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Preliminary study: The Readiness of WLAN Infrastructure at Malaysian Higher Education Institutes to Support Smart Campus Initiative

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Abstract — Smart campus initiative enables higher education to enhance services, decision-making, and campus sustainability. The initiatives are being actively implemented globally by higher education, including in Malaysia. The recent COVID-19 pandemic has underscored the need for the education sector to explore a digital revolution. The adaptation of digital technologies has improved many aspects, including the teaching and learning experiences and administration tasks, which results in more efficient task handling. This study investigates the readiness of the WLAN infrastructure at Malaysian Public Higher Education Institutes (HEIs) in implementing smart campus initiatives and measures readiness based on the availability of WLAN Infrastructure, WLAN logical architecture and WLAN populated coverage area. This study administered a questionnaire to 19 respondents, all of whom are IT personnel from Malaysian public HEIs to gather preliminary data on the readiness of WLAN infrastructure at Malaysian Public HEI to support the adaptation of smart campus initiatives in their teaching and learning activities. This study is a preliminary study concerning the readiness of WLAN infrastructure at Malaysian Public HEI in adapting smart campus initiatives. The findings show that, even though WLAN service is available at all Malaysian Public HEI, it is essential to enhance the adopted logical architecture and WLAN coverage to prepare HEI to become smart campuses. The findings of this study can provide the fundamental guidelines for the Ministry of Higher Education in determining the baseline of WLAN infrastructure required by Malaysian HEI to support smart campus initiatives.

Keywords — WLAN infrastructure; Wi-Fi; WLAN planning; smart campus; Malaysian higher education; network infrastructure; adaptation readiness.

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I. INTRODUCTION

Industrial Revolution (IR) 4.0 is a technological revolution in a specific industry encompassing big data, data analytics, cloud computing, robots, artificial intelligence, and the Internet of Things (IoT) [1]. The technologies in the industrial revolution have changed how people work and improved productivity in various aspects. Presently, most HEIs in Malaysia adopt conventional teaching and learning methods. The implementation of IR4.0 has caused the enhancement of teaching and learning experience by the student in the higher education sector. However, the COVID-19 pandemic has changed the education landscape in Malaysia, and HEIs gradually changed to be more flexible and accessible from anywhere. The transformation in digital learning has introduced a new concept called smart campus [2]. Delloite in

[3] defined a smart campus as a next-generation campus. Smart campus describes the HEI that utilizes next-generation technologies derived from well-architected infrastructure. The smart campuses adopt technologies that provide fast data delivery, robust communication, and touchless and intuitive experiences driven by a digitally connected community.

To ensure they can remain competitive and capable of supporting smart campus initiatives, HEIs must keep track of the time to ensure that students and the HEI management team can enjoy various benefits. In embracing the concept of a smart campus, numerous educational institutions all over the world have been enhanced with cutting-edge technologies, thus developing proactive relationships among all campus sectors to achieve successful outcomes [4].

This study is significant because it helps the researchers investigate the current readiness of various aspects of the

WLAN infrastructure in Malaysian HEIs. More importantly, the Ministry of Higher Education can use the findings of this study as input to measure the readiness of all Malaysian public HEIs in implementing smart campus initiatives. In addition, the recommendations in the discussion section can serve as a baseline for the ministry to improve the WLAN infrastructure at all Malaysian public HEIs to support smart campus initiatives and implement IR4.0.

A. Smart Campus

A smart campus is a campus environment that provides efficient technologies and infrastructures to deliver the services that support and improve teaching, research and student experience [5]. Embracing a smart campus strategy helps HEIs to remain sustainable and improve the experiences of students, administrators, researchers and other parties on the campus. According to Masitah *et al.* [5] several universities in Malaysia, including Universiti Tun Hussein Onn Malaysia (UTHM), Universiti Malaysia Pahang (UMP), Universiti Putra Malaysia (UPM), and Universiti Tenaga Nasional (UNITEN), have actively implemented smart campus initiatives in multiple domains. These universities implemented the smart campus initiative in the Smart Learning, Green Campus, Smart Management, and Smart Governance domain.

