Impact of COVID-19 Pandemic Measures and Restrictions on Cellular Network Traffic in Malaysia

Sallar Salam Murad[1], Salman Yussof[2]
Institute of Informatics and Computing in Energy
Universiti Tenaga Nasional (UNITEN)
Kajang, 43000, Malaysia

Rozin Badeel[3], Reham A. Ahmed[4]
Department of Communication Technology and Network
University Putra Malaysia (UPM)
Seri Kembangan, 43300, Malaysia

***Abstract*—Due to the COVID-19 pandemic, intensive controls were put in place to prevent the pandemic from spreading. People's habits have been altered by the COVID-19 measures and restrictions imposed such as social distance and lockdown measures. These unexpected changes created a significant impact on cellular networks, such as increased use of online services and content streaming, which increased the burden on wireless networks. This research work is basically a case study that aims to examine and investigate cellular network performance, including upload speed, download speed, and latency, during two periods (MCO, CMCO) in three different regions, including Kuala Lumpur, Selangor (Cheras), and Johor Bahru, to observe the effects of lockdown enforcement and other restrictions in Malaysia on cellular network traffic. We used the phone application Speedtest™ as a tool for data collection within different times during the day, considering the peak times, including morning, evening, and night times. The research findings show how COVID-19 has affected internet traffic in Malaysia significantly. This research would help perspective developers and companies to better understand and be prepared for tough times and higher load on cellular networks in future pandemics such as COVID-19.**

***Keywords*—Cellular networks; COVID-19; network performance; pandemic**

I. Introduction

COVID-19 has shifted public perceptions about pandemics, with far-reaching repercussions for the global health and economic systems that was started in Wuhan, China [1]. In barely six months (from January to June 2020), 210 nations and territories worldwide reported more than ten million sick persons, including more than 500 thousand deaths [2]. COVID-19 has caused huge economic losses in addition to the worldwide health catastrophe (e.g., a projected 25% unemployment rate in the United States) [3], as a result of that, one million Canadians lost their jobs in March 2020 [4]. The Australian economy shed 1.4 million jobs [5], as well as a global GDP loss of 3% [6]. Because of this, several analysts have projected a worldwide recession [7], [8]. Since there was no cure or vaccine back in 2020 and the virus was spreading rapidly, many countries have implemented various measures of social distancing [9], [10], [11], [12] to slow the spread of the pandemic and give more time for the pharmaceutical industry to develop a cure or vaccine. Few of these scenarios are contact tracing [13], tracking and monitoring [14], quarantine [15], and lockdown [16]. Specifically, such scenarios aim to reduce the transmission of illness by limiting the frequency and closeness of human physical contacts, such as closing public locations (e.g., schools and universities workplaces), avoiding large crowds and maintaining a safe gap among the people [9], [15]. However, the closure of schools and businesses means that many more people will have to work or study online, which will lead to an overwhelming rise in Internet traffic and online service needs, such as new Zoom users. Therefore, the load on the cellular networks has increased significantly [12], [17].

The social distancing and measures have a significant impact in reducing the spread of the virus. Malaysia was one of the countries that implemented social distancing solutions in early March 2020 [18], such as lockdown and restricted movement and measurements for individuals in outdoor areas, namely Movement Control Order (MCO) and Conditional Movement Control Order CMCO [18]. During that time, a substantial increase happened in data traffic and this has adverse effects on the network experience for the users in Malaysia. Note that Umobile, Maxis, Celcom, and Digi are the cellular networks providers in Malaysia. As soon as the MCO was launched, Malaysian smartphone users' average mobile data usage hit the roof, and this was followed by dramatic declines in the consumers' average 4G Download Speed Experience. Fig. 1 shows the recent social distancing scenarios [12] that were deployed during COVID-19 pandemic around the world.

In [19], Comcast, one of the major US operators, claims a 32% rise in upstream traffic growth and an 18% increase in downstream traffic growth outside of Europe as shown in Fig. 2, and Fig. 3 shows the increase of gaming downloads, streaming, and web video consumption and video conferencing.

It's worth noting that throughout that period in Malaysia, 4G Download Speeds for U Mobile customers increased by almost two times compared to pre-MCO levels. Until the week of May 18, data usage on most Malaysian networks was at its highest point. On average, Celcom's network experienced a 44 percent rise in data usage, followed by Maxis's 36 percent increase [18]. Compared to the beginning of the year, U Mobile subscribers' 4G download speeds were more than twice as fast by September 30th. According to [20], U Mobile has been bolstering its network infrastructure in recent months to keep up with the soaring demand for data by expanding its capacity and fine-tuning the performance of its current cells.

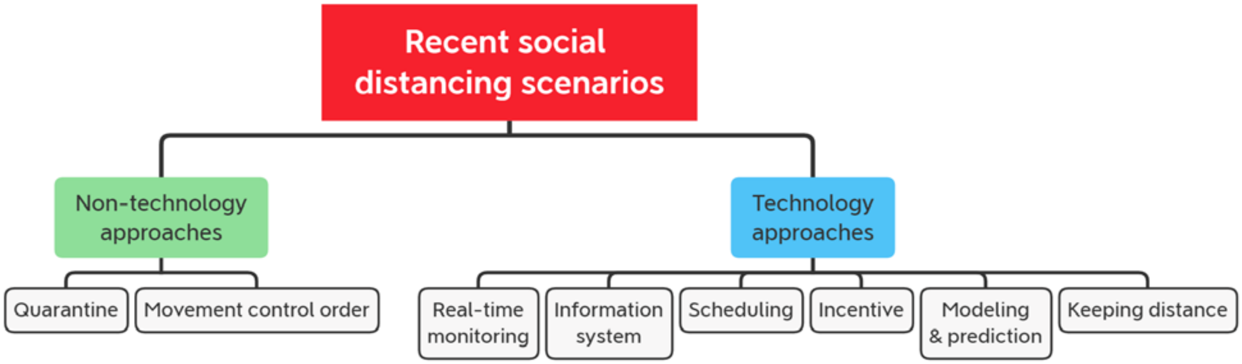


Fig. 1. COVID-19 Measures and Social Distancing Scenarios.

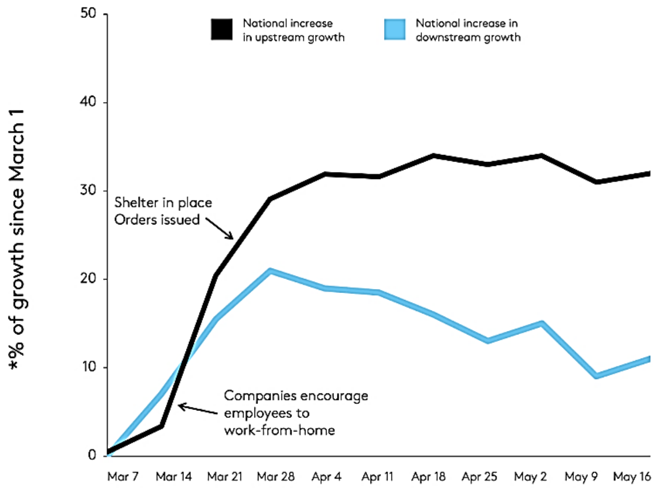


Fig. 2. Network Growth Over Time.

Fig. 3. Entertainment, Streaming, and Gaming Increase Rates.

This study aims to investigate and analyze the usage of internet services, including networks traffics, latency and speed of internet, to understand the pandemic's impact on our daily use of internet applications and services and to support future researchers and developers for maintaining and improving the digital infrastructure or services. By doing this, countries and authorities can avoid the negative side of social distancing in the future pandemic, such as negative economic impacts and disturbances of services provided by companies that rely on online connections.

The rest of the paper is organized as follows: Section II shows related research works. Section III introduces an overview of mobile data in response to the COVID-19 measures and cellular network service providers in Malaysia. Section IV presents the methodology and data collection method of this research. Section V illustrates the results and discussion. Limitations and future directions are shown in Section VI. Finally, Section VII summarizes the work as a conclusion.

II. Related Work

Microsoft claims that there has been an increase of 755% in the use of cloud servers [21], which means an increase in usage during the pandemic. Moreover, companies such as Netflix and YouTube concentrated the streaming quality in Europe to prevent network overload [22]. Moreover, since the shutdown in Italy, Cloudflare [23] and Fastly [24], two of the world's largest content delivery networks, have reported a 20–40 percent spike in daily traffic. Furthermore, according to ISPs, the rise in network traffic has been reported in public news and blog reports.

According to Vodafone [25], fixed broadband use has increased by more than 50% in Italy and Spain. With a 100% increase in upstream traffic and a 44% increase in downstream traffic during the pandemic. In [26], Telefonica IP networks had a traffic growth of about 40%, while mobile phone usage rose by approximately 50% and data usage increased by about 25% [27]. Moreover, in [26] and [28], traffic increased by 10–40% at European Internet Exchange Points. In [27], Malaysia's internet traffic increased by 23.5 percent during the first stage of the pandemic due to the additional burden of online education and video conferencing. Many cities have started using online shopping such as Lazada and grab car for food delivery and many people used streaming video services like Netflix to pass the time while they were confined to their homes.

Few studies have considered reporting some variations and statistics during COVID-19 pandemic. In the research work [29], the authors investigated the impact of the lockdown on Politecnico di Torino's campus network in Italy. They also noticed that inbound traffic had fallen significantly, but it has more than doubled outgoing traffic.

In [30], using data from a diverse set of vantage points (one ISP, three IXPs, and one metropolitan educational network), the authors examined the effect of these lockdowns on traffic shifts. We can observe that the Internet infrastructure was able to handle the new volume, as most traffic shifts occur outside of traditional peak hours. While many networks saw increased traffic demands, in particular, those providing services to residential users, academic networks experience major overall decreases. Yet, in these networks, we can observe substantial increases when considering applications associated to remote working and lecturing. The study also included the effect that government-mandated lockdowns had on the Internet by analyzing network data. Since all data sources exhibit vastly differing traffic characteristics and volumes, the authors normalized the data to make it easier to compare.

The Internet was a gateway to the world; the study [31] used data from Internet speed tests, consumer complaints, search engine optimization tools, and logs of Internet use from public libraries to understand the effects of the pandemic on Internet use and performance. Despite reports that the Internet handled the surge in traffic well, we find that complaints about Internet speed nearly tripled, and performance was degraded. The study stated that many people without Internet at home turned to public Wi-Fi hotspots during the pandemic. We find that this occurred disproportionately in neighborhoods with more students. Future distance learning initiatives should consider the challenges some students face in obtaining Internet access.

