Journal of Positive School Psychology
2022, Vol. 6, No. 3, 8599–8610 http://journalppw.com

Using Data-Driven for Improved Educational Experience During Covid19

Haryani Haron[1], Nasiroh Omar[2], Sharifah Aliman[3], Azlan Ismail[4], Mohamad Yusof Darus[5], Azizi Mohd Ariffin[6]

[1,2,3,4,5,6] Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
[1]harya265@uitm.edu.my, [1]haryani@tmsk.uitm.edu.my
[2] nasiroh@uitm.edu.my, [3]sharifahali@uitm.edu.my, [4]azlanismail@uitm.edu.my
[5] yusof@tmsk.uitm.edu.my, [6]mazizi@tmsk.uitm.edu.my

Abstract

The Covid19 pandemic shifted the higher education institutions learning ecosystem, from face-to-face teaching to online learning. In the era of data-driven, decisions made must be supported by data. While many studies focused on data analytics' learning potential, this research embark on the practical aspect of data analytics application to support decision making of the university's management for improved education experience among the students. The efficiency of online learning depends on students' internet accessibility. This research aims to gauge the students' internet accessibility and propose suitable approaches for teaching and learning. A three-phase data analytics process flow are employed, namely the data preparation, data transformation and data analysis. Data are gathered from two secondary sources, the university databases, consisting of students' records and telecommunication towers for network profiles. The findings of this research show about 1.3% of the students are without internet access. The fraction is small, however it made up to about 1958 students. The higher-end network type (4G) is best for online sessions, however about 2235 students (1.5%) have limited access to only 3G network. The diploma and degree students are the majority of students having access to lower-end network technology. Students using lower-end technology, such as 2G, may experience interruptions even if an asynchronous approach to online instruction is adopted. In line with the university's effort of 'no students left out' the numbers are a concern. This study contributed towards giving insights on the students' internet accessibility and developing a data-driven teaching and learning approaches based on network types. In terms of practical contribution, two applications are developed, a dashboard for the top management to refer for decision-making, the second one is the system for the lecturers to use to plan their teaching approaches taking into consideration of their students' internet accessibility.

Keywords: Big Data, Data Analytics, Higher Education Institutions, Pandemic, IR 4.0.

I. INTRODUCTION

The Industrial Revolution 4.0 (IR 4.0) bolsters the usage of technologies like big data analytics. The use of big data analytics in higher education has been explored extensively with applications ranging from student learning performance to improving higher education operations (Ashaari,2020; Daniel, 2015).

The COVID-19 pandemic disrupted the educational ecosystem, forcing sudden paradigm change especially to the teaching and learning process. The changing landscape of the learning ecosystem, transforming it into digital environment, forcing higher institutions to switch from face to face or blended learning approach (Mabni, Shamsudin, Aliman & Latif,

2020) to online teaching or open distance learning.

Few studies have been conducted into how higher education institutions are dealing with the shift. Many studies and assessments of the COVID-19's potential impact on higher education have been published and the ability of data analytics in enhancing learning process and enriching the learning experience in an online setting has been highlighted by Vanthienen and De Witte (2017). However, how the COVID-19's online learning is performed leans toward a generic perspective.

The effectiveness of online learning hinged on addressing students' internet accessibility needs. Limited internet connection, as well as insufficient online learning infrastructures, are issues in Malaysian online learning (Selvanathan, 2020; Lee, 2020), especially in rural and isolated locations.

In addressing the needs to integrate appropriate learning and learning approaches into online teaching, the students' internet availability based on their geo-locations (Hamidi, Ibrahim, Rahman & Shuhidan, 2017) has to be identified. This study aims to gauge and explore the insights emerging from the students' internet accessibility information. The scope of this study is confined on the mobile connectivity as ICT-support technology (Aziz, Haron & Harun, 2020), the commonly used and most affordable network services in Malaysia.

II. LITERATURE STUDY

According to a technical analysis published by the Internet Society (2017), internet connectivity presents significant opportunity to improve educational quality; but, in many countries, lack of internet connection is the most significant barrier to improving educational outcomes. Students' learning experiences are made more challenging when they face technological obstacles, as a result of their inability to purchase adequate online learning support facilities, notably internet connections (Al-Kumaim et al., 2021). Other studies from Tan (2021) and (Sundarasen et al, 2020) supported the role of internet access in ensuring the effectiveness of online learning.

The COVID-19 pandemic has reshaped the education delivery, shifting from traditional face to face towards virtual learning globally. As such, numerous studies have been conducted on the experience of conducting online learning. Table 1 summarizes the findings from the studies.