The Internet of Things (IoT) is an area that focuses on implementing smart campus initiatives [6]. IoT can resolve the hindrances and problems in an education system. For instance, lecturers and students can work together and have classes remotely using wireless support devices attached to a video camera, making teaching and learning more effective and flexible [7].

B. Industrial Revolution 4.0 (IR4.0)

Industrial Revolution (IR) 4.0 is a technological revolution in a specific industry encompassing big data, data analytics, cloud computing, robots, artificial intelligence and the Internet of Things (IoT). IR4.0 provides a paradigm shift to the landscape of many industries, such as manufacturing, healthcare, agriculture, tourism and education. The Malaysian economy is transitioning from a labour-intensive economy to a capital- and technology-intensive system, which significantly increases the relevance of human resource development policy, particularly in the education and training sectors. All students at Higher Education Institutions (HEIs) must leave their comfort zones and prepare for the challenges of IR4.0. Therefore, HEIs must be ready to implement IR4.0 in the education system. Many researchers have discussed the readiness of IR4.0 adaptation in the education sector from various perspectives, including curriculum, digital technologies and administrative systems [7]–[9].

In a recent discussion on unemployment in Malaysia, Balan *et al.* [8] pointed out that the problem was due primarily to the lack of IR4.0 skills. It is essential to instil work competency and preparedness skills in graduates to ensure that they can meet the demands of the IR 4.0 employment market. Therefore, it is crucial to provide a network infrastructure at HEIs that facilitates smooth teaching and learning activities and prepares students who are competent for the future industry. The achievement of these objectives can inspire

students to embrace the challenges of IR4.0 and motivate them to seek new knowledge.

C. WLAN infrastructure

The evolution of the nation's education system and smart campus initiatives have been impacted by the emergence of ICT infrastructure, including the 5G and IoT networks [10]. The growth of networking and communication increases speed, accuracy, reliability and cost-effectiveness, particularly in implementing smart campuses. The need for wireless networks, particularly local area networks, is more urgent with the invention of wireless networks [11]. A wireless local-area network (WLAN) can be defined as co-located computers or other devices communicating via radio broadcasts rather than the conventional connections tied to wired cable to form a network. The four main network components in WLANs are the distribution system, wireless medium, station, and access point. Devices with wireless network interfaces are called stations. A wireless router or bridge, known as an access point (AP), connects a wireless network to a wired network. WLAN, also known as wireless fidelity (Wi-Fi), allows a station to connect to the network and surf the Internet to gather information beyond boundaries. The two common types of WLAN configurations are infrastructure and ad-hoc [12]. A WLAN configured in infrastructure mode is a home or workplace Wi-Fi network. All endpoints are linked together and communicate with one another via a base station, which may also provide Internet access.

TABLE I
COMPARISON OF WLAN TECHNOLOGY

WLAN Standard	Brand Name	Max Data Rate	Frequency	Drawback Compatibility
802.11a	NA	54Mbps	5GHz	No
802.11b	NA	11Mbps	2.4GHz	No
802.11g	NA	54Mbps	2.4/5Ghz	802.11b
802.11n	Wifi 4	600Mbps	5GHz	802.11a/b/g
802.11ac	Wifi 5	1Gbps	2.4/5Ghz	802.11a/b/g/n
802.11ax	Wifi 6	3.5Gbps	2.4/5Ghz	802.11a/b/g/n/ac

In recent years, WLAN has been widely deployed in various areas such as public areas, campuses, companies and schools to provide users with better access to the Internet. Based on a study conducted by [13], all Malaysian Public HEIs deployed WLAN as one of the network communication mediums for accessing the network service on the campus. Flexible technology is crucial, particularly in supporting teaching and learning activities. Researchers have debated the impact of WLAN technology on student academic orientation for decades[14]. Many academics believe that WLAN technology is beneficial in allowing students to access campus learning resources [15].

