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Evaluating compliance with COVID-19 social distancing protocol in a university in the south-east of Nigeria using radio frequency identification

Ngozi C. Eli-Chukwu[1,*], Daniel Nmadu, Uma U. Uma, Marcellinus I. Eheduru, Ogah E. Ogah and Jerryson C. Emeh

Alex Ekwueme Federal University, Ndufu-Alike, Ikwo, Department of Electrical/Electronics Engineering, Faculty of Engineering and Technology, Abakaliki, Ebonyi State, Nigeria

Abstract. The 2019 coronavirus pandemic is considered a global health emergency and the greatest challenge human kind has faced since World War II. The disease has claimed many lives globally and has caused major economic deterioration. The most challenging is the constant change of the virus through mutations leading to emergence of different variants. There are stipulated measures to mitigate the spread of this virus amongst which social distancing protocol seems to be the most effective. This study measures compliance with COVID-19 social distancing protocol using Radio Frequency Identification in a university in Southeastern Nigeria. The result reveals low indicators of compliance with the social distancing precautionary measures. The results from different faculties indicate that the students did not comply, with an average compliance of 24 percent. The study contributes to present and future pandemic management as the rate at which the virus spreads despite the precautionary measures were alarming. Hence the need to measure compliance in real time rather than adopting an abstract method in a critical situation of this nature.

Keywords: COVID-19, social distancing protocol, preventive measures, radio frequency identification

1. Introduction

The emergence of the 2019 coronavirus (COVID-19) infection in different parts of the world cannot be underrated since it has posed a big health challenge and economic crisis globally (Hussaini, 2020; Zhu et al., 2020). COVID -19 is an infectious disease caused by a new strand of coronavirus known as SARS-COV-2 (Nishiura et al., 2020; Yang et al., 2020). It is a disease that affects the air passage in humans, thereby causing viral pneumonia. It was discovered first in the city of Wuhan in China. The disease has claimed more than 6947192 lives globally from the 30th of December 2019 to the 28th of June 2023 and there are over 767518723 confirmed cases of the disease (World Health Organization Geneva, 2020). The disease spreads from a person through infected air droplets that are projected during sneezing or coughing and by physical

*Corresponding author: Ngozi C. Eli-Chukwu, Alex Ekwueme Federal University, Ndufu-Alike, Ikwo, Department of Electrical/Electronics Engineering, Faculty of Engineering and Technology, P.M.B. 1010, Abakaliki, Ebonyi State, Nigeria. Tel.: +234 803 312 4913; E-mail: ngozieli@gmail.com.

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contact with an infected person or surface. Some infected people show severe body temperature, dry cough, breathing difficulty, inflammatory lung, etc. The symptoms showed by people infected with COVID-19 are like those of the common cold and some viruses that cause respiratory disease in humans such as Middle East Respiratory Syndrome (MERS), which is more common than COVID-19. Due to the high death rate orchestrated by the pandemic, testing is required to confirm if someone tests positive for COVID-19 for immediate treatment and possibly isolation (Li et al., 2020). To stop the spread of the virus, a mitigating mechanism must be adopted. Some of the mechanisms adopted to reduce the spread of the disease include ventilation of rooms and residential spaces, regular washing of hands, wearing of face masks, avoidance of crowds, sneezing, or coughing with or into a tissue or curled elbow, use of sanitisers, and social distancing which suggests that people stay at least two meters away from each other. Amongst these measures, social distancing is considered the most effective in managing the spread of COVID-19 (Ukonu and Mbamalu, 2021). This is because the virus is considerably large and heavy and may not travel farther than two meters while suspended in the air and may not survive the temperature or stress when it stays on a surface or on the ground for a long period. The Nigerian Centre for Disease Control (NCDC) recommends at least a distance of 2 metres between people for effective disease prevention, therefore these measures must be adhered to in order to reduce the spread of the virus. The measurement of compliance to the COVID-19 social distancing protocol is very key to the management or control of the spread of COVID-19 (Padidar et al., 2021). Since the outbreak of the virus, some researchers have used some methods like systematic review, face-to-face interview and online survey questionnaire to measure compliance of people to the COVID-19 social-distancing protocol. Padidar et al. (Padidar et al., 2021), deployed online surveys to assess the compliance and attitude of adults residing in the southern African kingdom of Eswatini. There findings revealed 70% compliance to the stipulated measure. Al-Shattarat and Amuda (Al-Shattarat and Amuda, 2021) evaluated the compliance to COVID-19 protocols using a comparative systematic review approach in Nigeria and Jordan, their findings showed indicators of compliance to precautionary measures against the spread of the virus. This report did not indicate the extent of compliance; besides, secondary data was used instead of primary data, hence the need to explore other approaches in measuring the actual compliance rate to the stipulated measures. Another study conducted among food and drink establishments in selected towns of Bench-Sheko and West-Omo zones using face-to-face interview revealed a very poor compliance with overall compliance rate of 55.5% (Kayrite et al., 2020). The study suggests that people in Ethiopia are not naturally complying. In Nigeria, critical analysis of the factors that foster the spread of the disease shows that some of the reasons why the efforts by the Nigerian government to manage the spread of the disease has proven almost abortive are because there is a very low compliance rate by Nigerians occasioned by psychology, cultural, educational and communication barriers or inclinations (Li et al., 2020).