Mobile sensing has played a key role in providing digital solutions to aid with COVID-19 containment policies, primarily to automate contact tracing and social distancing measures. Many COVID-19 technology solutions leverage positioning systems, generally using Bluetooth and GPS, and can theoretically be adapted to monitor safety compliance within dedicated environments. However, they may not be the ideal modalities for indoor positioning. The study [32] conjectures that analyzing user occupancy and mobility via deployed WiFi infrastructure can help institutions monitor and maintain safety compliance according to the public health guidelines. Using smartphones as a proxy for user location, their analysis demonstrated how coarse-grained WiFi data can sufficiently reflect the indoor occupancy spectrum when different COVID-19 policies were enacted. They have demonstrated how their data source can be a practical application for institutional crowd control and discussed the implications of their findings for policy-making.

The study [33] evaluated the impact on the Internet latency caused by the increased number of human activities that was carried out on-line. Their analysis of the impact of COVID-19 pandemic relied on the results generated by both Anchoring Measurements (AMs) and User-Defined Measurements (UDMs). Beside ICMP-based latency, an evaluation of latency as seen at the HTTP level was provided. Latency is particularly important not only because it has a profound effect on some classes of applications, but also because it is, by itself, an excellent indicator of the health status of the network. We believe that the provided numbers and the related analysis will definitely help in better understanding this previously unseen event in the history of the Internet.

The article [34] provided a perspective of the scale of Internet traffic growth and how well the Internet coped with the increased demand as seen from Facebook's edge network. They have used this infrastructure serving multiple large social networks and their related family of apps as vantage points to analyze how traffic and product properties changed over the course of the beginning of the Covid-19 pandemic.

The pandemic has significantly changed people's mobility and habits, subsequently impacting how they use telecommunication networks. The study [35] has investigated the effects of the COVID-19 emergency on a UK Mobile Network Operator (MNO). The authors have quantified the changes in users' mobility and investigate how this impacted the cellular network usage and performance. Their findings brought insights at different geo-temporal granularity on the status of the cellular network, from the decrease in data traffic volume in the cellular network and lower load on the radio network, counterposed to a surge in the conversational voice traffic volume.

Table I shows a summary of related works. The motivation for this study is that no study has investigated the impact of COVID-19 restrictions and measures on cellular network traffic in different times during the day and through the year 2021 in Malaysia. Moreover, the COVID-19 restrictions and measures such as social distancing and lockdowns have increased our daily use of internet services and applications; therefore it is important to study the variations of data speeds and usage.

TABLE I. RELATED WORK SUMMARY

Ref.	**Focus**	**Findings**	**Location**	**Time frame**		**Network type**
				From	**To**	
[29]	Analyzed the changes in the traffic patterns.	1. Reveals the importance of using different lenses to fully understand the COVID-19 pandemic's impact at the traffic level: Mornings and late evening hours see more traffic. 2. Conclude that the Interne did its job and coped well with unseen and rapid traffic shifts.	The Politecnico di Torino campus network / Italy.	February 2020.	April 2020	WiFi
[30]	Analyzed network flow data from multiple vantage points, including a large academic network and a large ISP at the edge, and, at the core.	1. They found that the traffic volume increased by 15-20% almost within a week-while overall still modest, this constitutes a large increase within this short time period. 2. Traffic increases in applications that people use when at home, such as Web conferencing, VPN, and gaming.	Three IXPs located in Europe and the US.	January 1, 2020.	June 24, 2020.	The core of the Internet (IXPs), and at the edge (a metropolitan university network).
[31]	To understand the effects of the pandemic on Internet use and performance.	1. Downstream data rates changed little, but median upstream data rates at midday dropped by about a third. 2. Significant increases in the use of many important categories of online content, including those used for work communications, education, grocery shopping, social media, news, and job searches.	Wi-Fi in 73 public libraries in Western Pennsylvania/ US.	December, 2019.	September, 2020.	WiFi
[32]	Analyzes staff and students' mobility data. Seeks to investigate if location data that is passively sensed from existing WiFi infrastructure can, in fact, show the real-world effects of various COVID-19 policies on institutions.	Show that online learning, split-team, and other space management policies effectively lower occupancy. However, they do not change the mobility for individuals transitioning between spaces.	2 campuses in Singapore, and 1 in the Northeastern United States.	January 6, 2020.	April 7, 2020.	WiFi
[33]	Analyzed the impact of the COVID-19 pandemic on the latency of the Internet. The analysis focuses on Italy.	1. The analysis of a large set of measurements shows that the impact on the network can be significant, especially in terms of increased variability of latency. 2. The impact is not negligible also for Italy and the other countries in the whole of Europe. 3. The major changes have been observed in the evening, the time of the day when most of the on-line activities are related to entertainment.	Italy, Spain, France, Germany, Sweden, and whole of Europe.	February 08, 2020.	March 28, 2020.	Not specified
[34]	Used Facebook's edge network serving content to users across Facebook's family of apps to provide a perspective on how the Internet coped with and reacted to the surge in demand induced by Covid-19. Assessed the impact of this traffic surge on network stress and performance.	1. Showed that there have been changes in traffic demand, user behavior and user experience. 2. Different regions of the world saw different magnitudes of impact with predominantly less developed regions exhibiting larger performance degradations. 3. North America and Europe did not show any signs of stress in their networks, India and parts of Sub-Saharan Africa and South America did witness signs of network stress translating into degraded video experience, higher amount of traffic overflowing to indirect links and secondary CDN locations, and higher network round trip times. 4. Found that traffic increases occurred mainly on broadband networks.	Facebook servers around the world with 2.5 billion monthly active users.	January, 2020.	Late July, 2020	Facebook's Edge Network
[35]	The study focused on presenting an analysis of the changes in mobility and their impact on the cellular network traffic.	1. An overall decrease of 50%, with non- uniform changes across different geographical areas and social backgrounds. 2. Despite significant pattern changes, the MNO was able to provide service maintaining quality standards: the radio load was below common values and per user throughput was likely application limited. 3. Identified one issue in voice traffic packet loss due to excess of congestion in the interconnection infrastructure MNOs use to exchange voice traffic.	The entire country to specific regions (London).	February 23, 2020.	May 31, 2020.	Cellular network

III. Malaysia's Response to COVID-19: Problem Definition

On March 18, the Malaysian government issued a continuous Movement Control Order (MCO) [36]. Throughout the crisis, as more Malaysians stayed at home to obey the order, they rely on mobile networks for business, education, information, and pleasure expanded. The Malaysian Communications and Multimedia Commission (MCMC) detected a significant rise in data traffic and suspected that this has significantly impacted consumers' network services in a variety of ways; furthermore, with students and staff working from home [37], as well as variations in user activity during the lockdown [38], [39]. Normal internet speed may have reduced during non-peak hours, reducing total speeds. Furthermore, in order to avoid being confined in the city and to save expenses, many city workers returned to their home towns in the suburbs or rural regions.

This swing in mobile usage geography suggests that users were spending additional time in places where the network infrastructure was not designed to support such a large number of users and their increasing mobile data consumption. Following that, Beginning April 1, 2020, until restrictions were reduced, the MCMC announced that few cellular companies such as Celcom, Digi, Maxis, and U Mobile would offer all of their customers (prepaid and postpaid) 1GB of free data each day between 8 a.m. and 6 p.m., while Unifi offered various unlimited plans to support its customers [1].

As data demand grew during the early months of the outbreak [40], more users experienced poorer average 4G download rates. Given the challenges, Malaysia's mobile operators have supplied consistent coverage to their customers in this extraordinary situation. However, mobile network service is not always steady or of high quality. Several basic Quality of Service (QoS) requirements for mobile broadband have been defined by the MCMC. While there was significant dissatisfaction with network speeds, Malaysians mainly accepted their situation until the COVID-19 epidemic triggered the MCO, which restricted people to their homes and increased their dependency on high-speed internet connection for business, school, and entertainment [2]. Malaysia's internet traffic grew by 23.5 % in the first week of the MCO. Median download speed fell from 13.7 Mbps in early February to 8.8 Mbps in late March, as each additional activity imposed at strain on the entire digital infrastructure. Local telecommunications and internet service companies moved quickly to upgrade wireless backhaul to fiber optic connections in order to reduce internet disruptions and increase network performance.

Malaysian internet traffic had shifted to residential areas and increased by 30-70% by September 2020, yet internet speed had declined by 30-40% [2]. Malaysia's internet speed has significantly decreased as a result of increased bandwidth demand since the MCO's implementation [3]. Congestion may occur as a result of increased data usage, resulting in slower speeds. This has had an effect on the user experience, with longer loading times noted, particularly when accessing bandwidth-intensive media such as High-Definition (HD) streaming services. However, comparable trends have been reported worldwide, according to MCMC, with operators experiencing an unprecedented increase in bandwidth demand as a result of this behavioral shift. The vast majority of today's leisure activities, such as streaming services [41], video chats, and online gaming, take a significant amount of data. All of this puts a considerable strain on existing infrastructure.

Furthermore, E-commerce is a massive platform that is expanding at an unprecedented rate around the world. E-commerce has experienced a huge increase in sales [42], as more shoppers turn to online grocery platforms to purchase their daily necessities. Digital media providers such as Netflix are becoming popularity [43]. Malaysia ranks fifth in the world and first in Southeast Asia in terms of social media adoption, according to Hootsuite's Digital 2020 research [44]. Fig. 4 shows meaningful statistical data on internet users as well as other important elements.

The employees who are working from home rely heavily on various online conference call platforms to continue their business discussion. Every day, the ordinary Malaysian internet user spends 7 hours and 57 minutes online, which equivalent to roughly 100 days per year. This is greater than the global average user time spent. Google, YouTube, Facebook, WhatsApp, and Maybank2u are the leading five most visited websites in Malaysia [44].

The use of E-wallets in Malaysia such as Touch and Go, Grab, Fave, Samsung Pay, and others has grown [45]. The ratio dipped to 55% at the beginning of 2020, but due to the "new normal, 70% of users now feel they will use e-wallet services even if no benefits are offered [46]–[48]. Fig. 5 shows the number of payments and E-wallets statistics as well as types of E-wallets in Malaysia. People are turning to online grocery platforms to purchase their daily requirements, which have resulted in a significant surge in e-commerce sales.

In China, for example, Carrefour China recorded a 600 percent year-over-year rise in vegetable deliveries during the Lunar New Year period, and JD.com observed a 215 percent growth in online grocery sales to 15,000 tonnes in just the first ten days of February 2020 [44].