Table 1 compares WLAN 802.11a, 802.11b, 802.11g, 802.11n, 802.11ac and 802.11ax. The information on WLAN standards was compiled from several sources and presented in Table 1 [16]–[18]. The WLAN speed of 802.11a, 802.11b and 802.11g support a low data rate compared to the other standards. Starting from IEEE 802.11n, the antenna is a

MIMO technology, which supports up to four spatial streams of MIMO; IEEE 802.11ac has been improved by supporting up to eight streams of MIMO, thus increasing the speed of data transmission between sender and receiver [17].

Many researchers have discussed the readiness of universities to implement smart campus initiatives from various perspectives, including digital technologies, concepts and applications and administrative systems [7]–[9]. However, there are limited discussions on the readiness of ICT infrastructure to support the implementation of a smart campus in Malaysian Public HEIs. Therefore, this preliminary study aimed to explore the readiness of WLAN infrastructure at Malaysian Public HEIs to support smart campus initiatives. The study surveyed Malaysian HEIs to investigate WLAN infrastructures and services provided to end users. The findings of this study will serve as a basis for a study to assess the readiness of HEIs to support smart campus initiatives.

II. MATERIALS AND METHODS

This study employed a questionnaire survey methodology to determine the readiness of HEIs to support smart campus initiatives. The survey sought to investigate the current WLAN infrastructure available at each HEI. The survey was carried out in October 2021 involving 20 Malaysian Public HEIs, and 19 of the HEIs participated in the survey. In general, this study started by (i) defining the research questions, (ii) creating the research instruments, (iii) choosing the sample size, and (iv) gathering the data from the respondents.

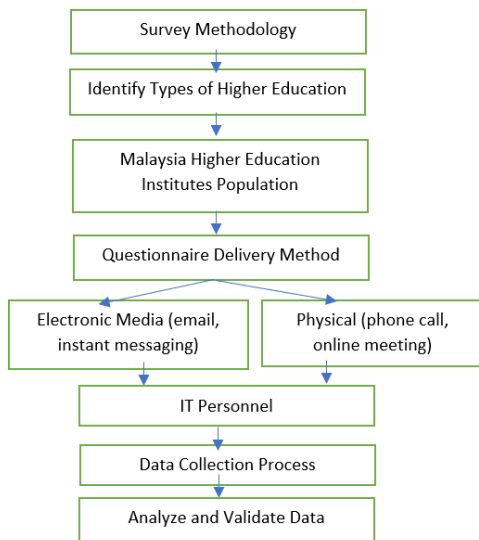


Fig. 1 The data collection and analysis method

The distributed questionnaire consists of five sections: (i) general information; (ii) network infrastructure; (iii) IR4.0 implementation; (iv) WLAN network infrastructure, and (v) WLAN planning method. This paper focuses on selected findings from category (iv), namely WLAN utilization, the adopted network applications, the type of devices for accessing WLAN, WLAN utilization monitoring practices, WLAN topology and the adopted standard, WLAN coverage area, and the average number of users accessing the WLAN service at a particular time.

Fig. 1 presents the data-gathering method and analysis employed in this study. The questionnaire survey was made

available to the sample population physically and electronically. The questionnaire was distributed to 20 IT personnel from all Malaysian Higher Education Institutes, and 19 respondents participated in the survey, which spans one month. The collected data were subjected to descriptive analysis.

Table 2 shows the distribution of respondents based on their role in their HEI. Fourteen (74%) respondents are network administrators, three (16%) are network security administrators, and two (10%) are IT executives. The respondents were selected for their role as IT personnel and person-in-charge of implementing and managing the network infrastructure at their higher institution, with a minimum of five years of working experience. It was crucial to select the appropriate respondents because it affected the study outcomes. The respondents provided their insights on the required information for network implementation based on their daily experiences.

