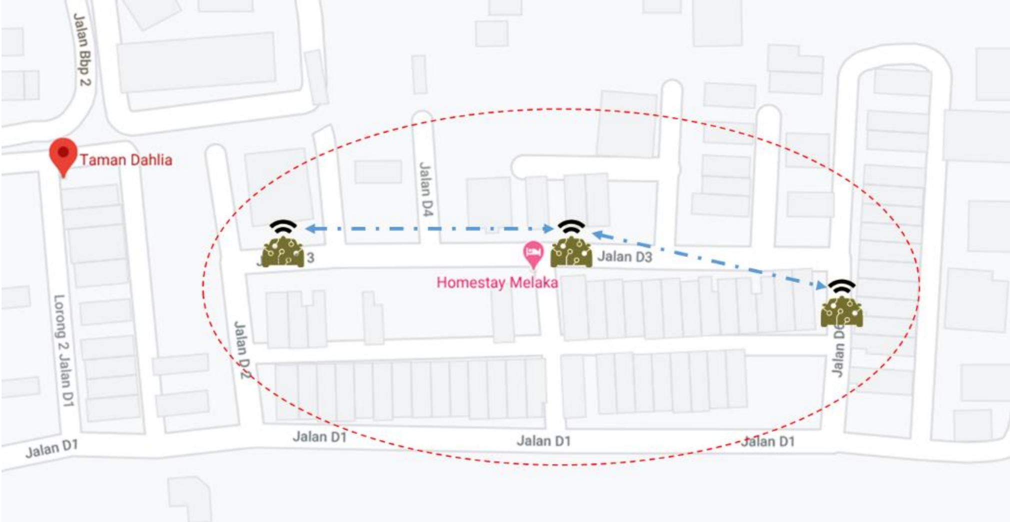


Figure 1. Environment settings

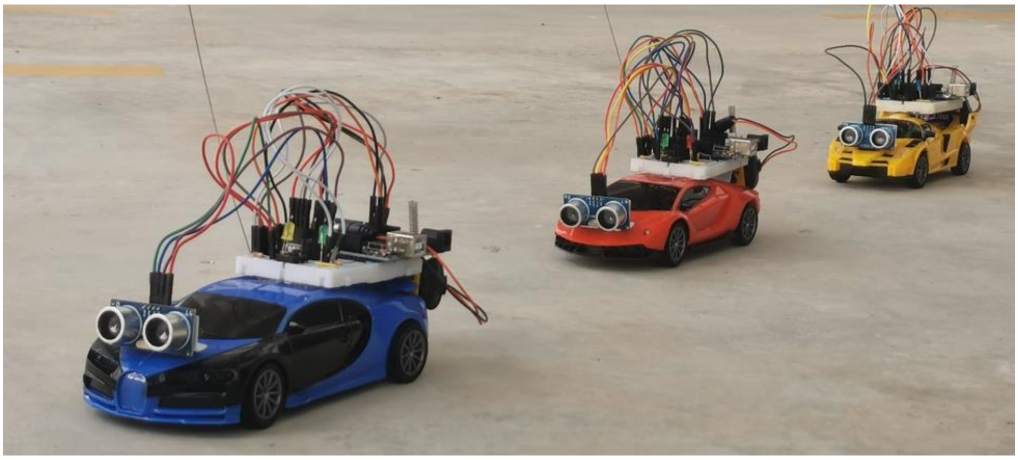

Figure 2. Initial prototype

### 3.3. Discussion

The testing for the HC-12, nRF24L01, and XBee module (three device sets) has been analysed in a controlled environment at Taman Dahlia, Bukit Beruang, Melaka. This testing phase is performed to observe the performance in terms of distance/range for potential collision use cases. The testing is directed with having the three separate HC-12, nRF24L01 and XBee modules with various distances connected to a 9 V battery placed in the range/distance discussed. These findings are presented in Tables 5-7.