Note that the growth of ecommerce before the crises of COVID-19 has increased significantly. According to the Worldwide Ecommerce Report 2019, global retail e-commerce sales are worth US$3.535 trillion and are predicted to hit US$6.5 trillion by 2023. Malaysia is among the top five fastest-growing e-commerce countries, indicating that the country has significant e-commerce potential. Fig. 6 presents some fast facts about online shopping growth in some countries [46].

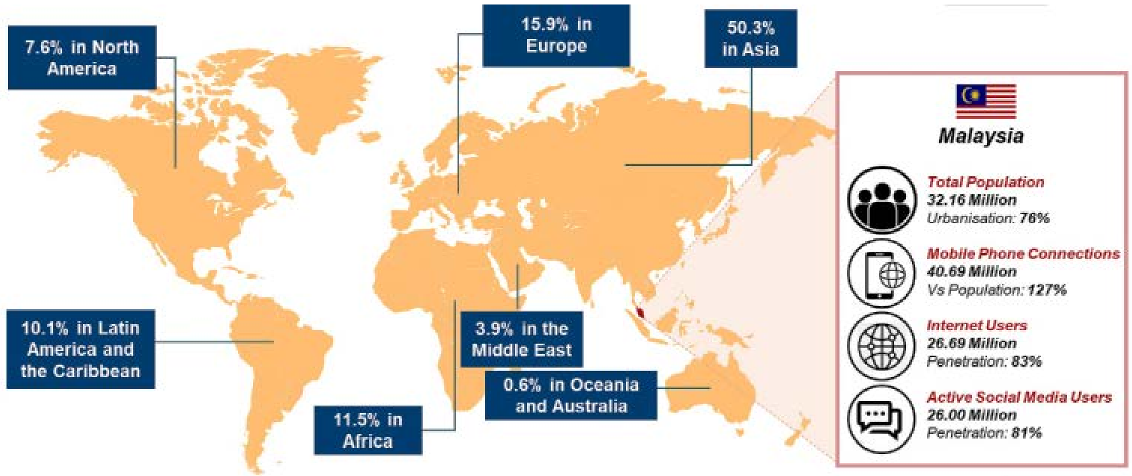
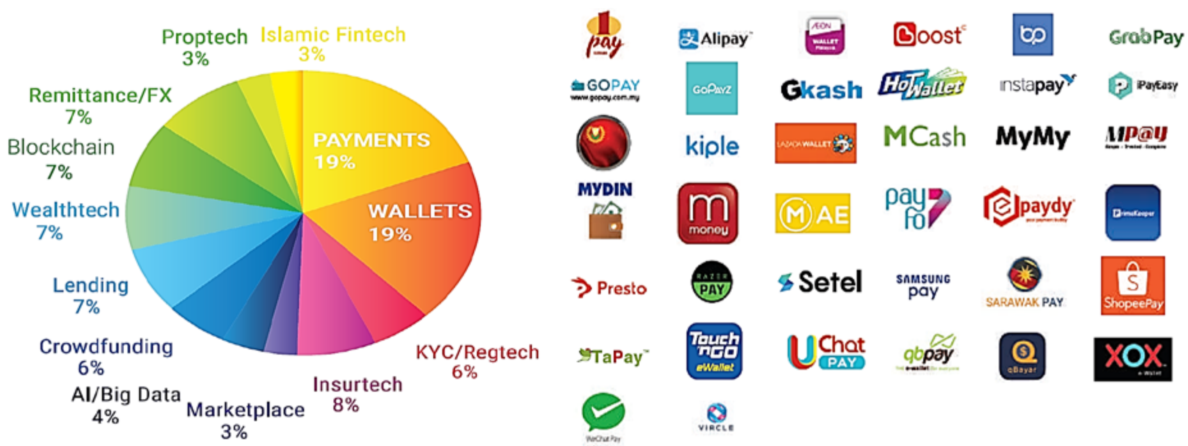


Fig. 4. State of Internet in January 2020 Around the World and in Malaysia.



(a) (b)

Fig. 5. (a): Payments and E-Wallets against other Elements during 2019 according to Fintech Report [42], (b) Most Popular E-Wallets in Malaysia.

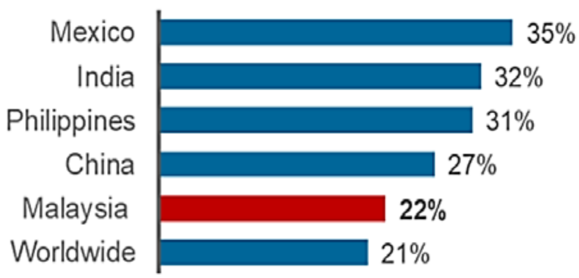


Fig. 6. State of Internet in January 2020 Around the World and in Malaysia.

IV. Methodology

In this section, the methodology process details are presented. In addition, the tool used for the data collection process with the details is explained. In this work, we have by used Speedtest phone application Ookla [49] for the data collection. Every day, approximately ten million individual tests are performed by users in places and at times when their connectivity is vital to them. Speedtest has delivered almost 35 billion tests since its establishment in 2006. After the data collection process, all data gathered and analyzed using Excel sheets, then converted to graphs as results. Customers are linking to networks everywhere such as on the road, in their cars, at home, at work, and everywhere else.

When paired with data on cell site locations, tools to priorities optimization and rollout efforts, and competitor comparisons, Cell Analytics offers an entire solution for mobile network operators to examine their networks and determine areas that demand upgrading. The data collected for this study was conducted by using different phone types.

The data were collected in three different times during the day, namely morning, afternoon, and evening. The data collection for the morning time starts from 10 am to 12pm, afternoon time 4pm to 6pm and evening 10 pm to 12 pm. An iPhone 12, Samsung galaxy s8 and Poco F2 Xiaomi were used. Details of data are summarized in Table II.

Fig. 7(a) and (b) shows a snapshot of an example of the application used in this study during the data collection process including testing the download speed and upload speed. The coverage areas of Umobile cellular networks in Kuala Lumpur and Johor Bharu provided by Speedtest are shown in Fig. 7(c) and (d), respectively. Fig. 8 shows the methodology steps and details. All the data were collected and analyzed using excel sheets.

TABLE II. DATA COLLECTION DETAILS

Matrices		***Details***
Country		Malaysia
Cities		Johor Bahru, Kuala Lumpur, and Cheras (Selangor)
Network type		Umobile
Performance matrices		Download speed, upload speeds, and latency
Smartphone types		iPhone 12, Samsung galaxy S8, and Poco F2 Xiaomi
Time of collection	***Morning time***	10-11:50 am
	Afternoon time	4-6 pm
	Evening time	10-11:59 pm
Date of collection	***Phase 1***	13 January – 13 February
	Phase 2	5 March – 2 April
Data collection tool		Speedtest phone App
Lockdown periods		MCO and CMCO

Fig. 7. (a): Snapshot of Speedtest Application showing the Collection of Download Speed Data, (b) Collection of Upload Speed Data, (c): UMobile Cellular Network Coverage in Kuala Lumpur, and (d): UMobile Cellular Network Coverage in Johor Bharu.

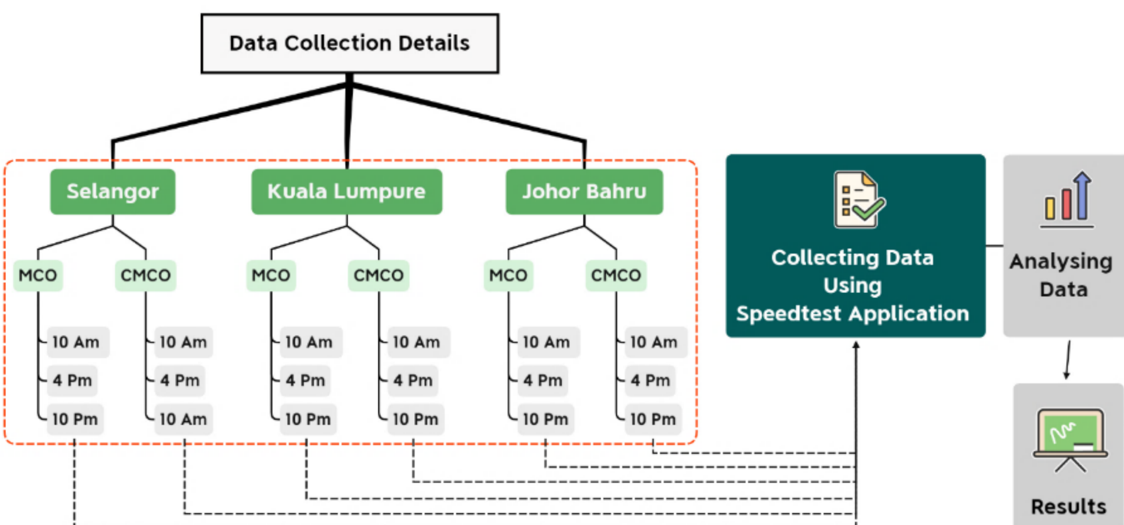


Fig. 8. Snapshot Methodology Process Details.

V. Results and Discussion

This section presents the results and discussion. The main data gathered for this study including the download speed rate and upload speed rate. In addition, the latency was also measured. All data were collected, transformed to readable graphs then analyzed. We evaluate the performance of cellular networks during two time periods, namely MCO and CMCO. In order to describe the data being studied, all data were analyzed and compared. Specifically, download speed in the morning is compared with afternoon and evening time within same period, same for the upload speed, then the latency. In addition, all performance metrics during MCO is compared with the performance during CMCO. Finally, an overall comparison is presented as final findings.

The first period, MCO started from 13 January 2021 to 13 February 2021, and the second-period CMCO began from 5 March 2021 to 2 April 2021.