TABLE II
DISTRIBUTION OF RESPONDENTS BASED ON THEIR ROLE IN HEI

General Information	Frequency (n)	Percentage (%)
<i>Position in HEI/ Organization</i>		
Network Administrator	14	74
Network Security Administrator	3	16
IT Executive	2	10

III. RESULTS AND DISCUSSION

The collected data were subjected to descriptive analysis. This study investigated and analysed the readiness of the WLAN infrastructure of Malaysian HEIs to support the implementation of smart campuses. The descriptive analysis was based on the categories described in the methodology section.

A. Availability of WLAN Infrastructure

The questionnaire asked the following questions to investigate the availability of WLAN infrastructure in Malaysia Public HEIs.

Q1: Does your HEI provide wireless service (WLAN) to the end users?

Q2: What is the estimated student population at your HEI?

Q3: What is the estimated number of staff (academic and non-academic) at your HEI?

Q4: Which types of end devices are connected to your HEI WLAN?

Malaysian HEIs are the centers that produce the human power that contribute to the nation's development. Each Malaysian HEI has a different number of students in various programs. The survey result showed that 95% of Malaysian HEIs have 4000 active students, and 5% have between 2000 to 3999 active students; all Malaysian HEIs have at least 500 academic and non-academic staff. All Malaysian HEIs have an Internet connection speed of between 1Gbps and 40Gbps to support teaching and learning activities in the new digital era [13].

It is crucial to provide a reliable, flexible, and high-availability network connection to the end users to ensure efficient access to information, online assessments and classes, and other teaching and learning activities [19]. The survey result showed that all Malaysian HEIs provided WLAN access to the on-campus users who use laptops, personal computers, smartphones, computer tablets, CCTV, printers, and photostat machines. Fig. 2 presents the number of Malaysian HEIs providing WLAN services to various end devices on their campuses. Nineteen Malaysian HEIs provided WLAN services to laptops, personal computers, smartphones and computer tablets, and six HEIs provided WLAN service to CCTV.

Campus safety is an essential element of smart campuses [6] and one way to ensure safety on the campus is by installing Close Circuit Camera Videos (CCTVs). A good connection between a laptop or remote monitoring device is essential to obtain high-quality video [20], which requires sufficient network bandwidth. High-quality videos require transmission bandwidths. A successful installation of wireless CCTV involves more than just purchasing the CCTVs in the market; it also requires an appropriate WLAN design and knowledge. The 5GHz frequency is the best option for supporting CCTV deployment on smart campuses because the frequency has less interference and more channels than 2.4GHz [21]. HEIs are encouraged to support smart campuses in the IR4.0 era by connecting CCTV to a WLAN network with 5GHz frequency because of its higher data rates, such as 802.11n and 802.11ax.

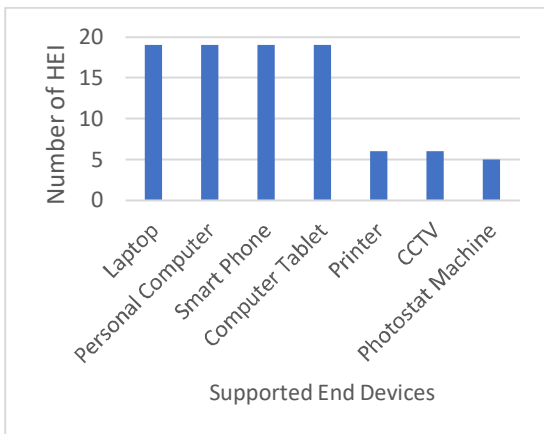


Fig. 2 The number of Malaysian HEIs vs the Supported End Devices

B. WLAN Logical Architecture

The survey asked the following questions to investigate the logical architecture at Malaysian Public HEIs.

Q1: Which wireless (WLAN) standard does your HEI use?

Q2: Which type of wireless topology (WLAN) does your HEI use?