Table 5. HC-12 range/distance

| Range/distance (m) | HC-12 | |
|---|---|---|
| | Object | No-object |
| 5 | ✓ | ✓ |
| 10 | ✓ | ✓ |
| 20 | ✓ | ✓ |
| 40 | ✓ | ✓ |
| 60 | ✓ | ✓ |
| 80 | ✓ | ✓ |
| 100 | ✓ | ✓ |
| 120 | × | ✓ |

✓Detected, ×Not detected

Table 6. nRF24L01 range/distance

| Range/distance (m) | nRF24L01 | |
|---|---|---|
| | Object | No-object |
| 5 | ✓ | ✓ |
| 10 | ✓ | ✓ |
| 20 | ✓ | ✓ |
| 40 | ✓ | ✓ |
| 60 | × | ✓ |
| 80 | × | ✓ |
| 100 | × | ✓ |
| 120 | × | × |

✓Detected, ×Not detected

Table 7. XBee range/distance

| Range/distance (m) | XBee | |
|---|---|---|
| | Object | No-object |
| 5 | ✓ | ✓ |
| 10 | ✓ | ✓ |
| 20 | ✓ | ✓ |
| 40 | ✓ | ✓ |
| 60 | ✓ | ✓ |
| 80 | ✓ | ✓ |
| 100 | ✓ | ✓ |
| 120 | ✓ | ✓ |

✓Detected, ×Not detected

## 4. CONCLUSION

Vehicular communication is a promising field for the road transportation system. However, the primary concern is addressing the communication medium between vehicles. In this paper, the project aims to provide a conceptual communication medium between multiple nodes. Thus, several modules, namely HC-12, nRF24L01, and Xbee, were used to analyse. The results acquired by observation, HC-12 and XBee work on wider distances than nRF24L01. In the future, the research will be compared with ESP8266 and LoRa and evaluate performance metrics, namely throughput, delay, jitter, and packet loss.

## ACKNOWLEDGEMENTS

The authors gratefully acknowledge the use of service and facilities of the Connected Car Services Research Group, Centre of Intelligent Cloud Computing at Multimedia University. The authors would like to thank each individual who contributed directly or indirectly to this research. We thank the anonymous reviewers for their constructive comments.

## REFERENCES

[1] C.-Y. Ting, N. Y.-Z. Tan, H. H. Hashim, C. C. Ho, and A. Shabadin, "Malaysian road accident severity: Variables and predictive models," in *Computational science and technology*, vol. 603, Singapura: Springer, 2020, pp. 699–708, doi: 10.1007/978-981-15-0058-9_67.

[2] L. Wundersitz, "Driver distraction and inattention in fatal and injury crashes: Findings from in-depth road crash data," *Traffic Injury Prevention*, vol. 20, no. 7, pp. 696–701, Oct. 2019, doi: 10.1080/15389588.2019.1644627.

[3] K. Mahajan and N. R. Velaga, "Effects of partial sleep deprivation on braking response of drivers in hazard scenarios," *Accident Analysis & Prevention*, vol. 142, pp. 1–14, Jul. 2020, doi: 10.1016/j.aap.2020.105545.

[4] O. Oviedo-Trespalacios, V. Truelove, B. Watson, and J. A. Hinton, "The impact of road advertising signs on driver behaviour and implications for road safety: A critical systematic review," *Transportation Research Part A: Policy and Practice*, vol. 122, pp. 85–98, Apr. 2019, doi: 10.1016/j.tra.2019.01.012.

[5] S. Zhang, J. Chen, F. Lyu, N. Cheng, W. Shi, and X. Shen, "Vehicular communication networks in the automated driving," *IEEE Communications Magazine*, vol. 56, no. 9, pp. 26–32, Sep. 2018, doi: 10.1109/MCOM.2018.1701171.

[6] S. Zeadally, J. Guerrero, and J. Contreras, "A tutorial survey on vehicle-to-vehicle communications," *Telecommunication Systems*, vol. 73, no. 3, pp. 469–489, Mar. 2020, doi: 10.1007/s11235-019-00639-8.

[7] B. Ji *et al.*, "Survey on the internet of vehicles: Network architectures and applications," *IEEE Communications Standards Magazine*, vol. 4, no. 1, pp. 34–41, Mar. 2020, doi: 10.1109/MCOMSTD.001.1900053.

[8] F. Duarte and C. Ratti, "The impact of autonomous vehicles on cities: A review," *Journal of Urban Technology*, vol. 25, no. 4, pp. 3–18, Oct. 2018, doi: 10.1080/10630732.2018.1493883.