Table 1 - Findings from Online Implementation During COVID-19 Pandemic

Authors	Findings
	• Less internet connection stability during Covid19
Barada, Doolan, Buri, Krolo & Tonkovi (2020)	i. Europe
Neupane, Sharma & Joshi (2020)	ii. India
Ghasem and Ghannam (2021)	iii. Arab
Cicha, Rizun, Rutecka & Strzelecki (2021)	iv. Poland
Dube (2020)	v. South Africa
Hasin and Nasir (2021)	• Inequity in education transmission based on the learners' demographic location
Shahzad et al. (2020)	• The success factors of e-learning portal.
Abdul-Hamid and Hamzah, 2021, Roslan and Halim, 2021, Tukiman, Khalid, Onn, Foong & Amran, 2020, Nik-Ahmad-Zuky, Baharuddin & Rahim, 2020).	• The variation of internet connectivity based on geo-locations for online learning.

Findings from Table 1 shows that internet connectivity is an area of concern for online learning implementation.

In the context of Malaysia, although the figure by the Department of Statistics, Malaysia, in 2020 shows an increment from 87 percent in 2018 to 90.1 percent in 2019 for household internet penetration, there is still a divide between underserved areas (Darus, 2021) and the rest of the country. According to a Multimedia Malaysian Communications and Multimedia Commission (2020) Internet user study, the percentage of Internet users in 2020 was 88.7%, up 1.3 percent from 87.4% in 2018, and smartphones are the most popular devices for accessing the internet, with a near-saturation level of 98.7%.

The MCMC’s Network Performance Report 2020 emphasises the need for Malaysia to improve mobile broadband coverage and speed for home internet packages as a result of Covid19. According to Roslan and Halim (2021), 71.9 percent of Malaysian participants had fourth generation (4G) mobile broadband speeds at home, 10.1 percent had third generation (3G), 0.6 percent had Enhanced data GSM evolution (EDGE), and 6.2 percent had high speed packet access (HSPA).

The findings from the studies and reports provide a general view of internet connectivity scenario. A micro-level analysis on a targeted institution will provide a more comprehensive and deeper view for actionable information. Data visualization has the ability to produce actionable information and insights.

Visualization is the key to turning data into useful information, especially when working with large amounts of data that may contain abnormalities and abstract elements that are difficult to recognise (Noh, Abidin, Omar, Aliman & Ardi, 2018; Wang et. al, 2015). Studies on COVID-19 have use several visualization techniques such as map-based, timeline graph, geospatial map and dashboard. Lakshmi and team (2021) used the map-based representations of the COVID-19 disease's spread, where the frequency of cases is represented in regions, and timeline-based data visualisation, known as Epidemic curves. Afzal (2020) used a geospatial map to create a spatiotemporal model simulation data related to COVID-19.

Multiple connected features can be explored simultaneously for actionable insights using visualization-based solutions via a data dashboard. Many researchers used a data dashboard to display multi-data perspectives including narrowband IoT coverage (Kousias, et al, 2020), people's travel patterns at public stations during Covid19 (Zuo, et al, 2020), and Covid19 spread (Zaman, Islam, Zaki & Hossain, 2020, Budd et. al, 2020). The interactive geo-spatial visualisation was created by Kousias and his colleagues (2020) to uncover operators' narrowband IoT coverage zones. Real-time traffic cameras were employed by Zuo et al. (2020) to visualise human motion. According to Budd et al. (2020), most COVID-19 dashboards, such as the WHO Coronavirus (COVID-19) Dashboard and the Covid19 Dashboard Ministry of Health Malaysia, offer time-series charts and geographic maps ranging from regional to individual coordinates.

According to the reviewed literature, there is a research gap in understanding overall internet connectivity that uses personalised data to provide management insights in two ways: state-of-the-art insights at a high level and low-level insights to view personalised details related to internet connectivity and ability. Such information is extremely useful in making appropriate and adaptable decisions in online teaching and learning.

III. METHODOLOGY

This study is carried out at one of Malaysia's largest universities. There are over 150,000 students enrolled, and academic programmes ranging from diploma to PhD level, as well as professional credentials, are available. Prior to the COVID-19 pandemic, the university only allowed up to 30% of studying and teaching to be done online, with the rest requiring face-to-face interaction. As a result, the national lockdown had a huge impact on university administration, forcing them to act quickly while maintaining educational quality and transitioning to entirely online study.

The students’ geographically dispersed, with some living in remote rural locations, making it difficult for them to subscribe to high-speed internet. As a result, high-level university management has an immediate need to gather comprehensive data on all students' internet connectivity and socioeconomic situation in relation to their branch, faculties, and current courses.

A pragmatic approach was used in this study to describe the students' internet accessibility. In order to achieve the objective of the study, a three-phase data analytic process flow is used, namely the data preparation phase, data transformation phase, and data analysis phase. Figure 1 depicts the flow of the data analytics process.

This study is carried out at one of Malaysia's largest universities. There are over 150,000 students enrolled, and academic programs ranging from diploma to PhD level, as well as professional credentials, are available. Prior to the COVID-19 pandemic, the university only allowed up to 30% of studying and teaching to be done online, with the rest requiring face-to-face interaction. As a result, the national lockdown had a huge impact on university administration, forcing them to act quickly while maintaining educational quality and transitioning to entirely online study.