Q3: Which of the following areas have access to WLAN?

Q4: What is the average number of wireless users in the following area/space in your HEI? [lecture room]/ [computer lab]/[Admin Office]/[Library]/[Hostel]

A network's logical architecture consists of the standards and protocols that enable connections between physical objects, or nodes, and regulate the data flow and routing between the nodes [22]. A WLAN design determines the performance of WLAN in an organisation, including Malaysian HEIs. Since WLAN

standards and bandwidth are related, it is crucial to deploy appropriate WLAN standards since it will determine the bandwidth received by the end users. Moreover, the applications used in a smart campus environment must be supported by a good WLAN bandwidth [13].

Fig. 3 illustrates the WLAN standards at Malaysian HEIs. The survey showed that Malaysian HEIs deployed various WLAN standards, including 802.11a, 802.11b, 802.11g, 802.11n, 802.11ac and 802.11ax. The highest standard deployed is 802.11n, and five HEIs, which have 26.3% of the population, were already deploying 802.11ax in their networks. However, 11% of the HEIs were still using 802.11a and 802.11b in their network, and surprisingly, one HEI offered up to 802.11g to their end users.

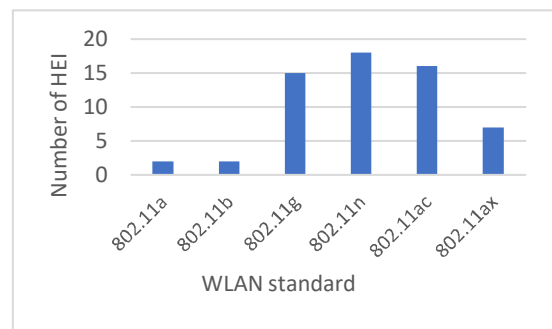


Fig. 3 The number of HEIs vs the WLAN standards Deployed

Table 2 shows the WLAN data rate provided by all 802.11 standards. The speed for 802.11a, 802.11b and 802.11g support a lower data rate than the other standards. Since 802.11a and 802.11b are legacy WLAN, most new access points no longer support these standards. The services are likely to be supported by an old model access point still functioning on the campus. 802.11a and 802.11b are unsuitable for supporting smart campus initiatives because of their low data rate. According to [23], 802.11a and 802.11b use different modulation techniques, OFDM and DSSS. These standards do not have drawback compatibility because they use two different modulation techniques. The performance of a network will be affected when users still using 802.11b connect to the network. Other WLAN standards have drawback compatibility and, therefore, can work with other WLAN devices with different standards and vice versa.

802.11ax or Wifi-6 is a new wireless standard introduced by IEEE and could be the reason for the small number of HEIs that have deployed it [24]. Upgrading the WLAN infrastructure in Malaysian HEIs will take time because of budget constraints. Wifi-6 is capable of handling end devices in high-density areas. As mentioned in section 4.1, 95% of the HEIs have to support 4000 active students at any one time and more than 2000 staff on campus, which resulted in a high-density network. All Malaysian HEIs must deploy Wifi-6 because the next-generation wireless network provides sophisticated applications with predictable performance, such as 4K or 8K video, high-density, high-definition collaborative apps, all-wireless workspaces and the Internet of Things (IoT)[16]. Only seven HEI have deployed Wifi-6 at the time of the survey. Hence, it is crucial for the remaining HEIs to deploy the same WLAN standard on their campuses.

Fig. 4 shows the average number of users accessing WLAN service by area in all Malaysian HEIs. The focus areas were the lecture room, administration office, libraries, and dormitories. Ten HEIs have between 51-100 concurrent users, and five HEIs have more than 101 concurrent users accessing WLAN in the lecture room. The libraries and dormitories have the most connected users, whereas ten HEIs have more than 101 concurrent users connected to the WLAN service in both locations.