[9] J. Contreras-Castillo, S. Zeadally, and J. A. Guerrero-Ibanez, "Internet of vehicles: Architecture, protocols, and security," *IEEE Internet of Things Journal*, vol. 5, no. 5, pp. 3701–3709, Oct. 2018, doi: 10.1109/JIOT.2017.2690902.

[10] H. J. Hassaballah and R. A. Fayadh, "Implementation of wireless sensor network for medical applications," *IOP Conference Series: Materials Science and Engineering*, vol. 745, no. 1, pp. 1–10, Feb. 2020, doi: 10.1088/1757-899X/745/1/012089.

[11] V. T. Jamdar, S. B. Deosarkar, and S. V. Khobragade, "An effective arduino based communication module for railway transportation system," in *2018 Second International Conference on Intelligent Computing and Control Systems (ICICCS)*, Jun. 2018, pp. 749–752, doi: 10.1109/ICCONS.2018.8662959.

[12] M. Saqib, T. A. Almohamad, and R. M. Mehmood, "A low-cost information monitoring system for smart farming applications," *Sensors*, vol. 20, no. 8, p. 2367, Apr. 2020, doi: 10.3390/s20082367.

[13] N. L. Marpaung, R. Amri, and E. Ervianto, "Analysis of wireless fire detector application to detect peat land fire based on temperature characteristic," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 846, no. 1, p. 012051, May 2020, doi: 10.1088/1757-899X/846/1/012051.

[14] D. P. Jose, A. L. Dsouza, A. A. Thomas, and D. Daniel, "IoT based water management using HC-12 and django," in *2019 International Conference on Data Science and Communication (IconDSC)*, Bangalore, India, Mar. 2019, pp. 1–6, doi: 10.1109/IconDSC.2019.8816917.

[15] C. H. J. Kishore, M. S. A. I. Tirumalesh, and M. Dedeepya, "Emergency vehicle detection system using rf module and ultrasonic sensor," *International Research Journal of Engineering and Technology(IRJET)*, vol. 4, no. 2, p. 1098, 2017.

[16] M. Vikram, "Problem identification in automatic vehicle overtaking system for accident avoidance," *International Journal for Research & Development in Technology*, vol. 5, no. 5, pp. 124–127, 2016.

[17] K. V. Krishnan, S. Khara, A. Bagubali, V. Chawla, and K. Ashok, "Spectrum management using cognitive radio for safety and security of coal mine workers," *Indian Journal of Science and Technology*, vol. 9, no. 44, pp. 1–5, Nov. 2016, doi: 10.17485/ijst/2016/v9i44/105292.

[18] M. Divya, R. Ramaprabha, and S. Devi, "Detection and rescue of object using PIC microcontroller," *International Journal of Advanced Research in Biology Engineering Science and Technology (IJARBEST)*, vol. 2, no. 15, pp. 257–263, 2016.

[19] F. C. Braescu and C. F. Caruntu, "Prototype model car design for vehicle platooning," in *2017 International Conference on Optimization of Electrical and Electronic Equipment (OPTIM) & 2017 Intl Aegean Conference on Electrical Machines and Power Electronics (ACEMP)*, May 2017, pp. 953–958, doi: 10.1109/OPTIM.2017.7975093.

[20] E. Hossain, N. Mamun, and M. F. Faisal, "Vehicle to vehicle communication using RF and IR technology," in *2017 2nd International Conference on Electrical & Electronic Engineering (ICEEE)*, Dec. 2017, pp. 1–5, doi: 10.1109/CEEE.2017.8412890.

[21] A. Surendran, J. Jayan, and M. Ninshad, "Traffic signal control system with ambulance assistance," *IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)*, vol. 12, no. 4, pp. 71–79, 2017.

[22] M. M. Islam and M. H. Chowdhury, "Bangladesh perspective: Vehicle speed proposition system using localised wireless identification," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 6, no. 5, pp. 2134–2139, Oct. 2016, doi: 10.11591/ijece.v6i5.10973.