The students' geographically dispersed, with some living in remote rural locations, making it difficult for them to subscribe to high-speed internet. As a result, high-level university management has an immediate need to gather comprehensive data on all students' internet connectivity and socioeconomic situation in relation to their branch, faculties, and current courses.

A pragmatic approach was used in this study to describe the students' internet accessibility. In order to achieve the objective of the study, a three-phase data analytic process flow is used, namely the data preparation phase, data transformation phase, and data analysis phase. Figure 1 depicts the flow of the data analytics process.

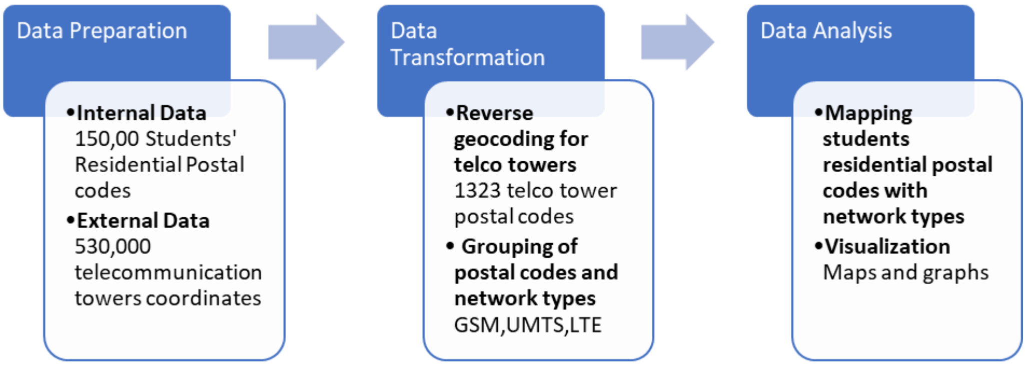

Figure 1: Data Analytics Process Flow

In the data preparation phase, data are collected data from two secondary sources, which is the students' records (internal data) and telecommunication towers coordinates (external data). All the data gathered are from reliable sources, students' records are extracted from the university's database, and telecommunication towers longitude and latitude are downloaded from open signal database. The output for data preparation phase is two sets of data, the students' residential postal codes and the telecommunication tower coordinates.

Data transformation phase's activities involves extracting the telecommunication towers postcodes through reverse geocoding process using ArcGIS software, a geographical information system (GIS) mapping software. Once the tower's postcodes are discovered, the network coverage can be identified. Basically, there are three types of network coverage, which are: -

i. Global System for Mobile Communications (GSM), a second-generation (2G) digital cellular networks technology.

ii. Universal Mobile Telecommunications System (UMTS), a third generation (3G) mobile cellular networks technology.

iii. Long Term Evolution (LTE), a 4th generation (4G) of radio technologies networks.

In the data analysis phase, mapping of student's residential postal codes and telecommunication towers are done through descriptive statistical tests. Students' network coverage based on their residential addresses are derived. Visualization of the information are done through bubble maps and graphs.

IV. RESULTS AND FINDINGS

A total of 150,821 student profiles are collected. According to the overall student profiles, about half of the students are enrolled in a degree programme, followed by those pursuing a diploma. 47 percent of students are from the central zone, 20% from the northern zone, 13% from the southern zone, 12% from the eastern zone, and 8% from Sabah and Sarawak. The socioeconomic position of the students reveals that slightly more than half of them fall into the B40 category.

In terms of network coverage, network data is obtained in the form of coordinates that indicate the longitude and latitude of telecommunication towers. The OpenSignal database, which is a crowdsourcing database used by the public and telecommunications industry, has been used to obtain a total of 530,000 coordinates. When the coordinates are reverse geocoded, the nearest postal code for the tower location and network types is identified. Telecommunication towers are dispersed throughout 1323 postal codes. In total, there are 2,864 postal codes in the country.

A total of 1700 postal codes corresponded to the 150,821 students' home addresses. The discovered telecommunication towers' postal codes (1323 postal codes) are overlaid with the students' residential postal codes to establish the students' network coverage (1700). There were 1019 postal codes that matched, indicating that 304 telecommunication towers do not correspond to any of the students' postal codes. However, none of the 681 students' residence postal codes correspond to any of the telecommunication towers' postcodes. The absence of network profiles could be due to a lack of network connectivity or a failure to recognise tower postcodes. As mentioned in the methodology section, three types of networks are available, mainly the GSM with 2G technology, UMTS with 3G technology, and LTE with 4G technology, and in a single postal code, there can be many types of network. Table 2 lists the number and percentage of postal codes along with their network profiles. The calculation of percentage is based on two decimal points, therefore the total percentage may not be equal to 100%.

