Specifics of operating systems of terminal devices in generating data traffic

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Abstract—**This paper presents the differences between operating systems (OS) of terminal devices and their characteristics in generating data traffic. An important factor in generating data traffic is also the OS of terminal device because each OS does not generate equal amount of data traffic. The aim of this paper is to show how much data traffic generate terminal devices that use different OSs. By accessing different networks, the same device also detects differences in generating data traffic. Obtained data from the study also shows the differences and characteristics of each OS. Data traffic measurements were performed by viewing the same video track using the YouTube application on all terminal devices and using NetWorx, SurPlusMeter, My Data Manager and Daily Data Sense applications. Access to the data network was achieved using Wi-Fi, UMTS and LTE networks. Based on obtained data by this study, a comparison of data traffic was made for each OS.**

Keywords– terminal devices, operating system, data traffic, measurements, comparison

I. INTRODUCTION

Today, there is a large number of OSs in the world and they are all intended for the same purpose, which is to enable the connection between the hardware and the user programs. However, OSs are different and each of them has certain characteristics that make it more or less quality depending on what the user requires. Without OS, no terminal device could work.

Generating data traffic is an inevitable segment of any modern terminal device, and the main reason for this is the implementation of a large number of applications and other device functionalities. A factor that greatly influences the generation of data traffic of a terminal device is an OS. In addition to the OS, factors such as screen size and resolution, device settings, device categories, web browser capabilities, individual cellular network communications technology, system and application updates, and complementary access networks also affect the usage of data traffic.

A. Previous research

The amount of data traffic generated by users of different smartphones varies considerably from the researches shown in [1] [2] [3]. As noted by the authors in [1], mobile Internet usage is shown on all mobile devices that enable the generation of mobile data traffic (MDT), also there are the factors that influence the generation of data traffic.

The measurements performed on mobile devices shown in [4] were supplemented by users who were participants in the research itself. According to [5] measurements on mobile devices were made to gather information related to the period of use of these mobile phones. The data was collected by test users who had pre-installed software/application that serves to monitor data traffic. The gathered data were used to describe the context of using mobile devices that help understand the user's behavior. The research presented in [6] focuses on measuring data traffic using mobile networks, and enables the application of market intelligence to different subjects.

The recent research shown in [7] demonstrates that the highest level of data traffic is generated by Mac OS, and the least Linux. Other research carried out by other telecommunications companies, such as Ericsson, has shown that Android devices generate more traffic than iOS due to larger screens, resulting in downloading larger files and video records with more pixels.

B. Research methodology

This paper compares the most frequently used OS, namely: Windows and Mac OS that are used on computer devices, and Android, iOS, and Windows Phone that are used on mobile devices. The measurements were done using different applications. The NetWorx and SurPlusMeter applications were used on the computer OS, which have the same function, respectively, they enable the measurement of data traffic generation. NetWorx is a program that allows to measure data traffic generation on Windows computers, and SurPlusMeter serves the same purpose on Mac OS of computers.

My Data Manager and Daily Data Sense were used on mobile devices. When data generation was measured, the My Data Manager application on Android and iOS was used, and the Daily Data Sense application on the Windows Phone. Both applications have the same purpose which is to measure generation of data traffic on mobile devices.

A video track was viewed for metrics purposes and data traffic measurement. The video track is available at "https://www.youtube.com/watch?v=FnzDneTj9YY" link and has a duration of 11:10 minutes. The video track was viewed at 480p quality, except for the Windows Phone that did not allow automatic quality change or display of the same.

II. DISTRIBUTION OF TERMINAL DEVICES

In today's time there are distinguished a large number of terminal devices. Every terminal device has its own characteristics such as size, version of the device, manufacturer, price of the device and appearance. The common characteristic of all terminal devices is that they all have access to the Internet. Figure 1 shows the use of various terminal devices in the world.
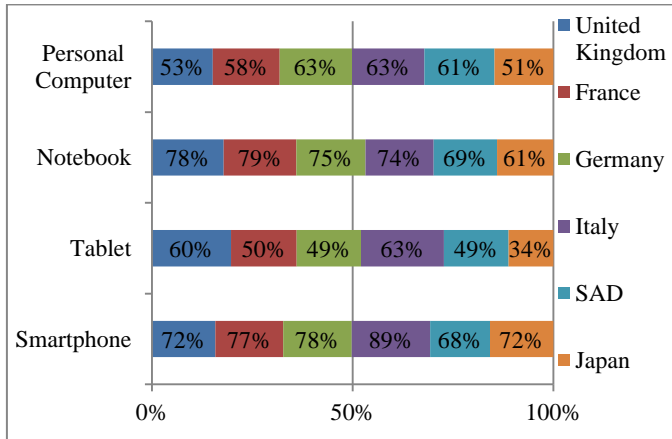

Figure 1.   Use of various terminal devices in the world [7]

The Figure 1 shows that smartphones have the largest increase in usage of all of the above mentioned terminal devices. The reason is that smartphones provide almost identical services as other mentioned devices, but because of their size, they are more suitable for users to use.