[23] A. Singh, U. Mishra, P. Gupta, and A. K. Singh, "Collision prevention and warning system for vehicles," *International Journal Of Engineering Research & Management Technology*, vol. 2, no. 2, pp. 229–233, 2015.

[24] R. K. Kanna, T. M. Prasath, N. Subhalakshmi, and R. Vasuki, "Intelligent helmet for bikers using sensors," *Drug Invention Today*, vol. 11, no. 7, pp. 1696–1699, 2019.

[25] S. Ranjan, M. Gupta, R. Roshan, K. Revanth, M. Bharat, and B. Pruthviraj, "Advanced accident prevention helmet with smart vehicle protection system," *International Journal of Advance Research, Ideas and Innovations in Technology*, vol. 4, no. 2, pp. 2604–2609, 2018.

[26] W. A. Syafei, R. Afiq, Wahyudi, and A. Hidayatno, "Development of controller for internet of things based anti pollution smart toll gate system," in *2020 7th International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE)*, Semarang, Indonesia, Sep. 2020, pp. 282–286, doi: 10.1109/ICITACEE50144.2020.9239163.

[27] K. Sundralingam, S. A. A. Bakar, M. F. M. Said, and M. Muralitharan, "Development onboard and wireless data telemetry systems for electric vehicle," *IOP Conference Series: Materials Science and Engineering*, vol. 884, no. 1, pp. 1–5, Jul. 2020, doi: 10.1088/1757-899X/884/1/012090.

[28] S. Rakshit, S. Kar, T. K. Banerjee, and S. Das, "Piezoelectric transducer and arduino based wirelessly controlled energy-saving scheme for street lights," in *Advances in Computer, Communication and Control*, vol. 41, 2019, pp. 297–304, doi: 10.1007/978-981-13-3122-0_28.

[29] A. J. Mankar and P. P. Tasgoankar, "IoT based accident location system & traffic management (ALSTM)," in *2018 4th International Conference for Convergence in Technology (I2CT)*, Oct. 2018, pp. 1–4, doi: 10.1109/I2CT42659.2018.9057858.

[30] V. Kulasekara, S. Balasooriya, J. Chandran, and I. Kavalchuk, "Novel low-power NRF24L01 based wireless network design for autonomous robots," in *2019 25th Asia-Pacific Conference on Communications (APCC)*, Nov. 2019, pp. 342–346, doi: 10.1109/APCC47188.2019.9026452.

[31] A. B. Bakri, R. Adnan, and F. A. Ruslan, "Wireless hand gesture controlled robotic arm via NRF24L01 transceiver," in *2019 IEEE 9th Symposium on Computer Applications & Industrial Electronics (ISCAIE)*, Apr. 2019, pp. 16–22, doi: 10.1109/ISCAIE.2019.8743772.

[32] J. Wang, M. Wang, K. Zheng, and X. Huang, "Model checking nRF24L01-based internet of things systems," in *2018 9th International Conference on Information Technology in Medicine and Education (ITME)*, Oct. 2018, pp. 867–871, doi: 10.1109/ITME.2018.00194.

[33] M. Z. U. Rahman, E. J. S. S. T. Varma, C. S. Avinash, and G. P. Kumar, "IoT and wireless sensor network based surveillance robot for health care applications," *European Journal of Molecular and Clinical Medicine*, vol. 7, no. 4, pp. 1027–1039, 2020.

[34] X. R. Jiang, Y. M. Lv, and X. H. Cheng, "Design of wireless communication system based on nRF24L01," *Advanced Materials Research*, vol. 945, pp. 1756–1759, Jun. 2014, doi: 10.4028/www.scientific.net/AMR.945-949.1756.

[35] S. Liu, Z. Yuan, and Y. Chen, "Design of wireless temperature measuring system based on the nRF24L01," *International Journal of Advanced Computer Science and Applications*, vol. 7, no. 2, pp. 314–317, 2016, doi: 10.14569/IJACSA.2016.070244.

[36] M. Mahbub, "Design and implementation of multipurpose radio controller unit using nRF24L01 wireless transceiver module and arduino as MCU," *International Journal of Digital Information and Wireless Communications*, vol. 9, no. 2, pp. 61–72, 2019, doi: 10.17781/P002598.