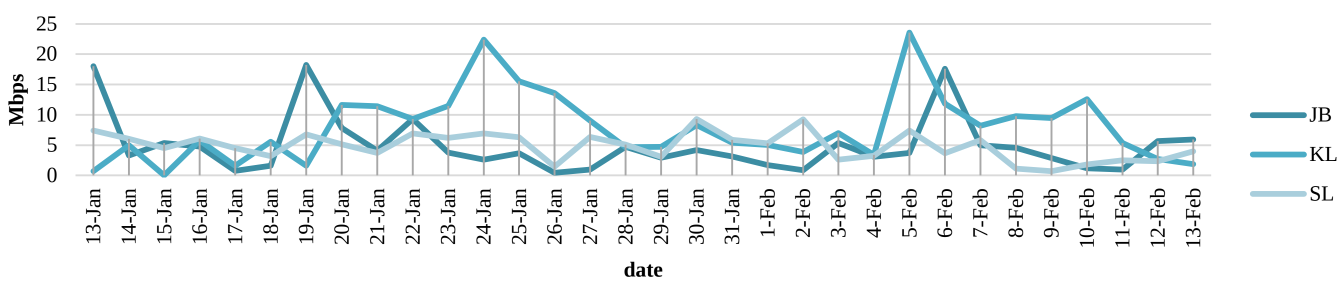
Microsoft Excel was used to combine and compare the data from three cite to measure the network speed and latency in (LTE cellular, U-mobile). It should be noted that the variations of data taken into consideration may be caused by the traffic volume and the peak hours for people using the internet for example work, online study or video streaming.

Since the performance of the considered cellular networks presented in this study is highly dependent on network parameters and a few other variables such as i) number of users connected to the BS [50], ii) time of data collection where speed and data traffic varies from time to time based on the density of users which relies on population when comparing different cellular networks performance from different areas. The data rate requirements per user also play an important role in load variations on the BS which represents the data usage [51]. In the data collection phase, we had to collect data from three different cities in Malaysia in order to make a fair comparison of cellular networks within different user density, and to simulate diverse network conditions and verify the impact of COVID-19 measures and restrictions.

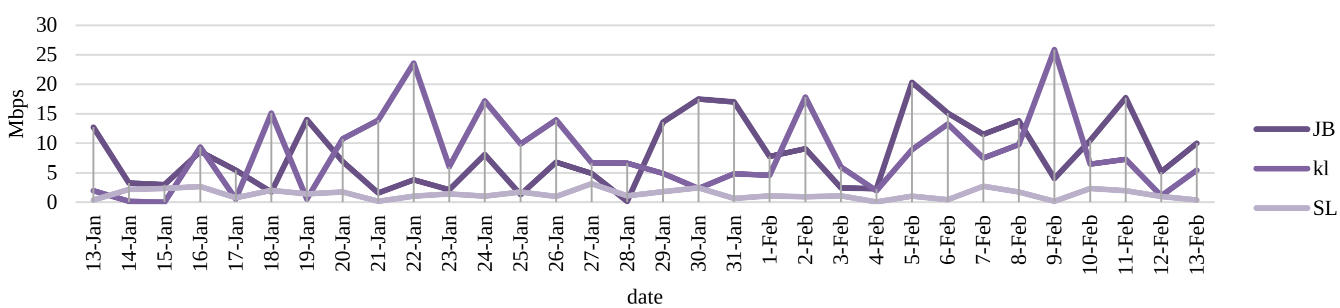
All data collection were conducted on smartphones (iPhone 13, Samsung S8), with 60 GB of RAM memory. Exceptionally in this scenario, since the phone application used by the client is making calculations and data measurements, it is affected only by network conditions and the server connected nearby the cellular BS. To verify the use of different smartphone types, we had to utilize all smartphones on same network operators that is popular in Malaysia and subscribed to the same broadband subscription which is Umobile. Note that the average download speed while using a cellular network during normal times (before the crises of COVID-19) was around 4-8Mb/s.

Since download speed rates are the most important aspect of the network speed, our focus will be on the download speed rates in this discussion. Fig. 9 describes the network performance during MCO at 10 am from 13 of January to 13 of February.

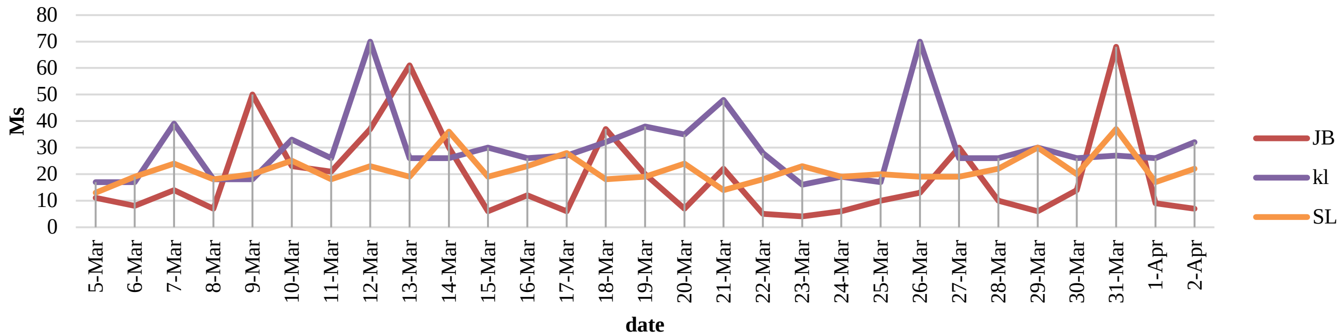
It is shown that the download and upload speed in KL and JB increases in some days especially weekends, and decreases in weekdays. This is because the necessity for services and applications for business, education, and/or online meetings is higher on weekdays; therefore the load on the network is higher. In addition, it can be seen the download and upload speed rates are higher in KL. This is because the population there is much higher than other areas in Malaysia, thus there are more cellular networks installed in the area. The highest download speed during this period is around 23Mbps in KL, while the lowest is near to 0 Mbps on some days for KL and JB.



(a) Download Speed at 10 AM.



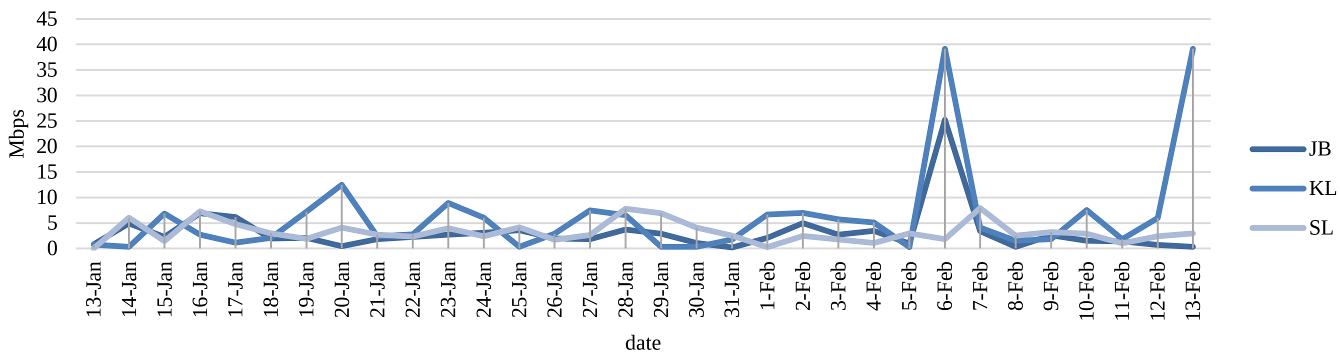
(b) Upload Speed at 10 AM.



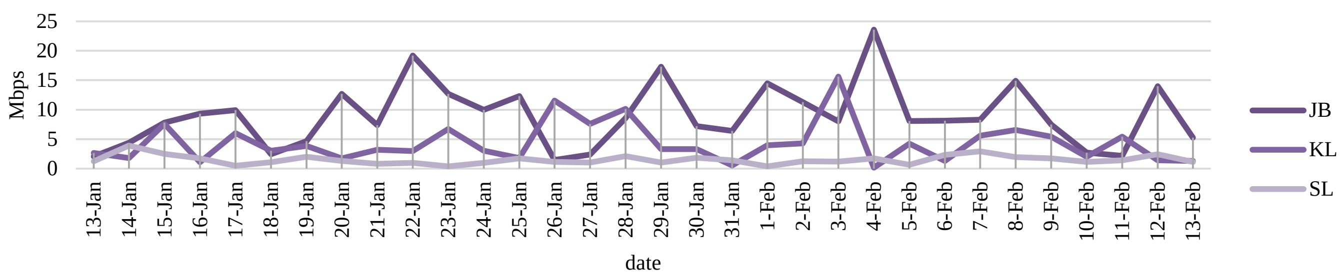
(c) Latency at 10 AM.

Fig. 9. Network Performance during MCO at 10AM.

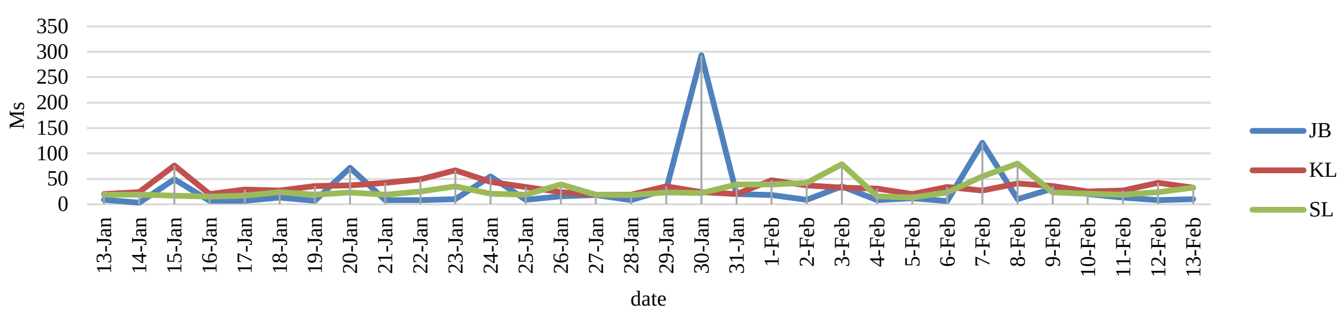
Fig. 10 presents the network performance during MCO at 4 pm from 13 of January to 13 of February. It is obvious that there is performance differences compared with the 10 am rates. Specifically, during this period all rates were quite low except in 6 of February and 13 of February (weekends) in KL and JB. The highest rate measured during this period was 30-40Mbps for download speed.



(a) Download Speed at 4:00 PM.



(b) Upload Speed at 4:00 PM.