Table 2 – Distribution of Postcodes and Network Types

Postal Codes and Network Types	Number	Percentage (%)
Postal code with GSM, LTE, UMTS	879	51.71
Postal code with GSM, UMTS	61	0.06
Postal code with GSM, LTE	1	0.06
Postal code with UMT, LTE	11	0.65
Postal code with UMTS	43	2.53
Postal code with GSM	11	0.65
Postal code with LTE	4	0.23
Postal code without network Information	681	40.06
Total	**1700**	**99.47**

Since the study aims to obtain the information on the students' network coverage, a deepr analysis is done. The number of students in each postal codes are extracted and mapped with the network types. In Table 3, the number and percentage of students is tabulated according to the network types that they have access to. As mentioned earlier, the calculation of percentage is based on two decimal points, therefore the total percentage may not be equal to 100%.

Table 3 – Distribution of Students Based on Postcodes and Network Types

Postal Codes and Network Types	Number of Postcode (approx..%)	Number of Students (%)
Postal code with GSM, LTE, UMTS	879	146.440 (97.1%)
Postal code with GSM, UMTS	61	1467 (0.97%)
Postal code with GSM, LTE	1	6 (0.004%)
Postal code with UMT, LTE	11	162 (0.11%)
Postal code with UMTS	43	645 (0.43%)
Postal code with GSM	11	123 (0.08%)
Postal code with LTE	4	20 (0.01%)
Total Postcodes and Students	1,019(60%)	148,863 (98.7%)
Postcode with no network profiles	681(40%)	1958 (1.3%)
Total	**1700**	**150,821**

A big percentage about 98.7 percent (148,863) of students have access to network coverage, but the types of networks vary. Almost all students with network coverage are accessible to the faster 4G technology (LTE) (97.1% , 146,440).Although only 0.08 percent of pupils who have access to a network can use 2G technology (GSM), the number reaches 123.

To provide deeper insights and provide a suitable way of teaching and learning, a deeper analysis of the students' profiles in terms of their level of studies and network coverage is required. Table 4 illustrates a comparison of network types versus study level. The majority of students (98%) with the lower 2G technology (GSM) coverage are enrolled in diploma and degree programmes. Although the percentage reflected only 2% of the students are accessible up to 3G network coverage, the number come out to 2235 students.

Table 4 – Network Coverage Types and Level of Study

	GSM	LTE	LTE, GSM	UMTS	UMTS, GMS	UMTS, LTE	UMTS, LTE, GMS	Total
Matriculation/Certificate	1			11	30	2	3656	**3700**
Diploma	55	7	4	258	636	76	63051	**64,087**
Degree/Advanced Diploma	65	12	2	358	766	79	72686	**73,968**
Master		1		12	26	4	4600	**4643**
PhD	2			6	8	1	1742	**1759**
Professional					1		705	**706**
Total	**123**	**20**	**6**	**645**	**1467**	**162**	**146,440**	**148863**

Academic programmes have different network coverage requirements. Science and technology-based academic programmes, for example, require higher-end connectivity technologies because the studies involve using lab sessions with simulation environments or specialised software. As a result, additional cross-analysis of the students' network coverage and academic programmes is carried out as shown in Table 5. Science and Technology (S&T), Business and Management (B&M), and Social Science and Humanities (SS&H) are the three academic programmes clusters.

Table 5 – Network Coverage Types based on Academic Program Cluster

	GSM	LTE	LTE, GSM	UMTS	UMTS, GMS	UMTS, LTE	UMTS, LTE, GMS	Total
Science and Technology	52	12	3	233	579	61	53163	**54103**
Business and Management	44	5	3	290	588	73	65947	**66950**
Social Science and Humanities (SS&H)	27	3		122	300	28	27330	**27810**
Total	**123**	**20**	**6**	**645**	**1467**	**162**	**146,440**	**148863**

About 99% (66,028) of the S&T students are accessible to up 4G technology, however the 1% students who are accessible up to 3G technology is about 922 students.

V. DISCUSSION

The objective of the study is to analyse the internet accessibility of the students in supporting online teaching and learning during Covid-19. Internet accessibility is scoped into network coverage including network types. Based on the analysis and results, a total of 1958 (1.3%) students can be classified without network coverage. In terms of percentage this is only a small fraction of the overall students, nevertheless, the number is a concern.

As for the network coverage types, the higher end network type (4G) is suitable for online session. Similar to the small percentage of students without network, only 2% of the students are only accessible up to 3G network coverage but the number is 2235 students. This is another factor that needs to be considered when making decisions on teaching and learning.

Another important insight is, the diploma and degree students madeup the majority of students which have the lower end network technology (2G). The diploma and degree programs are inclined heavily towards face to face learning. Although asynchronous approach can be utilised for online teaching, students with lower end technology like 2G, may experience interrupted services.