[37] N. Pothirasan and M. P. Rajasekaran, "Automatic vehicle to vehicle communication and vehicle to infrastructure communication using NRF24L01 module," in *2016 International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT)*, Dec. 2016, pp. 400–405, doi: 10.1109/ICCICCT.2016.7987982.

[38] B. Babusiak, M. Smondrk, and S. Borik, "Design of ultra-low-energy temperature and humidity sensor based on nRF24 wireless technology," in *2019 42nd International Conference on Telecommunications and Signal Processing (TSP)*, Jul. 2019, pp. 397–401, doi: 10.1109/TSP.2019.8768890.

[39] A. D. Nisio, T. D. Noia, C. G. C. Carducci, and M. Spadavecchia, "Design of a low cost multipurpose wireless sensor network," in *2015 IEEE International Workshop on Measurements & Networking (M&N)*, Oct. 2015, pp. 1–6, doi: 10.1109/IWMN.2015.7322986.

[40] W. Siyang and Q. Yingjie, "Research and design of vehicle control system based on CAN bus," *Agro Food Industry Hi-Tech*, vol. 28, no. 1, pp. 1024–1028, 2017.

[41] H. Xingna, M. Jun, C. Shouhong, and T. Daiyu, "Design of data collection box based on NRF24L01," *MATEC Web of Conferences*, vol. 173, pp. 1–4, Jun. 2018, doi: 10.1051/matecconf/201817301006.

[42] S. ThoiThoi, K. C. Kodur, and W. Arif, "Quaternion based wireless AHRS data transfer using nRF24L01 and HC-05," in *2016 International Conference on Microelectronics, Computing and Communications (MicroCom)*, Jan. 2016, pp. 1–6, doi: 10.1109/MicroCom.2016.7522534.

[43] A. Khan, G. Lakshmi, and C. J. A. Kumar, "Railroad switch and anti-collision system with automatic gate control using arduino," *International Journal of Engineering Research & Technology (IJERT)*, vol. 7, no. 10, pp. 1–5, 2019.

[44] D. Sunehra and S. Rajasri, "Automatic street light control system using wireless sensor networks," in *2017 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI)*, Sep. 2017, pp. 2915–2919, doi: 10.1109/ICPCSI.2017.8392257.

[45] N. H. Noordin, A. C. Y. Hui, N. Hassan, and R. Samad, "Inter vehicle communication system for collision avoidance," in *Lecture Notes in Electrical Engineering*, 2019, pp. 475–483, doi: 10.1007/978-981-13-3708-6_41.

[46] R. P. Adithya, "Vehicular communication establishment using nrf with emergency alert system," *International Journal for Research in Applied Science and Engineering Technology*, vol. 8, no. 11, pp. 455–460, Nov. 2020, doi: 10.22214/ijraset.2020.32191.

[47] A. Shufian, M. J. I. Rashed, M. A. Miah, M. Hasibuzzaman, and A. Sarker, "Design of a solar assisted autonomous surveillance vehicle," in *2020 IEEE Region 10 Symposium (TENSYMP)*, 2020, pp. 499–503, doi: 10.1109/TENSYMP50017.2020.9230960.

[48] H. Y. Lam, S. S. Yi, U. N. B. M. Hussin, M. B. Ishak, and F. Mustafa, "Development of prototype smart helmet and blind spot detection for motorcyclist safety features," *Advances in Computing and Intelligent System*, vol. 2, no. 2, pp. 1–6, 2020.

[49] M. E. Alim, S. Ahmad, M. N. Dorabati, and I. Hassoun, "Design & implementation of iot based smart helmet for road accident detection," in *2020 11th IEEE Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON)*, Nov. 2020, pp. 0576–0581, doi: 10.1109/IEMCON51383.2020.9284820.

[50] P. D. P. Adi and A. Kitagawa, "Qualityof service and power consumption optimisation on the IEEE 802.15.4 pulse sensor node based on internet of things," *International Journal of Advanced Computer Science and Applications*, vol. 10, no. 5, pp. 144–154, 2019, doi: 10.14569/IJACSA.2019.0100518.