Notwithstanding the implementation of many preventive and control systems established by governments, the spread of COVID-19 is frighteningly increasing from time to time all over the world. This questions the compliance data from literature, hence adopting a real time data collection approach to measure compliance to the social distancing measure using Radio Frequency Identification (RFID) is proposed.

Radio Frequency Identification (RFID) is a radio frequency identification technology used to identify and track objects or people in real-time. The system consists of an RFID reader, an RFID tag, and a PC or Server which hosts the operational application software. Radio Frequency Identification (RFID) technology is very suited to locating objects, particularly in an indoor environment. RFID is applied in access control systems, employee ID badge applications, national ID, and healthcare cards. RFID is used in contactless smartcards, transit ticketing, speed payment, identification of people, electronic toll collection, etc. (Chawla et al., 2013).

RFID technology employs some techniques in tracking or wireless positioning which includes Received Signal Strength (RSS), where the position or distance of a tag to a reference point is measured considering the strength or energy of the reflected power from the tag, the Angle of Arrival (AoA), here, the position of a tag can be determined based on the angle from which its response signal is propagated. Time of Arrival (ToA) is a technique used to estimate the distance or position of a tag based on the time of arrival of the response signal, etc. (Finkenzeller, 2003). RFID can be used to measure distance (tag-reader distance) by measuring the signal's propagation strength up to the point where the signal starts to attenuate. According to the Friis transmission equation, the tag-reader radio signal and distance over free space can be calculated using

$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi d}\right)^2 \tag{1}$$

where P_r is the power received at the receiver, the tag and P_t is the power transmitted by the transmitter, the reader. G_r and G_t are respectively the antenna gains for the tag and reader, λ is the radio signal wavelength, d is the tag-reader distance (Friis, 1946). RFID is used with a block-chain based application to track bottled products that have RFID tags on them.

During the post COVID-19 era, establishments considered an RFID-based automated counter and access system which regulates the number of persons inside a firm in an office at a time. As the customers come close to the entrance, the RFID reader identifies the tags and as they start entering, the system takes count of how many people entered and when the number of people that had entered inside is equal to the preset number, it displays a red light signalling 'no entrance'. When the people inside are coming out, the system takes count again and when the count matches the former count, the system displays a green light signalling 'go in' and customers go in. The process continues until all the customers have been attended to (Mekic, 2020).

A review of the literature gave us insight into the various methods researchers employed to establish whether people are complying to specifically the social-distancing protocol and nobody has employed Radio Frequency Identification (RFID) for that purpose. The use of Radio Frequency Identification (RFID) in determining the compliance of a people to COVID-19 social-distance protocol is an effective method because it is relatively very empirical with high accuracy when compared to the methods used by other researchers such as face-to-face interview and questionnaire.