Different academic programs requires different network coverage. Science and technology based academic programs requires a higher end of network technology. There is 922 students enrolled in Science and Technology academic programs are accessible only to the 3G network. Data-driven decisions are important in handling uncertainties during COVID19 pandemic. In order to support teaching and learning, and more importantly to ensure inclusivity for learning, the university undertakes this study. Lesson learned from experience of other higher education embarking into online learning and the insights from this study are important considerations in making decisions for teaching and learning approaches during COVID19. Therefore, when the university decided to embark on Open Distance Learning (ODL) rather than online learning, the decision is supported with data on the distribution of students and their network connectivity.

As a guideline, this study proposed teaching and learning approaches based on network types. However for the students without network coverage, locating to nearest campuses or sending materials by courier services are some of the options.

Table 6 - A Framework of Proposed Teaching and Learning Methods based on Network Coverage.

Network Type	Proposed Method	Justification
1. GSM (Indicate whether the area has data connectivity via EDGE or GPRS (2G or 3G)) SMS, MMS, WhatApps, and text files are all supported.	• SMS, MMS, WhatApps, and text files are all supported. • Only text files with a file size of less than 1MB should be shared. • Appropriate for asynchronous learning and teaching.	• 2G networks deliver 64 Kbps data transfer, according to the ETSI standard. • Thus, downloading a 1 MB file from 2G takes about 15 minutes.
2. UMTS (Indicate whether the location has HSDPA or 3G+ data access.)	• SMS, MMS, and WhatApps, as well as text files, multimedia files (images, audio, animation), and movies are all supported. • There is no specific file size that is ideal, however a large file may cause a delay in downloading time. • Webex, Google Meet, and other synchronous teaching learning platforms perform admirably.	• According to Obaidat, Nicopolitidis, and Zarai (2015), a 3G network's practical data rate is 2Mbps. • The download time for a 1MB file is approximately 1 second.
3. LTE (Indicate whether or not the location has 4G service.)	• All types of video streaming are supported. As a result, 4G is ideal for video streaming services like Google Meet and Zoom. • For synchronous teaching and learning, the network coverage is ideal.	• The 4G network offers a data transfer rate of up to 20Mbps in practise (Ezhilarasan & Dinakaran, 2017). • For 4G, downloading a 1MB file takes only a fraction of a second.

For the sustainability of the study, the invaluable data and analysis are incorporated into an application named Student Signal Coverage Quick Search, which was developed for the usage of lecturers. This system will assist the lecturers in identifying the students network coverage for a better planning in developing the most suitable ODL approach besides coming up with suitable teaching and learning materials. In total, about 23,000 lecturers have accessed and used the application. Figure 2 is a snapshot of the system which is linked to the University's website under Academic Affairs Department.

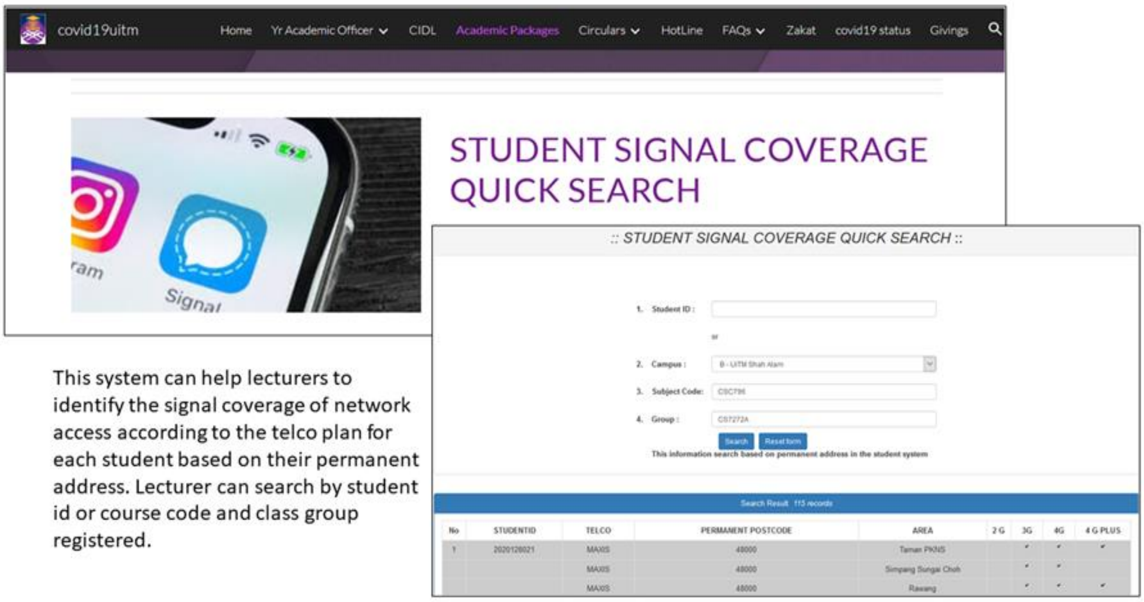

Figure 2: Snapshot of Student Signal Coverage Quick Search

As for the top management usage, a dashboard application is developed. The dashboard system provides a comprehensive visualization through bubble maps provide in-time information for any decision-making process. Each bubble are color coded based on the network types. Zooming in into each bubble will reveal the students' number and profiles in a certain bubble or location. A report of the students in a certain location can be downloaded in a worksheet. Figure 3 shows the snapshot of the dashboard from the top management's view on the students' network accessibility.