[51] A. Acakpovi, "Transformer wireless monitoring system using Arduino/XBEE," *American Journal of Electrical Power and Energy Systems*, vol. 8, no. 1, pp. 1–10, 2019, doi: 10.11648/j.epes.20190801.11.

[52] A. Y. Ardiansyah and R. Sarno, "Performance analysis of wireless sensor network with load balancing for data transmission using

xbee zb module," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 18, no. 1, pp. 88–100, Apr. 2020, doi: 10.11591/ijeecs.v18.i1.pp88-100.
[53] Z. Li and T. He, "Longbee: Enabling long-range cross-technology communication," in *IEEE INFOCOM 2018 - IEEE Conference on Computer Communications*, Apr. 2018, pp. 162–170, doi: 10.1109/INFOCOM.2018.8485938.
[54] N. Marriwala, O. P. Sahu, and A. Vohra, "Real-time analysis of low-cost software-defined radio transceiver using ZigBee protocol," in *International Conference on Intelligent Computing and Smart Communication 2019*, 2020, pp. 1151–1169, doi: 10.1007/978-981-15-0633-8_115.
[55] F. Wu, C. W. Tan, M. Sarvi, C. Rudiger, and M. R. Yuce, "Design and implementation of a low-power wireless sensor network platform based on XBee," in *2017 IEEE 85th Vehicular Technology Conference (VTC Spring)*, Jun. 2017, pp. 1–5, doi: 10.1109/VTCSpring.2017.8108667.
[56] K. N. Tuan, "A wireless sensor network for aquaculture using raspberry pi, arduino and xbee," in *2019 International Conference on System Science and Engineering (ICSSE)*, Jul. 2019, pp. 235–238, doi: 10.1109/ICSSE.2019.8823104.
[57] S. Sharma, K. Chand, D. Sharma, and P. Guha, "Development of an early detection system for fire using wireless sensor networks and Arduino," in *2018 International Conference on Sustainable Energy, Electronics, and Computing Systems (SEEMS)*, Oct. 2018, pp. 1–5, doi: 10.1109/SEEMS.2018.8687333.
[58] T. S. Sollu, A. Alamsyah, M. Bachtiar, and A. G. Sooai, "Patients' heart monitoring system based on wireless sensor network," *IOP Conference Series: Materials Science and Engineering*, vol. 336, no. 1, pp. 1–10, Apr. 2018, doi: 10.1088/1757-899X/336/1/012009.
[59] K. Guravaiah, R. G. Thivyavignesh, and R. L. Velusamy, "Vehicle monitoring using internet of things," in *Proceedings of the 1st International Conference on Internet of Things and Machine Learning*, Oct. 2017, pp. 1–7, doi: 10.1145/3109761.3109785.
[60] R. P. Hudhajanto, N. Fahmi, E. Prayitno, and R. Rosmida, "Real-time monitoring for environmental through wireless sensor network technology," in *2018 International Conference on Applied Engineering (ICAE)*, Oct. 2018, pp. 1–5, doi: 10.1109/INCAE.2018.8579377.
[61] I. Mat, M. R. M. Kassim, A. N. Harun, and I. M. Yusoff, "Environment control for smart mushroom house," in *2017 IEEE Conference on Open Systems (ICOS)*, Nov. 2017, pp. 38–42, doi: 10.1109/ICOS.2017.8280271.
[62] M. U. Shahzad, A. Q. Khan, S. M. R. Bukhari, A. Aslam, and M. O. Zaib, "Wireless control robot using Xbee module with multiple sensor acknowledgment on HMI," in *2017 International Symposium on Recent Advances in Electrical Engineering (RAEE)*, Oct. 2017, pp. 1–4, doi: 10.1109/RAEE.2017.8246034.
[63] I. K. Ibraheem and S. W. Hadi, "Design and implementation of a low-cost secure vehicle tracking system," in *2018 International Conference on Engineering Technology and their Applications (IICETA)*, May 2018, pp. 146–150, doi: 10.1109/IICETA.2018.8458096.
[64] A. D. Deshmukh and U. B. Shinde, "A low cost environment monitoring system using raspberry Pi and arduino with Zigbee," in *2016 International Conference on Inventive Computation Technologies (ICICT)*, Aug. 2016, pp. 1–6, doi: 10.1109/INVENTIVE.2016.7830096.
[65] E. Munguia, "Smart parking infrastructure (SPI)." *Comprehensive Design Report*, pp. 1–7, 2020.
[66] T. Biswas, "IoT based driver assistant system," *International Journal for Research in Applied Science and Engineering Technology*, vol. 8, no. 10, pp. 10–16, Oct. 2020, doi: 10.22214/ijraset.2020.31788.
[67] P. Devi and S. Anila, "Intelligent ambulance with automatic traffic control," in *2020 International Conference on Computing and Information Technology (ICCIT-1441)*, Sep. 2020, pp. 1–4, doi: 10.1109/ICCIT-144147971.2020.9213796.
[68] R. Nono, R. Alsudais, R. Alshmrani, S. Alamoudi, and A. O. Aljahdali, "Intelligent traffic light for ambulance clearance," *ADCAIJ: Advances in Distributed Computing and Artificial Intelligence Journal*, vol. 9, no. 3, pp. 89–104, Nov. 2020, doi: 10.14201/ADCAIJ20209389104.
[69] A. Joshi, N. Jain, and A. Pandey, "IoT-based traffic management system including emergency vehicle priority," in *International Conference on Intelligent Computing and Smart Communication 2019*, 2020, pp. 1501–1507, doi: 10.1007/978-981-15-0633-8_147.