2. Materials and methods

2.1. Sampling methodology

In calculating the required sample size, the following steps were taken:

- Determine the desired level of confidence which is based on how confident you want to be that the actual mean falls within your margin of error. 95% was selected which corresponds to a *z-score* of 1.96.
- Estimate the population proportion p that is likely to follow compliance rules based on prior knowledge (here we used 25% or 0.25).
- Determine the desired margin of error which is the difference between the mean number of the sample and the mean number of the population (5% or 0.05 was selected).
- The equation presented in Equation (2) was used to calculate the sample size.

$$n = \frac{z^2 \times p \times (1 - p)}{E^2} \tag{2}$$

$n =$ required sample size

$z =$ z-score (1.96)

$p =$ estimated proportion (0.25)

$E =$ margin of error (0.05)

Plugging in the above numbers would give us a rough sample size estimate of 300 (50 per faculty). Participation and consent forms were distributed to all registered students in the 6 faculties and they were assigned a number from $1 - 5000$ and then 50 students per faculty were randomly selected from the total population. The consent rate was above 70% (100%) so there was no chance of self-selection bias in the sample.

2.2. Radio frequency identification localisation setup model

As shown in Fig. 1, we considered the RFID model setup consisting of the antenna, transponder (tag), interrogator (reader), computer, and the users. The RFID deployed is the UHF RFID HF – FI16 RFID system which uses GS1's EPC (Electronic Product Code) Gen2 air interface protocol with an operational frequency of ISM 902-928MHz/ISM 865-868MHz and its mode of operation is broad-spectrum frequency hopping. The transponder denoted as (T) is placed on the door where the users (U) to estimate the distance between each user as they queue up to enter the classroom. The antenna (A) which serves as a transceiver that interfaces between the transponder (tag) and the interrogator (reader). Figure 2 shows a typical experimental setup.

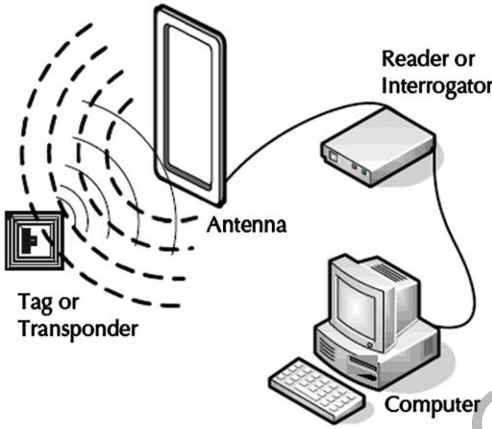

Fig. 1. The RFID localisation setup.

In this network, the transmission mode is frequency-hopping spread spectrum (FHSS) mode. The essence of choosing the FHSS mode is to reduce interference especially when cluster of users are moving into the hall through the door at the same time. In terms of information transmission, the antenna in the network is connected in-between the interrogator and the transponder and the interrogator connected to the computer. The computer contains all the content files (tag numbers) that will be requested by the interrogator. As the users approach the entrance door, the reader interrogates the transponder by sending out electromagnetic wave. The transponder responds by back scattering a fraction of the received signal to the reader. The reader sends the information to the application software installed in the computer for computation.

2.3. Transmission model

The technique adopted in this research for distance estimation is the use of read-time, gait speed and the classic distance formula. This technique involves the reader recording the time it read each tag and notifying us through its buzzer. This time is then used directly in the classic distance formula to get the distance of each user from another knowing the normal gait speed of humans. The received power from the tag is measured using the Friis equation as stated below:

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} \tag{3}$$

where P_t = transmitted power, $P_r(d)$ = received power as a function of the distance of the tags from the reader, G_t = transmitter antenna gain, G_r = receiver (tag) antenna gain, L = loss (propagation/system loss), λ = wavelength in meters. The antenna gain is calculated using the formula below:

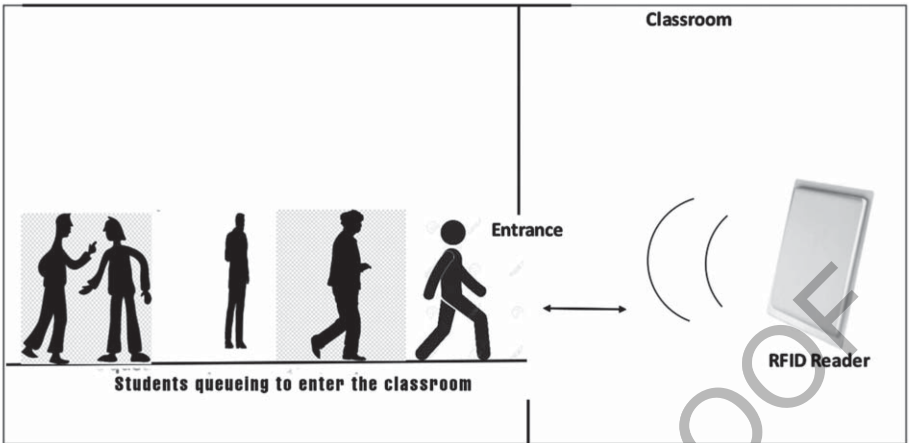

Fig. 2. Experimental Setup.

$$G = \frac{4\pi A_e}{\lambda^2} \tag{4}$$

where G = antenna gain, A_e = effective antenna aperture, and λ = wavelength in meters. Also the wavelength is calculated thus:

$$\lambda = \frac{c}{f} \tag{5}$$

where c = speed of light, f = frequency. Considering that the distance of the next user to enter the class from the first would be determined using the classic formula. Therefore:

$$D = vt \tag{6}$$

where v = the normal gait speed of human beings (1.3 ± 0.3) m/s (Bohannon, 1997), t = the time the tag was read (which is displayed by the reader).

3. Results and discussion

The experiment was conducted three times each at the Faculties of Humanities, Engineering, Management Science, Agriculture, Medical Sciences, and Education. The RFID tags were labelled with the last four alpha-numeric identity of their EPC for identification. The experiment was repeated three times in order to have a wider data set from which concrete inference could be drawn – if the experiment was conducted once, the compliance of a student to the COVID-19 social distancing protocol might be loosely established because he/she may have accidentally observed the protocol but, if the experiment is repeated at least three times and a student happens to comply on the

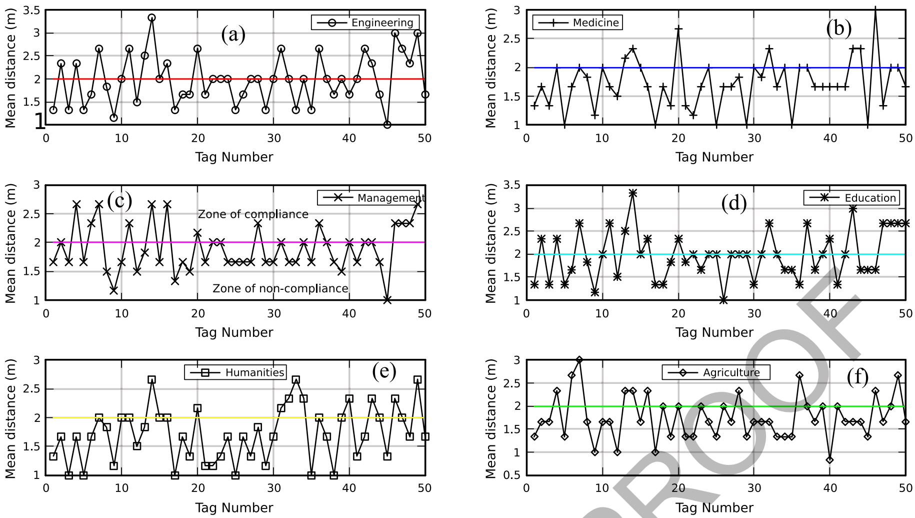

Fig. 3. Mean compliance for all faculties.

average, it means that such a student was actually intentional and indeed observed the protocol.