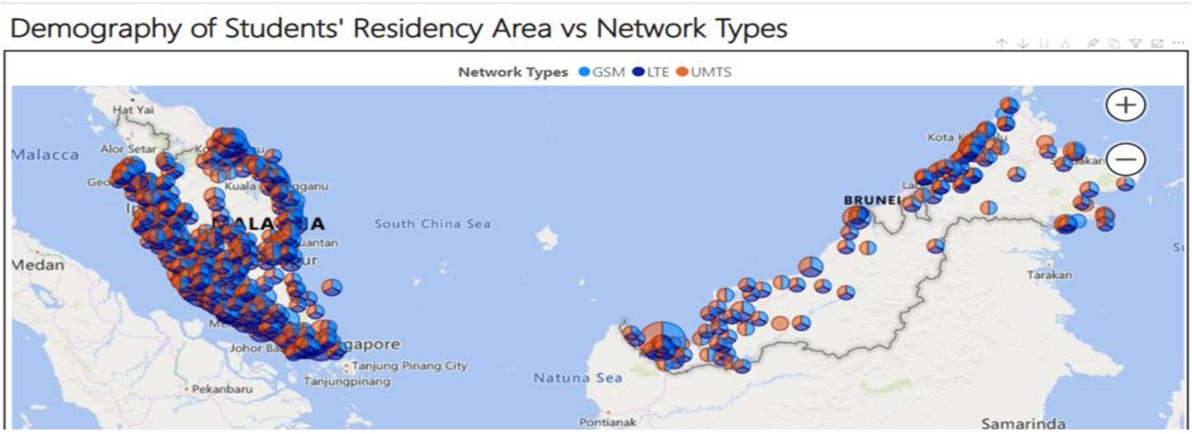

Figure 3 : Bubble map visualization for Students' Network Types

VI. CONCLUSION

Internet connectivity is an important factor for an online learning environment. The internet connectivity in different parts of Malaysia varies and in some cases, isolated geographic places are not accessible to network coverage. This study leverages on data analytics to profile students' internet accessibility according on their geographic location, and proposes a guideline for suitable approaches for online teaching and learning for a better educational experience during Covid-19 in Malaysian higher education

There are limitations for the study, firstly the network data downloaded from the telecommunication towers using the open signal database. Opensignal database is a collection of data through crowdsourcing by public and telecommunication providers. Thererefore there may be some network coverage data which have not been updated.

Another limitation is the scope of the study covers only mobile communication services, which is widely used and most affordable in Malaysia. It does not include broadbands services. It is important to highlight that cellular network capacity also depends on the Telco Tower mobile backhaul capacity. Although the last mile access for a cellular network is using the wireless medium for the mobile user and the capacity of the medium is based on the allocated spectrum (e.g 4G-LTE, up to 20Mbps), the network packet needs to be routed back to centralized telco office IP-based network for internet connectivity. If the backhaul link between the telco tower and the telco office is congested, it can impact the capacity and internet speed of mobile users connected to the telco tower. According to a study by Ahamed & Faruque (2018), the mobile backhaul capacity varies and depends on the implementation and business strategy of the telco provider.

Nevertheless, this study expanded the applications of data analytics in higher education for improving the services provided particularly in teaching and learning. The study contributed practically in developing two systems for the lecturers and another one for the top management from the data collected. The proposed guideline for teaching and learning approaches based on network connectivity contributed towards new knowledge.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, for providing funds and permission to present this research at the 2nd International Conference on Information Security and Computer Technology (ICISCT 2021) which formerly known as ICAIS2020 (International Conference of Advanced Information Security).