## BIOGRAPHIES OF AUTHORS

**Sumendra Yogarayan** is currently a Lecturer in the Faculty of Information Science and Technology, Multimedia University (MMU), Melaka, Malaysia. He is an active member of the Centre for Intelligent Cloud Computing (CICC), Multimedia University (MMU). He graduated from Multimedia University (MMU) with a Master of Science (Information Technology) in 2019 and a Bachelor of Information Technology (Security Technology) in 2015. He is currently pursuing his Doctor of Philosophy (PhD) in Information Technology at Multimedia University (MMU). His research interest includes intelligent transportation systems, vehicular ad hoc networks, wireless communication, and mesh networks. He can be contacted at email: sumendra@mmu.edu.my.

**Siti Fatimah Abdul Razak** has been a Lecturer at the Faculty of Information Science and Technology, Multimedia University, since 2005. She graduated from Multimedia University (MMU) with a Doctor of Philosophy (PhD) in Information Technology in 2018 and a Master of Information Technology (Science and System Management) in 2004. She is also an active member of the Centre for Intelligent Cloud Computing. Her research interest includes vehicle safety applications, the internet of things, rule mining, information systems development, and educational technology. She can be contacted at email: fatimah.razak@mmu.edu.my.

**Mohd. Fikri Azli Abdullah** has been a Lecturer in the Faculty of Information Science and Technology at Multimedia University (MMU), Melaka, Malaysia, since 2005. He graduated from the University of Melbourne, Australia, with a Master in Software System Engineering. He was a researcher at Advance Network Lab at Chonnam National University, South Korea, in 2010. His research interest includes mobile computing, image processing and pattern recognition. He can be contacted at email: mfikriazli.abdullah@mmu.edu.my.

**Afizan Azman** is a Senior Lecturer at Taylors University, Selangor, Malaysia. Previously he was the Vice Chancellor of Research and Innovation at Kolej Universiti Islam Melaka (KUIM). He graduated from Loughborough University with a Doctor of Philosophy (PhD) in Computer Science in 2013 and from University College of London with a Master of Information Technology in Computer Science in 2005. His research interests include human-computer interaction, artificial intelligence, vehicle systems and technology, data analytics, and the internet of things. He can be contacted at email: afizan.azman@taylors.edu.my.

**Vethanayagi Arultas** received her Diploma in Information Technology in 2017 and Bachelor of Information Technology (Hons) Security Technology in 2022 from Multimedia University (MMU). Her research interest includes wireless communication technology, internet of things and sensor modules. She can be contacted at email: vetha97@gmail.com.

**Suneetha Sri Raman** received her Bachelor of Information Technology (Hons) Data Communications and Networking in 2020 from Multimedia University (MMU). Her research interest includes internet of things, mobile and wireless network and embedded device. She can be contacted at email: suneetha98@yahoo.com.