Figure 3(a) represents the mean compliance with the COVID-19 social-distancing protocol by students of the Faculty of Engineering. The findings reveal a mean compliance of 32%, non-compliance of 42% and at risk compliance of 26%. We classed students who were at the mean distance of 2 metres to be at risk. The calculated population mean distance and standard deviation for engineering were ($\mu = 1.9867$) and ($\sigma = 0.7187$). This data shows that compliance in the Engineering faculty was quite poor. This can also be readily confirmed by visual inspection of Fig. 3(a) which shows fewer data points above the red horizontal compliance line than below.

Also, at the Faculty of Humanities (see, Fig. 3(e)), our findings reveal a mean compliance of 20%, non-compliance of 62% and at risk compliance of 18%. The calculated population mean distance and standard deviation for humanities were ($\mu = 1.72$) and ($\sigma = 0.7564$). Compliance in this faculty was also quite poor as evinced by the data and visual inspection of Fig. 3(e).

At the Faculty of Management (Fig. 3(c)), the results show a mean compliance of 26.5%, non-compliance of 55.10% and at risk compliance of 18.37%. The calculated population mean distance and standard deviation for management were ($\mu = 1.8893$) and ($\sigma = 0.7440$). Compliance in this faculty was also quite poor as evinced by the data and visual inspection of Fig. 3(c).

Results from the Faculty of Medicine (Fig. 3(b)) show a mean compliance of 14%, non-compliance of 62% and at risk compliance of 22%. The calculated population mean distance and standard deviation for medicine were ($\mu = 1.7233$) and ($\sigma = 0.6916$). Compliance in this faculty was also very poor as shown by the data and visual inspection of Fig. 3(b).

Table 1
Mean compliance, non-compliance and at risk percentage for all faculties

Faculty	Compliance (%)	Non-compliance (%)	At risk (%)
Agriculture	20	64	16
Education	32	44	24
Engineering	32	42	26
Humanities	20	62	18
Medicine	14	64	22
Management	26.5	55.10	18.37

Results from the Faculty of Agriculture (Fig. 3(f)) show a mean compliance of 20%, non-compliance of 64% and at risk compliance of 16%. The calculated population mean distance and standard deviation for agriculture were ($\mu = 1.7567$) and ($\sigma = 0.7206$). Compliance in this faculty was also very poor as shown by the data and visual inspection of Fig. 3(f).

Finally results from the Faculty of Education (Fig. 3(d)) show a mean compliance of 32%, non-compliance of 44% and at risk compliance of 24%. The calculated population mean distance and standard deviation for education were ($\mu = 1.9737$) and ($\sigma = 0.7228$). Compliance in this faculty was also bad as shown by the data and visual inspection of Fig. 3(d).

In summary compliance with the social distancing protocol across the faculties was quite poor with medicine surprisingly coming out as the worst performing faculty (14% compliance) while relatively speaking, the faculties of education and engineering were the best performing at 32% compliance each.

4. Conclusions

The study measures compliance with the COVID-19 social distancing protocol in the six faculties of the university using RFID technology. In this work, we were able to establish the percentage compliance of students of the university using RFID with a considerably fair sample population of 300 students, 50 each from each of the six faculties. The sample population from Faculties of Engineering, Basic Medical Sciences, Humanities, Agriculture, Education, and Management Sciences complied very poorly with the COVID-19 social distancing protocols. The Faculty of Medicine was the worst performing faculty at 14% compliance, while relatively speaking Engineering and Education were the best performing faculties at 32% compliance. Conclusively, there is a low percentage of compliance with social distancing protocols and hence, the disease will spread faster through close contact within the university if preventive measures are not employed.

4.1. Recommendations

The use of Radio Frequency Identification (RFID) in determining the compliance of a given community with COVID-19 social distancing protocols is a highly effective method because it is relatively very empirical with high accuracy when compared to the methods used by other researchers such as face-to-face interviews and questionnaires.

The findings from this study will enable the government, health workers, policy makers, and the school management to make informed decisions on what measures to deploy to effectively manage the spread of COVID-19.