BIBLIOGRAPHY

1. ABDUL-HAMID, S., & HAMZAH, R. (2021, March). How Ready Were Malaysian Undergraduates for the Sudden Online Classes During the COVID-19 Pandemic?. In First International Conference on Science, Technology, Engineering and Industrial Revolution (ICSTEIR 2020), pp. 423-430. Atlantis Press.
2. AFZAL, S., GHANI, S., JENKINS-SMITH, H. C., EBERT, D. S., HADWIGER, M., & HOTEIT, I. (2020, October). A Visual Analytics Based Decision Making Environment for COVID-19 Modeling and Visualization. 2020 IEEE Visualization Conference (VIS), pp. 86-90
3. AHAMED, M., & FARUQUE, S. (2018). 5G Backhaul: Requirements, Challenges, and Emerging Technologies. Broadband Communications Networks - Recent Advances And Lessons From Practice. doi: 10.5772/intechopen.78615
4. ASHAARI, MOHAMED, AMRAN, AZLAN, SINGH KARPAL AND SINGH DARA (2020), Big Data Analytics Capability for Improved Performance of Higher Education Institutions in the Era of IR 4.0: A Proposed Conceptual Framework, International Journal of Innovation, Creativity and Change. 13(8) 2020
5. AL-KUMAIM, N. H., ALHAZMI, A. K., MOHAMMED, F., GAZEM, N. A., SHABBIR, M. S., & FAZEA, Y. (2021). Exploring the impact of the COVID-19 pandemic on university students' learning life: An integrated conceptual motivational model for

sustainable and healthy online learning. Sustainability, 13(5), 2546.

6. AL-KUMAIM, N. H., MOHAMMED, F., GAZEM, N. A., FAZEA, Y., ALHAZMI, A. K., & DAKKAK, O. (2021). Exploring the Impact of Transformation to Fully Online Learning During COVID-19 on Malaysian University Students' Academic Life and Performance. International Journal of Interactive Mobile Technologies, 15(5).
7. AZIZ, N. H. N., HARON, H., & HARUN, A. F. (2020). ICT-supported for participatory engagement within E-learning community. Indonesian Journal of Electrical Engineering and Computer Science, 20(1), 492-499.
8. BARADA, V., DOOLAN, K., BURIĆ, I., KROLO, K., & TONKOVIĆ, Ž. (2020). Student life during the COVID-19 pandemic lockdown: Europe-Wide Insights. University of Zadar.
9. BUDD, J., MILLER, B. S., MANNING, E. M., LAMPOS, V., ZHUANG, M., EDELSTEIN, M., ... & MCKENDRY, R. A. (2020). Digital technologies in the public-health response to COVID-19. Nature medicine, 26(8), 1183-1192.
10. CICHA, K., RIZUN, M., RUTECKA, P., & STRZELECKI, A. (2021). COVID-19 and higher education: first-year students’ expectations toward distance learning. Sustainability, 13(4), 1889.
11. COVID19 DASHBOARD MINISTRY OF HEALTH MALAYSIA, http://covid-19.moh.gov.my/ (accessed 2 June 2021).
12. DARUS, M. Y. (2021). A Case Study On Digital Divide And Access To Information Communication Technologies (ICTs) In Pulau Tuba, Langkawi, Malaysia. Turkish Journal of Computer and Mathematics Education (TURCOMAT), 12(5), 1710-1718.
13. DANIEL, B. (2015). Big Data and analytics in higher education: Opportunities and challenges. British journal of educational technology, 46(5), 904-920.
14. VANTHIENEN, J. & WITTE, K.D, (2017).Data Analytics Applications in Education, Publisher: Taylor and Francis
15. DUBE, B. (2020). Rural online learning in the context of COVID 19 in South Africa: Evoking an inclusive education approach. Multidisciplinary Journal of Educational Research, 10(2), 135-157.
16. EZHILARASAN, E., & DINAKARAN, M. (2017). A Review on Mobile Technologies: 3G, 4G and 5G. 2017 Second International Conference On Recent Trends And Challenges In Computational Models (ICRTCCM). doi: 10.1109/icrtccm.2017.90
17. GHASEM, N., & GHANNAM, M. (2021). Challenges, Benefits & Drawbacks of Chemical Engineering On-Line Teaching During Covid-19 Pandemic. Education for Chemical Engineers. 36,107-114
18. HAMIDI, S. R., IBRAHIM, E. N. M., RAHMAN, M. F. B. A., & SHUHIDAN, S. M. (2017, November). Industry 4.0 urban mobility: goNpark smart parking tracking module. In Proceedings of the 3rd International Conference on Communication and Information Processing pp. 503-507.
19. HASIN, I., & NASIR, M. K. M. (2021). The Effectiveness of the Use of Information and Communication Technology (ICT) in Rural Secondary Schools in Malaysia. Journal of Education and e-Learning Research, 8(1), 59-64.