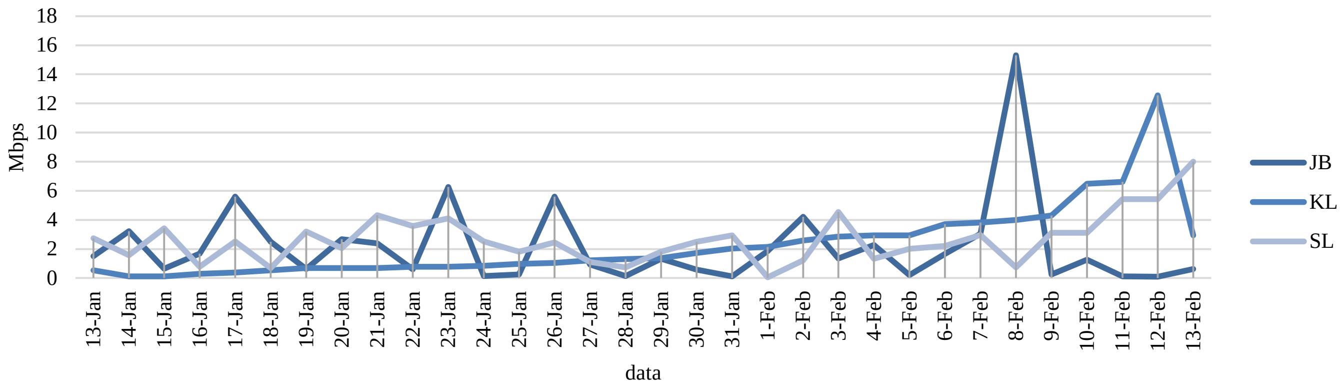
(c) Latency at 4:00 PM.

Fig. 10. Network Performance during MCO at 4PM.

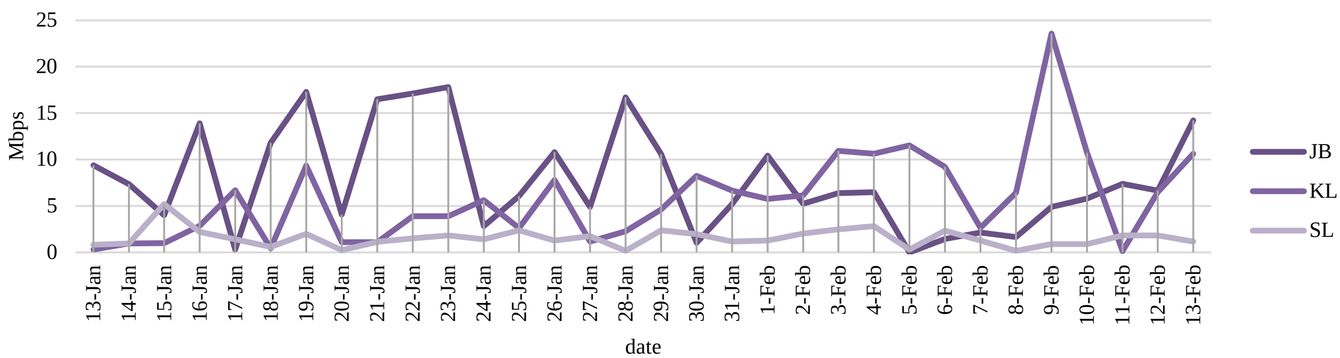
On the other hand, most of the weekdays during this peak time (4 pm) has the lowest rates, this is because most services and online meetings shifted afternoon in MCO.

Fig. 11 presents the network performance during MCO at 10 pm from 13 of January to 13 of February. The download speed is low overall, mostly in KL. This is because the usage of online services and streaming such as Netflix has risen after the pandemic, especially in the evening. Moreover, it can be seen that the rates are lower when comparing it with the morning and afternoon rates. This is because the government of Malaysia ordered people not to go out in the evening, and most of the markets were closed, therefore the usage of the internet has increased. It can be seen that from 8 of February, the download speed rates increase as the MCO period is about to finish.

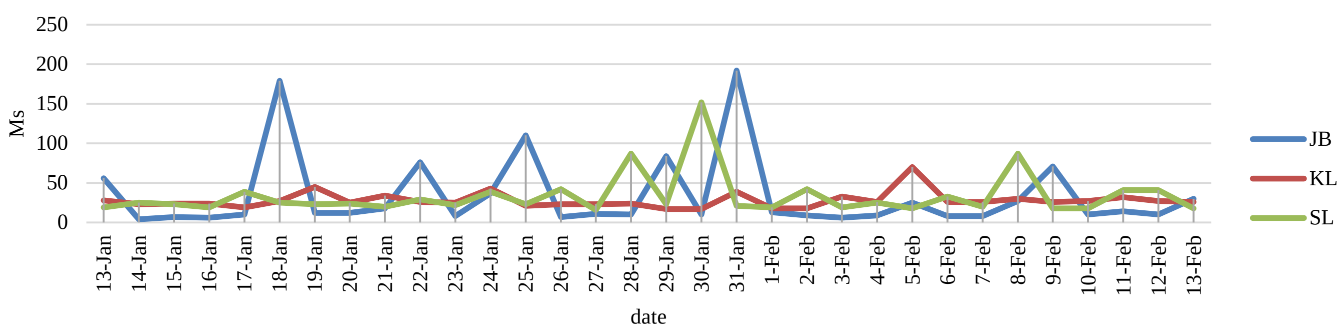
Fig. 12 presents the network performance during CMCO at 10 am from 5 of March to 2 of April. This figure shows the decreased download speed rate in the morning time (10 am) compared with the morning time of MCO. This is because the restrictions were less during CMCO and people could go out shopping and more businesses opened after the MCO period. In addition, during CMCO, the users of cellular networks service increased compared with MCO due to the fact that in the MCO period, people spent more time at home which means most of the users change their connection to WiFi network.



(a) Download Speed at 10 PM.

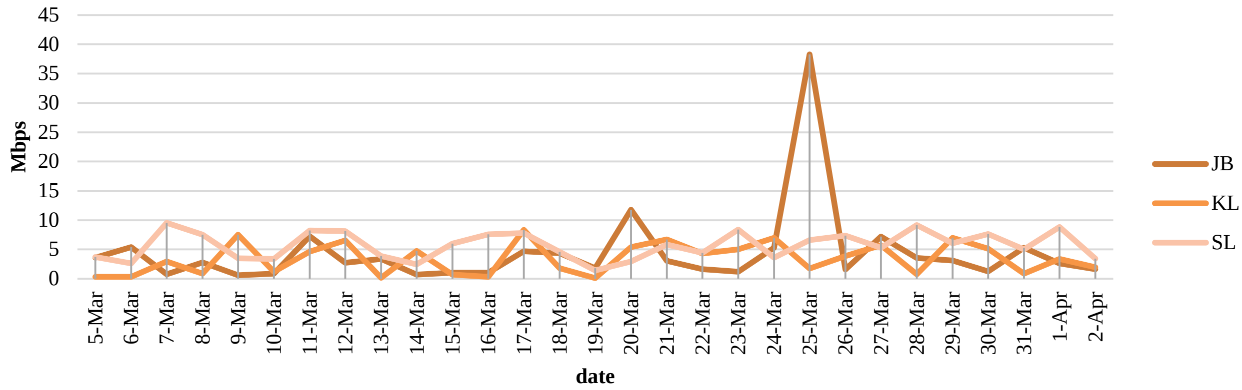


(b) Upload Speed at 10 PM.

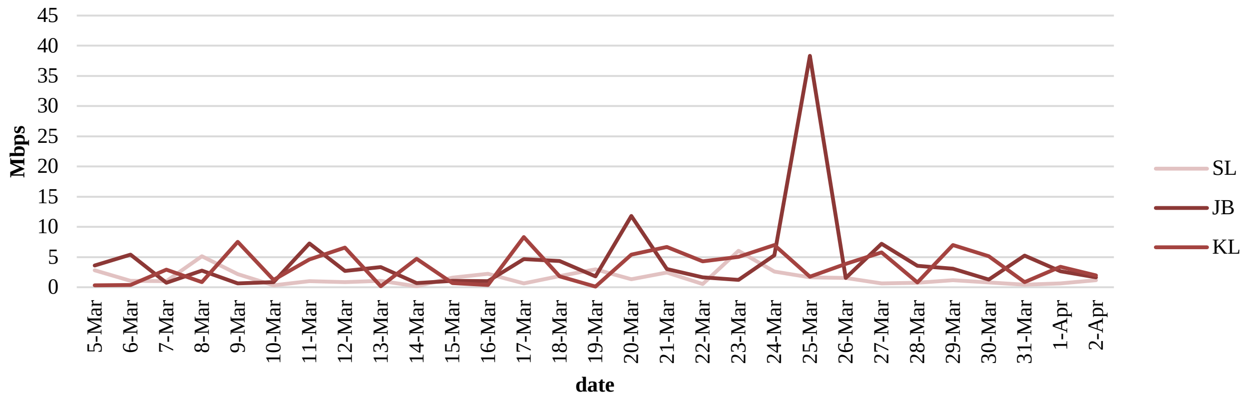


(c) Latency at 10 PM.

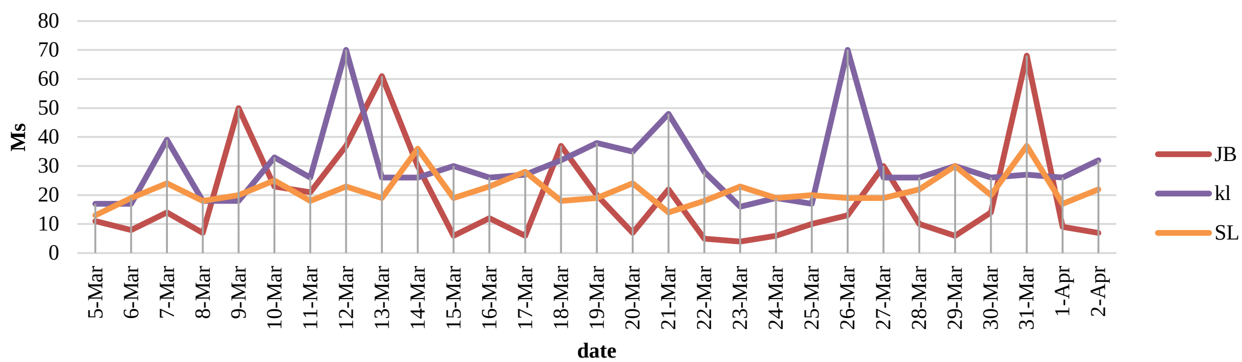
Fig. 11. Network Performance during MCO at 10PM.



(a) Download Speed at 10:00 AM.



(b) Upload Speed at 10:00 AM.