4.2. Limitations and implications for further studies

The use of RSS (Received Signal Strength) allowed for more flexibility of the research procedure. During this experiment, we discovered that some students would rather pocket the RFID tags than keep them up at an orientation that would make it to be read by the RFID reader easily and this affected the read time of some tags which is a major limitation. Also, The RS232 connection mode posed a challenge during the experimental setup due to the short length of the cable. These have provided substantial directions for future research in order to further improve the results of this report.

References

Al-Shattarat, B., & Amuda, Y.J. (2021). Comparative report of compliance to precautionary measures against COVID-19 in Nigeria and Jordan. *Heliyon 7*(8), e07793.

Bohannon, R.W. (1997). Comfortable and maximum walking speed of adults aged 2079 years: reference values and determinants. *Age and Ageing 26*(1), 15–19.

Chawla, K., McFarland, C., Robins, G. & Shope, C. (2013). Real-time RFID localization using RSS. *2013 International Conference on Localization and GNSS (ICL-GNSS)*, IEEE, pp. 1–6.

Finkenzeller, K. (2003). *RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification.*, John Wiley & Sons Ltd, Chichester, West Sussex, England.

Friis, H.T. (1946). A note on a simple transmission formula. *Proceedings of the IRE 34*(5), 254–256.

Hussaini, S.M.Q. (2020). Dearth of infectious diseases physicians as the USA faces a global pandemic. *The Lancet Infectious Diseases 20*(6), 648–649.

Kayrite, Q.Q., Hailu, A.A., Tola, T.N., Adula, T.D., & Lambyo, S.H. (2020). Compliance with COVID-19 preventive and control measures among food and drink establishments in Bench-Sheko andWest-Omo zones, Ethiopia, 2020. *International Journal of General Medicine 13*, 1147–1155.

Li, Q., Guan, X., Wu, P., Wang, X., Zhou, L., Tong, Y., Ren, R., Leung, K.S., Lau, E.H., Wong, J.Y. et al. (2020). Early transmission dynamics in Wuhan, China, of novel coronavirus–infected pneumonia. *New England Journal of Medicine 382*(13), 1199–1207.

Mekic, M. (2020). RFID for Social Distancing: TAGnologys Clever Setup Prevents Crowding in Stores, https://www.nxp.com/company/blog/rfid for-social-distancing-tagnologys-clever-setup-prevents crowding-in-stores:BL-RFID-FOR-SOCIAL-DISTANCING-TAGNOLOGY. Online, accessed 13-11-2022.

Nishiura, H., Jung, S.-M., Linton, N.M., Kinoshita, R., Yang, Y., Hayashi, K., Kobayashi, T., Yuan, B., & Akhmetzhanov, A.R. (2020). The extent of transmission of novel coronavirus in Wuhan, China, 2020. *Journal of Clinical Medicine 9*(2), 330.

Padidar, S., Liao, S.-M., Magagula, S., Mahlaba, T.A., Nhlabatsi, N.M., & Lukas, S. (2021). Assessment of early COVID-19 compliance to and challenges with public health and social prevention measures in the Kingdom of Eswatini, using an online survey. *Plos One 16*(6), e0253954.

Ukonu, M.O., & Mbamalu, M. (2021). Predictors of compliance to COVID-19 containment communications in Nigerias Federal Capital Territory, Enugu, and Lagos States. *Sage Open 11*(3), 21582440211047243.

World Health Organization Geneva (2020). WHO COVID-19 Dashboard, https://covid19.who.int/. Online accessed 29-06-2023.

Yang, J., Zheng, Y., Gou, X., Pu, K., Chen, Z., Guo, Q., Ji, R., Wang, H., Wang, Y., & Zhou, Y. (2020). Prevalence of comorbidities and its effects in patients infected with SARS-CoV-2: a systematic review and meta-analysis. *International Journal of Infectious Diseases 94*, 91–95.

Zhu, N., Zhang, D., Wang, W., Li, X., Yang, B., Song, J., Zhao, X., Huang, B., Shi, W., Lu, R. et al. (2020). A novel coronavirus from patients with pneumonia in China, 2019. *New England Journal of Medicine 382*(8), 727–733.