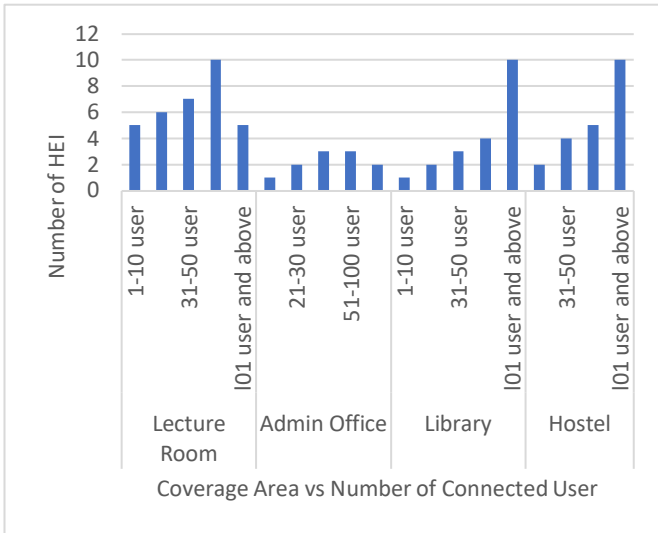


Fig. 4 The Number of HEIs vs the Number of Users by Area

In WLAN technology, the bandwidth is shared by the number of users concurrently connected to the network [25]. A user may experience a slower data rate when more users connect to the WLAN. Therefore, high WLAN bandwidths are necessary to ensure the smooth running of teaching and learning activities using sophisticated tools. In addition, most of the WLAN users at HEIs are the students and staff, who often use laptops and smartphones to access the WLAN. One of the factors determining the WLAN quality of the received signal is the sensitivity of the transmitter and receiver devices [26]. Most new end devices, such as laptops and smartphones, support new WLAN standards such as 802.11ac and 802.11ax. However, since some HEIs still offer the old 802.11 standards such as 802.11a, 802.11b, 802.11g, and 802.11n, the user's end device could not receive the high-speed data rate because there is no drawback compatibility between the user devices and the existing access points. In 2011, Craig Mathias [27] stated that the 802.11n introduced in 2009 was almost obsolete with the introduction of the new 802.11ac. 802.11ac and 802.11ax were deployed in 2022. Table 1 shows that 802.11ac and 802.11ax have improved the performance of WLAN technology and solved issues in 802.11n. Malaysian HEIs must deploy more reliable, compatible, updated technology WLAN with less interference. In particular, Malaysian HEIs must deploy 802.11ac as the minimum WLAN standard to support smart campus implementation.

C. WLAN Populated Coverage Area

The survey asked the following questions to investigate the WLAN coverage area at Malaysian Public HEIs.

Q1: What is the percentage of populated areas covered by WLAN?

Q2: What is the average monthly percentage of wireless network bandwidth utilisation by end users at your HEI?

Q3: What are the preferred categories of network applications accessed by wireless network end users in your HEI?

Q4: Which of the following areas have access to WLAN?

The survey result showed that the users at HEIs used WLAN to access several categories of network services, web applications, entertainment, finance, businesses and social media. A good network bandwidth provided throughout WLAN coverage must be available to ensure uninterrupted access to network applications [12]. Sufficient WLAN coverage is necessary to ensure the availability of WLAN services at all HEIs.

WLAN is often deployed in a network, including by HEIs, because of its easy installation and flexible access. However, good placement of the access point is crucial to ensure maximum coverage with minimal access points. Wan *et al.* [28] proposed using the Brute Force algorithm to predict the best place for the access point for indoor WLAN. Network implementors often employ heat mapping techniques using the available heat mapper tools on the Internet to indicate the signal strength and coverage planning for some areas [29].

A smart campus must provide access to information throughout the campus [7]. Therefore, WLAN coverage in Malaysian HEIs should be sufficient to support smart campus initiatives and strengthen teaching and learning activities. The readiness of WLAN coverage at HEIs to support smart campuses can be measured based on the area with WLAN coverage over the whole HEI area.