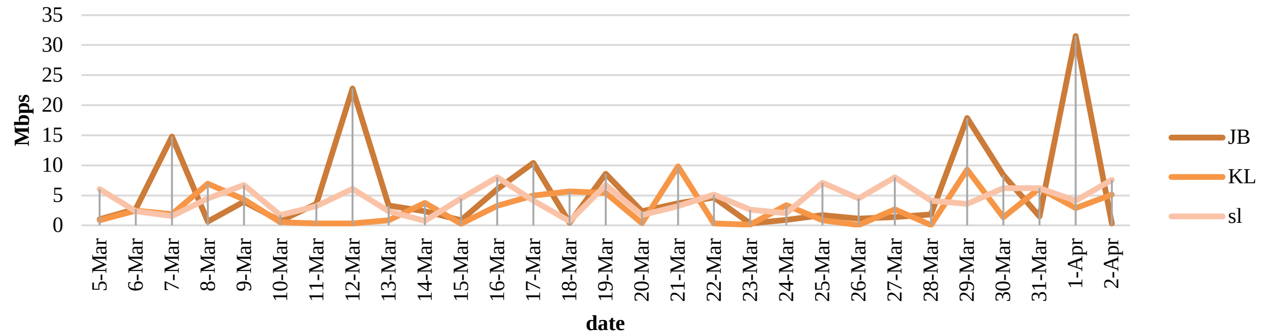


(c) Latency at 10:00 AM.

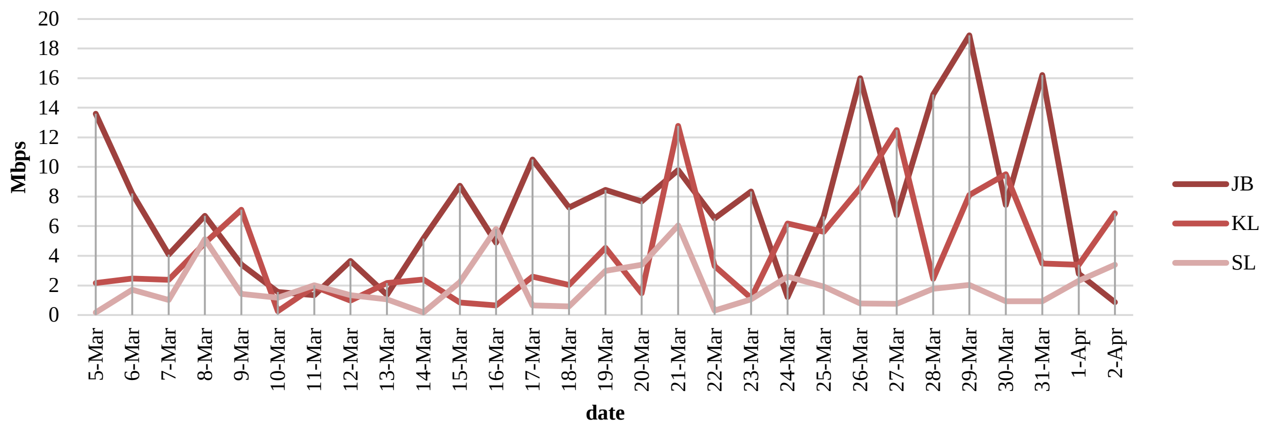
Fig. 12. Network Performance during CMCO at 10AM.

While in the CMCO period when people had the chance to go out, they shifted back to the cellular network connections. The rates of the download speed for the morning time were more stable than MCO, as well as for the upload speed. The highest value measured was on 20 of March (weekend) and 25 of March. On the other hand, the latency value increased near and on the weekend as well on 12, 21 and 26 of March for KL, and on 13 and 31 of March JB. Overall latency in this period is higher than the latency measured in the morning of MCO due to the increased usage during the CMCO.

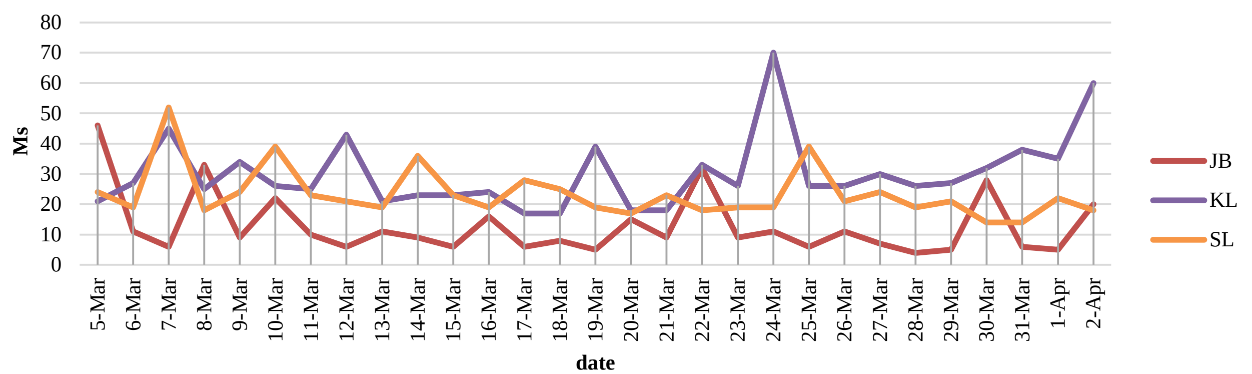
Fig. 13 presents the network performance during CMCO at 4 PM from 5 of March to 2 of April. The download speed during this period has slightly increased compared with the morning time. This is because in the CMCO time, the peak time has shifted mostly in the morning to the afternoon because the measures and restrictions has been minimized by the government, therefore the load on the network is expected to be less in the afternoon and evening times. The highest rate achieved by the network for the download speed is around 25-30Mbps on 12 of March and 1 of April during the weekend (Saturday and Sunday) and in Friday.



(a) Download Speed at 04:00 PM.



(b) Upload Speed at 04:00 PM.



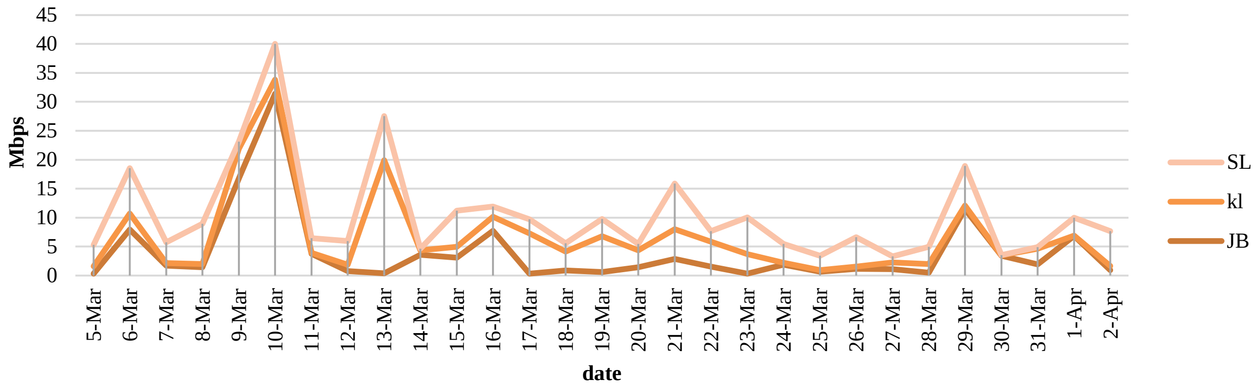
(c) Latency at 04:00 PM.

Fig. 13. Network Performance during CMCO at 4PM.

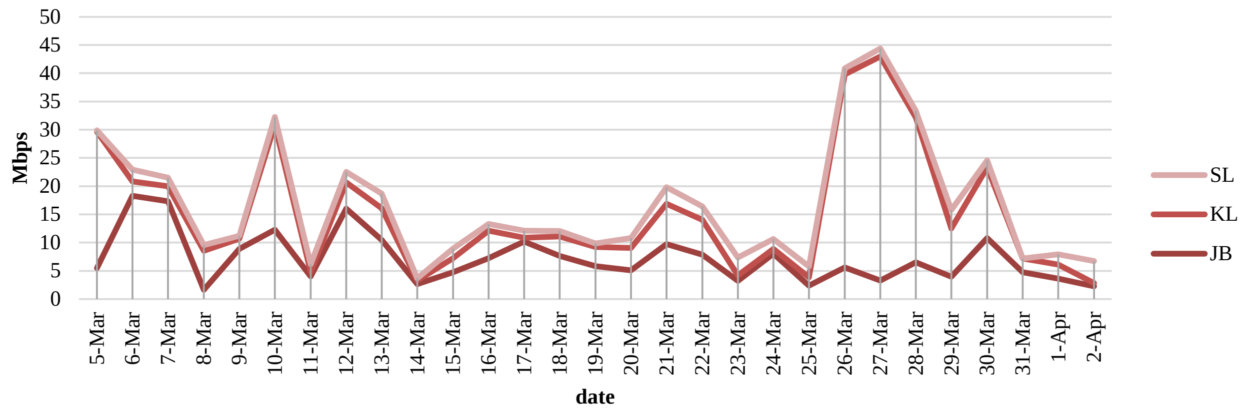
For the latency, due to the increased number of users of the cellular networks, the rates of latency have increased significantly, especially in KL in 24 of March and 2 of April.

Fig. 14 presents the network performance during CMCO at 10 PM from 5 of March to 2 of April. Overall rates including download, upload and latency are higher than the morning and afternoon times. The download speed rate in this period is slightly higher when comparing it with the evening time of the MCO period. This is because people had to go home after 8 pm, which means the number of cellular users decreased significantly. The highest upload speed rate achieved was around 45Mbps on 27 of March (weekend) in KL and Cheras. The lowest value of latency is around 0-50ms, and the highest has reached 200ms same as the value of latency in the MCO evening time.

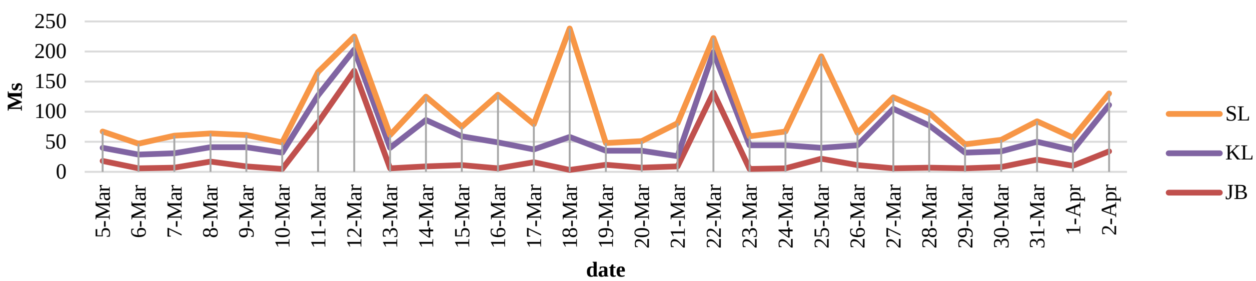
This is because of the increased number of users during the CMCO than the MCO period. In addition, the number of people subscribed to a broadband subscription plan has increased during CMCO.