20. INTERNET SOCIETY, A Policy Framework for Enabling Internet Access, 2017,
21. https://www.internetsociety.org/wp-content/uploads/2021/01/bp-EnablingEnvironment-20170411-en.pdf
22. KOUSIAS, K., CASO, G., ALAY, O., BRUNSTROM, A., DE NARDIS, L., DI BENEDETTO, M. G., & NERI, M. (2020). Coverage and deployment analysis of narrowband internet of things in the wild. IEEE Communications Magazine, 58(9), 39-45.
23. LEE, S (2020, 16 June). Sabah student stays overnight in tree to get better Internet connection for online university exams. Available at: https://www.thestar.com.my/news/nation/2020/06/16/sabah-uni-student-stays-overnight-in-tree-to-get-better-internet-connection-for-online-exams (accessed 16 June, 2020).
24. MABNI, Z., SHAMSUDIN, N., ALIMAN, S., & LATIF, R. A. (2020). Factors Influencing Students' Performance in the First Computer Programming Course Taught Using Blended Learning Approach. Environment-Behaviour Proceedings Journal, 5(SI3), 181-186.
25. MAHISWARAN SELVANATHAN, NUR ATIKAH MOHAMED HUSSIN, NOOR ALVANI NOR AZAZI (2020). Students learning experiences during COVID-19: Work from home period in Malaysian Higher Teaching Public Administration 1–10 ª DOI: 10.1177/0144739420977900 journals.sagepub.com/home/tp.
26. MALAYSIAN COMMUNICATIONS AND MULTIMEDIA COMMISSION. Network Performance Report 2020,
27. https://www.mcmc.gov.my/skmmgovmy/media/General/pdf/Network-Performance-Report-2020.pdf
28. MB, LAKSHMI, REHNA BABY JOSEPH, R. SUNDER, AND M. RAJESWARI. (2021). "A Review of COVID-19 Outbreak Analysis Using Visual Analytics Approach." Available at SSRN 3851235
29. NIK-AHMAD-ZUKY, N. L., BAHARUDDIN, K. A., & RAHIM, A. F. A. (2020). Online Clinical Teaching and Learning for Medical Undergraduates during the COVID-19 Pandemic: The Universiti Sains Malaysia (USM) Experience. Education in Medicine Journal, 12(2), 75-80.
30. NOH, Z., Z ABIDIN, S. Z., OMAR, N., ALIMAN, S., & ARDI, N. (2018). An Overview of Information Visualization for Malay Poetry Studies.
31. OBAIDAT, M., NICOPOLITIDIS, P., & ZARAI, F. (2015). Modeling and simulation of computer networks and systems. Waltham, MA: Morgan Kaufmann.
32. ROSLAN, N. S., & HALIM, A. S. (2021). Enablers and Barriers to Online Learning among Medical Students during COVID-19 Pandemic: An Explanatory Mixed-Method Study. Sustainability 2021, 13, 6086.
33. SHAHZAD, A., HASSAN, R., AREMU, A. Y., HUSSAIN, A., & LODHI, R. N. (2020). Effects of COVID-19 in E-learning on higher education institution students: the group comparison between male and female. Quality & quantity, 1-22.
34. SHARMA, K., DEO, G., TIMALSINA, S., JOSHI, A., SHRESTHA, N., & NEUPANE, H. C. (2020). Online learning in the face of COVID-19 pandemic: Assessment of students’ satisfaction at Chitwan medical college of Nepal. Kathmandu

University Medical Journal, 18(2), 40-47.

35. SUNDARASEN, S., CHINNA, K., KAMALUDIN, K., NURUNNABI, M., BALOCH, G. M., KHOSHAIM, H. B., ... & SUKAYT, A. (2020). Psychological impact of COVID-19 and lockdown among university students in Malaysia: Implications and policy recommendations. International journal of environmental research and public health, 17(17), 6206.
36. TAN, C. (2021). The impact of COVID-19 pandemic on student learning performance from the perspectives of the community of inquiry. Corporate Governance: The International Journal of Business in Society.
37. TUKIMAN, N., KHALID, A. K., ONN, M., FOONG, N. S., & AMRAN, M. A. M. (2020). Online Learning Challenges and Students' Preference on Mode of Learning during COVID-19 Pandemic. International Journal of Advanced Research in Education and Society, 2(3), 72-79.
38. WANG, Y., SHEN, Q., ARCHAMBAULT, D., ZHOU, Z., ZHU, M., YANG, S., & QU, H. (2015). Ambiguityvis: Visualization of ambiguity in graph layouts. IEEE Transactions on Visualization and Computer Graphics, 22(1), 359-368.
39. WIBOWO, W., SARI, N. P., WILANTARI, R. N., & ABDUL-RAHMAN, S. (2021, May). Association rule mining method for the identification of internet use. In Journal of Physics: Conference Series (Vol. 1874, No. 1, p. 012009). IOP Publishing.
40. WHO Coronavirus (COVID-19) Dashboard https://covid19.who.int/ (accessed 2 June 2021)
41. ZAMAN, A., ISLAM, M. N., ZAKI, T., & HOSSAIN, M. S. (2020). ICT intervention in the containment of the pandemic spread of COVID-19: An exploratory study. arXiv preprint arXiv:2004.09888.
42. ZUO, F., WANG, J., GAO, J., OZBAY, K., BAN, X. J., SHEN, Y., ... & IYER, S. (2020). An interactive data visualization and analytics tool to evaluate mobility and sociability trends during covid-19. arXiv preprint arXiv:2006.14882.