Assuming a wide coverage area, HEIs must be prepared to implement smart campus initiatives. The formula for calculating is as follows.

$$R = C/T * 100 \quad (1)$$

Where:

R= Readiness

C= Total Covered (the total area in HEI with WLAN coverage)

T= Area to be covered (the total area in HEI with student population)

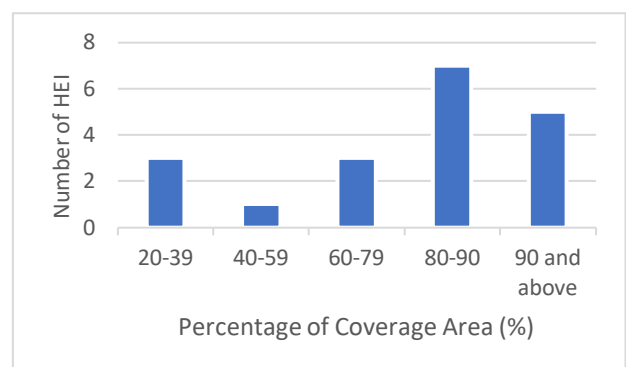


Fig. 5 Percentage of WLAN Coverage Area in the HEIs

This study focused on indoor WLAN deployment. The survey asked about the percentage of WLAN-populated areas to know the status of the WLAN coverage deployment area in

the HEIs. Fig. 5 presents the study result, which shows that five HEIs have less than 60% WLAN coverage over the indoor campus area, ten have between 60-89%, and five HEI have at least 90%.

Based on the results in Figs. 4 and 5, this study concluded that all main areas in the HEIs have WLAN coverage. However, the signal coverage in each main HEI area did not reach 100%. In this case, the areas probably have a dead area zone, which causes the mobility advantage offered by WLAN not to be delivered to the end users because the users roaming within the floor may lose connection to the network. For example, a student downloading or uploading online materials from the HEI's online learning portal while moving on the floor may lose network connection when passing through the dead area zone, causing the downloading and uploading activity to be discarded. It is crucial to ensure there is no gap between the adjacent areas. The areas in HEI must have at least a 10-15% overlapping coverage to allow uninterrupted roaming. Proper signal measurement using WLAN signal strength measurement tools and rearranging the position of the access points can minimize or remove the dead zone areas [30]. HEIs with less than 60% WLAN coverage must redesign the network to avoid too many dead areas in their network since this will disrupt the teaching and learning activities on the campus.

IV. CONCLUSION

The Ministry of Higher Education (MOHE) must ensure that Malaysian Public HEIs are ready to adopt smart campus initiatives and IR4.0. The ninth shift outlined in the Malaysia Blueprint 2015-2025 (Higher Education) stated that it is almost impossible to achieve globalised online learning without a good ICT infrastructure, which includes a WLAN infrastructure. This study has achieved its objective of measuring the readiness of WLAN infrastructure to support smart campus initiatives. The discussion in this paper considered several factors, namely the availability of WLAN infrastructure, WLAN logical architecture, and WLAN populated coverage area. All Malaysian HEIs are ready with the availability of WLAN since they have deployed the services to the end users. Concerning WLAN logical architecture, all HEIs deployed mixed WLAN standards. However, three Malaysian HEIs are still not ready to support smart campus initiatives as the WLAN standard deployed in their HEI did not reach the minimum 802.11ac requirement of the WLAN standard and required device upgrading. Finally, four HEIs are not ready in terms of WLAN populated coverage area because their populated indoor areas have less than 50% WLAN coverage. These HEIs must redesign their WLAN to minimize the dead zone before implementing the smart campus initiatives. Malaysian public HEIs would be better prepared to support smart campus initiatives for the factors discussed in this paper if they have an appropriate WLAN network plan. Therefore, we must develop a model for predicting WLAN performance in the planning phase.

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