(a) Download Speed at 10:00 PM.



(b) Upload Speed at 10:00 PM.



(c) Latency at 10:00 PM.

Fig. 14. Network Performance during CMCO at 10PM.

To summarize and extract the findings from all the above results, the average rates are presented in Fig. 15. In addition, the highest and the lowest values of all times for all cities are shown and highlighted in red and yellow colours, respectively. The highest value of all rates within all times among the three cities is highlighted in blue colour. While the lowest values are highlighted in yellow color. Specifically, the average rates of the download speed are presented in Fig. 15(a). As shown in the figure, the highest value in the MCO period was in KL in the morning time. This is because, as mentioned earlier, the cellular towers and BS deployed in that area are much more than in other areas, and the peak time of workers who relied on the internet connection in the morning time of the MCO was shifted to work from home in fixable times. The lowest value was in the evening time in JB. On the other hand, the highest value in the CMCO period was in SL (Cheras) in the morning time. While the lowest value was in KL in the evening time.

Fig. 15(b) shows the upload speed rates. The highest value in the MCO period was in JB in the Afternoon time and the lowest value was in SL (Cheras) in the morning time. On the other hand, the highest value in the CMCO period was in JB during morning time, and the lowest value was in SL (Cheras) during the evening time.

Fig. 15(c) presents the latency values for all cities in all times. The longest time of latency in the MCO period was in JB during the morning time, which expresses the best value, and the highest time of latency was in SL (Cheras) in the morning time as well, which was the worst value. The highest time of latency in the CMCO period was in KL in the evening time, while the lowest time was in JB during the afternoon time.

In Fig. 16, the total volume values of downloads, uploads, and latency in a percentage manner are presented. In Fig. 16(a) during MCO, the biggest volume of downloads was in KL which is 45%, while the rates in JB and SL are almost the same. On the other hand, during CMCO, the biggest overall value of downloads was in SL which is 42%, and the lowest value was in Kl which is 25%. In Fig. 16(b), the upload speed total value is presented. During MCO, the higher values were in both KL and JB which are 46%, and the lowest was in SL which is 8%. In addition, during the CMCO, the greatest value of upload speed total value was in JB which is 54%, and the lowest was in SL at 10%. In Fig. 16(c), the overall latency is shown. The highest volume of latency during the MCO was in SL at 42%, and the lowest was in JB at 22%. Moreover, the greater value during the CMCO was in KL at 42%, and the least value was in JB at 27%. That means the total volume of downloads was at the highest value in KL during MCO at 45%, and the biggest total volume of uploads was in JB during CMCO at 54%. In addition, the worst value of total latency was in the SL during MCO and in KL during CMCO at 42%. Therefore, to accelerate the performance of cellular networks, and to decrease the burden, it is important to use another wireless technology such as WiFi, visible light communication, and other types of optical wireless communications to support the network and to deliver higher data rates [52].

To conclude, for the overall evaluation of cellular networks during the two periods, it can be seen that the performance of cellular networks has decreased especially in the peak times and during weekdays during the CMCO more than the MCO times. The speed rates depend on the number of computing devices that work concurrently in addition to the user requirements and the usage of data. The processing of such a big amount of data requires intensive computing tasks.

Times		**Download rate**		
		JB	KL	SL
MCO	10AM	4.94	7.88	4.83
	4PM	3.15	6.24	3.23
	10PM	2.16	2.31	2.66
CMCO	10AM	4.43	3.43	5.69
	4PM	5.35	2.83	4.20
	10PM	4.04	2.71	3.69

(a)

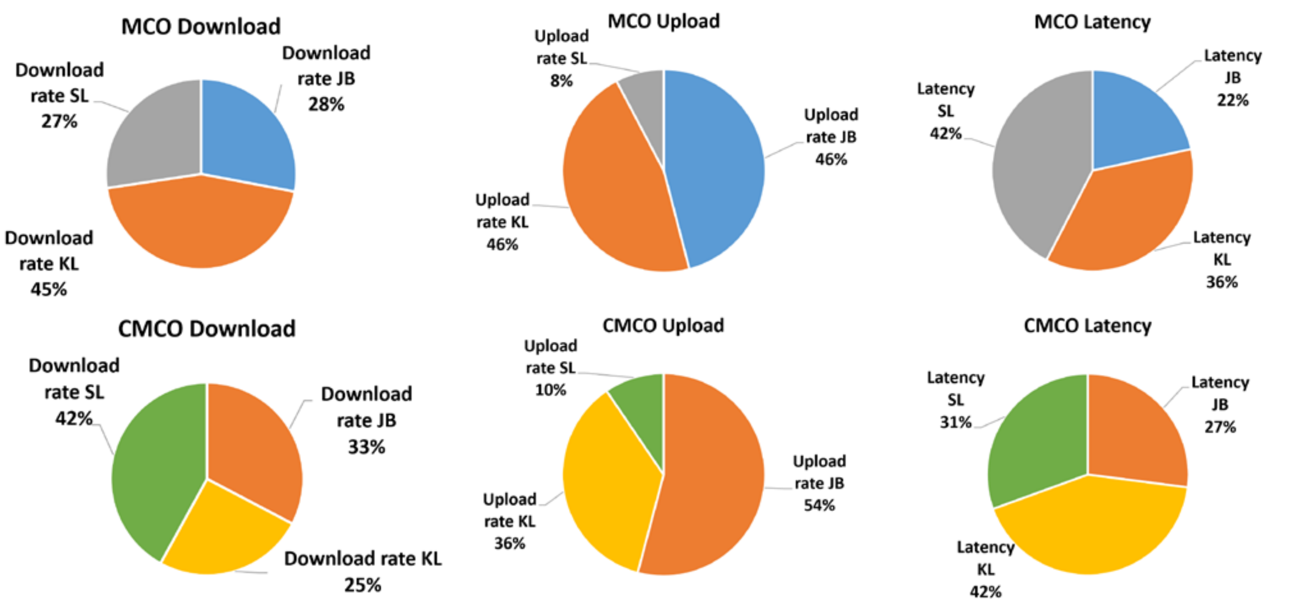
Times		**Upload rate**		
		JB	KL	SL
MCO	10AM	8.19	8.26	1.37
	4PM	8.96	4.35	1.51
	10PM	8.07	5.79	1.55
CMCO	10AM	9.17	6.16	1.61
	4PM	7.34	4.24	1.92
	10PM	7.24	7.92	1.60

(b)

Times		**Latency**		
		JB	KL	SL
MCO	10AM	18.41	30.72	36.22
	4PM	29.44	33.72	28.09
	10PM	34.03	27.88	33.44
CMCO	10AM	19.10	29.97	21.59
	4PM	12.83	30.17	23.34
	10PM	22.69	38.86	35.76

(c)

Fig. 15. Network Performance Average Values during MCO and CMCO in All Times for All Cities.



(a) (b) (c)

Fig. 16. Overview of Total Values of All Rates during MCO and CMCO.

VI. Limitations and Future Directions

The main limitation of the study can be divided into few points as follows: i) data collection: only three cities were taken into account, ii) only Umobile network service provider was considered, iii) the exact location of users and distance to the cellular BS was neglected due to some difficulties, especially during the mobility around the city in the CMCO period. According to the above limitations, it is only possible to make further steps for future directions related to this study, where similar situations and circumstances would be available during a pandemic similar to COVID-19. Therefore, when studying cellular network traffic during a pandemic in Malaysia or any other country, more cities can be taken into account in addition to other factors. However, when a pandemic happens, lockdown and other types of movement restrictions take place immediately which makes it hard to conduct such research study.

VII. Conclusion

A new age in wireless networks has been accompanied in by the COVID-19 pandemic. Computer wireless communications is a complex challenge since multiple features are involved. The present pandemic situation and the debate in this paper clearly describe the need for efficient impact analysis in this digital era. In this paper, we investigate the effect of COVID-19 measures and restrictions on cellular network traffic in Malaysia. The results show a significant impact on our daily use of network services and applications including download speed, upload speed, and latency. Moreover, three cities were taken into account which is Kuala Lumpur, Johor Bahru, and Selangor (Cheras) using Speedtest phone applications during two periods namely MCO and CMCO. In addition, Umobile was taken into account as a cellular network provider which is one of the most popular network service providers in Malaysia. This study used a simple approach as a method of calculation and analysis of cellular networks performance. The proposed analysis is presented as a case study that consists of different components and factors for the presented findings. Companies will also be required to optimize budgets and accelerate their digital revolutions as they adjust to the new normal post-crisis. By leveraging the emerging technologies and service models transformed to do more with less, communications leaders would have to embrace these initiatives.

Acknowledgment

The publication of this research is supported by the UNITEN BOLD Refresh publication fund. The authors declare that they have no conflicts of interest.

References

[1] World Health Organization. Timeline of WHO's Response to COVID-19. 2020. Available online: https://www.who.int/news room/ detail/29-06-2020-covidtimeline (accessed on 29 June 2021).

[2] World Health Organization. Coronavirus (COVID-19). 2020. Available online: https://covid19.who.int/ (accessed on 20 August 2021).

[3] E. Lempinen. COVID-19: Economic Impact, Human Solutions. Berkeley News. Available online: https://news.berkeley.edu/2020/04/10/covid-19-economic impacthuman-solutions/ (accessed on 20 April 2021).

[4] Evans, P. Canada Lost More Than 1 Million Jobs Last Month as COVID-19 Struck. CBC News. 2020. Available online: https://www.cbc.ca/news/business/canada-jobs-march-covid-19-1.5527359 (accessed on 20 April 2021).

[5] Sullivan, K. ABC News. Unemployment Rate Predicted to Reach 10 Per Cent Amid Coronavirus Pandemic, Pushing Australia Into Recession. 2020. Available online: https://www.abc.net.au/news/2020-04-13/coronavirus-unemploy (accessed on 22 April 2021).

[6] Gopinath, G. International Monetary Fund Blog. The Great Lockdown: Worst Economic Downturn Since the Great Depression. 2020. Available online: https://blogs.imf.org/2020/04/14/the-great-lockdown-worst-economicdowntur (accessed on 26 April 2021).

[7] Pickert, R.; Qiu, Y.; McIntyre, A. Bloomberg. U.S. Recession Model at 100% Confirms Downturn is Already Here. 2020. Available online: https://www.bloomberg.com/graphics/us-economic-recession-tracker/ (accessed on 28 April 2021).

[8] BBC News. Coronavirus: World Economy May Face Double Recession. 2020. Available online: https://www.bbc.com/news/business-52306001 (accessed on 11 May 2021).

[9] N.M. Ferguson, D.A. Cummings, S. Cauchemez, C. Fraser, S. Riley et al., "Strategies for containing an emerging influenza pandemic in Southeast Asia," Nature, vol. 437, no. 7056, pp. 209–214, 2005.

[10] C. Fraser, S. Riley, R. M. Anderson and N. M. Ferguson, "Factors that make an infectious disease outbreak controllable," Proceedings of the National Academy of Sciences, vol. 101, no. 16, pp. 6146–6151, 2004.

[11] N. M. Ferguson, D. A. T. Cummings, C. Fraser, J. C. Cajka and P. C. Cooley, "Strategies for mitigating an influenza pandemic," Nature, vol. 442, no. 7101, pp. 448–452, 2006.

[12] S. S. Murad, S. Yussof and R. Badeel, "Wireless Technologies for Social Distancing in The Time Of COVID-19: Literature Review, Open Issues, and Limitations," Sensors, vol. 22, no. 6, p. 2313, 2022.

[13] Safer Together. TraceTogether. Available online: https://www.tracetogether.gov.sg/ (accessed on 13 May 2021).

[14] MIT. PACT: Private Automated Contact Tracing. Available online: https://pact.mit.edu/ (accessed on 14 May 2021).

[15] C. Adlhoch, European centre for disease prevention and control. In Considerations Relating to Social Distancing Measures in Response to COVID-19_Second Update; ECDC: Stockholm, Sweden, 2020. Available online: https://www.ecdc/ (accessed on 16 May 2021).

[16] M. Jancowicz, At Least 6 Countries Reimposed Lockdown Measures as New Coronavirus Cases Flared Up Again. Here's What they Looked Like. Business Insider. 2020. Available online: https://www.businessinsider.com/countriesi/ (accessed on 02 June 2021).

[17] S. Williams, IT Brief. COVID-19: Zoom Downloads Explode as People Work From Home. 2020. Available online: https://itbrief.com.au/story/covid-19-zoomdownloads-explode-as-people-work-from-home/ (accessed on 02 June 2021).

[18] H. Khatri. Analyzing Malaysia's mobile data consumption, and its effects on 4G Download Speed. Available online: https://www.opensignal.com/2020/10/29/analyzing-malaysias-mobile-data-consumption-and-its-effects-on-4g-download-speed/ (accessed on 08 June 2021).

[19] COVID-19 RESPONSE. COVID-19 Network Update. Available online: https://corporate.comcast.com/covid-19/network/may-20-2020/ (accessed on 03 July 2021).

[20] R. Gong. Malaysia's Response to COVID-19: Mobile Data and Infrastructure. Available online: https://blogs.lse.ac.uk/seac/2020/11/23/malaysias-response-to-covid-19-mobile-data-and-infrastructure/ (accessed on 11 June 2021).

[21] S. S. Murad, R. Badeel, N. S. A. Alsandi ***et al.***, "Optimized Min-Min Task Scheduling Algorithm for Scientific Workflows in A Cloud Environment," Journal of Theoretical and Applied Information Technology, vol. 100, no. 2, p. 408-506, 2022.

[22] Netflix. Available online: https://edition.cnn.com/ (accessed on 14 June 2021).

[23] Cloudflare. A global network built for the cloud. Available online: https:/blog.cloudflare.com/ (accessed on 16 June 2021).

[24] Fastly. How COVID-19 is affecting internet performance. Available

online: https://www.fastly.com/blog/how-covid-19-is-affecting-internet-performance/ (accessed on 19 June 2021).

[25] Vodafone. An update on Vodafone's networks. Available online: https://www.vodafone.com/news/technology/update-on-vodafone-networks/ (accessed on 23 June 2021).

[26] Telefonica. Operators advise a rational and responsible use of telecommunication networks to cope with traffic increases. Available online: https://www.telefonica.com/en/communication-room/operators-advise-a-rational-and-responsible-use-of-telecommunication-networks-to-cope-with-traffic-increases/ (accessed on 23 June 2021).

[27] R. Gong. Malaysia's Response to COVID-19: Mobile Data and Infrastructure. Available online: https://blogs.lse.ac.uk/seac/2020/11/23/malaysias-response-to-covid-19-mobile-data-and-infrastructure/ (accessed on 11 June 2021).

[28] AMS-IX NEWS. 17% traffic increase on the AMS-IX platform due to Corona/ COVID-19 crisis. Available online: https://www.ams-ix.net/ams/news/17-traffic-increase-on-the-ams-ix-platform-due-to-corona-covid-19-crisis/ (accessed on 26 June 2021).

[29] T. Favale, F. Soro, M. Trevisan, I. Drago and M. Mellia, "Campus traffic and e-Learning during COVID-19 pandemic" Computer networks, 176, 107290. 2020.

[30] A. Feldmann *et al.*, "The Lockdown Effect: Implications of the COVID-19 Pandemic on Internet Traffic," Proceedings of the ACM Internet Measurement Conference, pp. 1–18, 2020.

[31] S. Dahiya, L. N. Rokanas, S. Singh, M. Yang, and J. M. Peha, "Lessons From Internet Use and Performance During Covid-19," *J. Inf. Policy*, vol. 11, pp. 202–221, 2021.

[32] C. Zakaria, A. Trivedi, E. Cecchet, M. Chee, P. Shenoy, and R. Balan, "Analyzing the Impact of COVID-19 Control Policies on Campus Occupancy and Mobility via WiFi Sensing," *ACM Trans. Spat. Algorithms Syst.*, vol. 1, no. 1, 2022.

[33] M. Candela, V. Luconi, and A. Vecchio, "Impact of the COVID-19 pandemic on the Internet latency: A large-scale study," *Comput. Networks*, vol. 182, no. August, p. 107495, 2020.

[34] T. Böttger, G. Ibrahim, and B. Vallis, *How the Internet reacted to Covid-19: A perspective from Facebook's Edge Network*, vol. 1, no. 1. Association for Computing Machinery, 2020.

[35] A. Lutu, D. Perino, M. Bagnulo, E. Frias-Martinez, and J. Khangosstar, "A Characterization of the COVID-19 Pandemic Impact on a Mobile Network Operator Traffic," *Proc. ACM SIGCOMM Internet Meas. Conf. IMC*, pp. 19–33, 2020.

[36] The Malaysian Communications and Multimedia Commission. Available online: https://www.mcmc.gov.my/en/home/ (accessed 11 February 2022).

[37] E. Bolisani, E. Scarso, C. Ipsen, K. Kirchner, and J. P. Hansen, "Working from home during COVID-19 pandemic: lessons learned and issues," Management & Marketing. Challenges for the Knowledge Society, vol. 15, no. s1, pp. 458–476, 2020.

[38] A. Lutu, D. Perino, M. Bagnulo, E. Frias-Martinez, and J. Khangosstar, "A characterization of the COVID-19 pandemic impact on a mobile network operator traffic," in Proceedings of the ACM internet measurement conference, 2020, pp. 19–33.

[39] G. Heiler, T. Reisch, J. Hurt, M. Forghani, A. Omani et al., "Country-wide mobility changes observed using mobile phone data during COVID-19 pandemic," in 2020 IEEE International Conference on Big Data (Big Data), 2020, pp. 3123–3132.

[40] V. Bhandari, "Improving internet connectivity during Covid-19," Digital Pathways at Oxford Paper Series, no. 4, 2020.

[41] N. Wlömert and D. Papies, "On-demand streaming services and music industry revenues—Insights from Spotify's market entry," International Journal of Research in Marketing, vol. 33, no. 2, pp. 314–327, 2016.

[42] S. Dinesh and Y. MuniRaju, "Scalability of e-commerce in the COVID-19 era," International journal of research, vol. 9, no. 1, pp. 123–128, 2021.

[43] M. Batool, H. Ghulam, M.A. Hayat, M.Z. Naeem, A. Ejaz et al., "How COVID-19 has shaken the sharing economy? An analysis using Google trends data," Economic Research-Ekonomska Istraživanja, vol. 34, no. 1, pp. 2374–2386, 2021.

[44] Hootsuite. Aquick assessment of malaysias internet usage according to the Digital, 2020. Available online: https://27.group/a-quick-assessment-of-malaysias-internet-usage/ (accessed on 10 December 2021).

[45] H. M. Aji, I. Berakon and M. Md Husin, "COVID-19 and e-wallet usage intention: A multigroup analysis between Indonesia and Malaysia," Cogent Business & Management, vol. 7, no. 1, p. 1804181, 2020.

[46] Fintech Malaysia Report 2021. Fintech Reaches an Inflection Point in Malaysia. Available online: https://fintechnews.my/27070/malaysia/fintech-malaysia-report-2021/ (accessed 13 February 2022).

[47] Opptus. Full-service Bespoke Market Research Company in Malaysia. Available online: https://www.oppotus.com/ (accessed 15 February 2022).

[48] D. Portal. Available online: https://datareportal.com/reports/digital-2021-malaysia/ (accessed 15 February 2022).

[49] Okkla. Available online: http://www.speedtest.net/apps/android/ (accessed 17 February 2022).

[50] M. Z. Shafiq, L. Ji, A. X. Liu, J. Pang, S. Venkataraman et al., "A first look at cellular network performance during crowded events," ACM SIGMETRICS Performance Evaluation Review, vol. 41, no. 1, pp. 17–28, 2013.

[51] F. Hu, Y. Deng, W. Saad, M. Bennis, and A. H. Aghvami, "Cellular-connected wireless virtual reality: Requirements, challenges, and solutions," IEEE Communication Magazine, vol. 58, no. 5, pp. 105–111, 2020.

[52] R. Badeel, S. K. Subramaniam, Z. M. Hanapi, and A. Muhammed, "A Review on LiFi Network Research: Open Issues, Applications and Future Directions," Applied Sciences, vol. 11, no. 23, p. 11118, 2021.