Although these devices offer similar services, there are differences between them. Not all devices have the same price. Computers have different OSs than tablets and smartphones. Also, not all devices achieve the same rate of data transfer, or have the same resolution and screen size. All of these factors, expect the price of the device, affect the usage of data traffic. As the device has a higher screen resolution and aspect ratio, the quality of the content that is displayed on the screen will be higher, which will generate a larger amount of data traffic.

III. ANALYZED OPERATING SYSTEMS

OS is a software program that acts as a connection between computer users and computer hardware. OSs have been developed to allow the use of different types of applications on terminal devices. OSs differ in different types of devices, as well as their capabilities and specifics. In this paper are described OSs of mobile devices as well as OSs of computers.

A. Computer operating systems

Today there is a large number of OSs which differ in details, where some are more significant than others. However, this paper will cover only two types of computer OSs, as well as their variants and specifications of some, and these are: Windows and Mac OS. Figure 2 shows that Windows is the most widely used OS today.
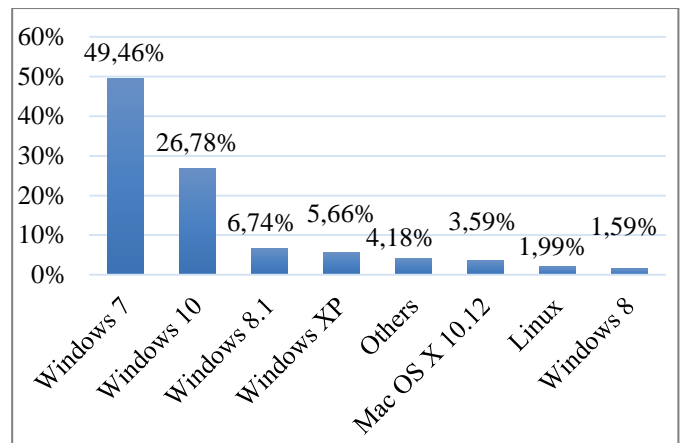

Figure 2.   View of usage of different types of computer OSs [8]

Also, according to the picture, it is possible to see that Windows 7 is the most widely used version of Windows that is built on the core of Windows Vista. The most widely used version has become very popular, and the users used it most often for playing games.

1) Windows operating system

Most used Microsoft's OS is a Windows OS that can be used on almost all computers. It belongs to the category of open OS[1], and it is the most popular OS.

In this research, the Acer Aspire E1-532 notebook was used with OS Windows 10, which enables the "Start" menu that was not enabled in the previous version. What this system has is a quick start, embedded security, and returning the "Start" menu in an expand format [9].

2) Mac operating system

The MacBook Pro notebook used in this work has a built-in version of "Sierra" that is the last but one version of Mac OS X with new features: adding Siri to enable voice commands, optimized data storage, permissions for photos, messages, and iTunes. Also there is no credit card number entry through Apple Pay and transactions are protected [10].

B. Operating systems of mobile devices

The development of OS on mobile devices has been ongoing for a long time, and because of their complexity, it is still developing. Mobile OS combines OS of personal computer features with features that are required for manual or mobile use. There are different types of OS for mobile devices, and some of them are Android, Bada, Blackberry, iOS, Windows Phone, MeeGo, Palm, Symbian, etc.

Nowadays, most people use the Android OS which is more popular than the Windows OS used on computers. Accordingly, users on their mobile devices, even 80.7% of them use Android. In Figure 3 below we can see the percentage of usage of certain mobile OSs.

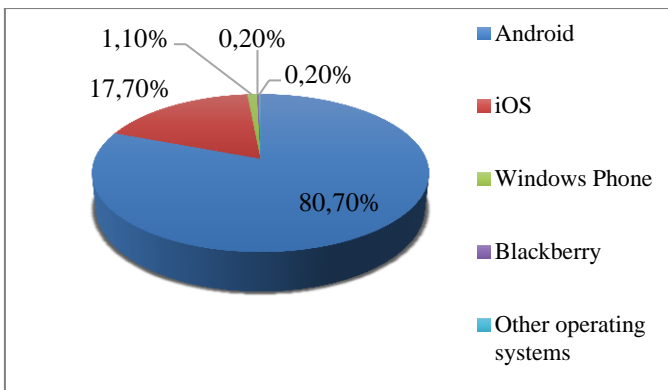[1]   An operating system developed for execution on various hardware platforms.

Figure 3. Percentage of OS usage on mobile devices [11]

1) Android operating system

Android is the first open OS for mobile devices launched by Google and run by the Open Handset Alliance. This system is based on the Linux core, and provides a platform that allows to create different applications and games for your users [12]. Shortly after entering the market, Android gains great popularity on the basis of an acceptable and beautiful look, as well as its efficient and productive work. The openness that Android offers makes it a favorite to different types of users, and that has marked a large increase in the demand for certain applications that can be found on their official Google Play store.

During the research, Samsung Galaxy A5 2015 device was used, and the OS version on it is 6.0.1 which is called Marshmallow. This version has a USB type C support, and fingerprint authentication support. In addition, it also provides Android Pay and improvements to Google Now [13].

2) iOS operativni sustav

iOS is actually abbreviation for the iPhone OS (iPhone Operating System) and runs only on Apple's mobile devices, such as: iPhone, iPad, and iPod Touch. Apple iOS includes the following features:

- Wi-Fi, Bluetooth and cellular connectivity, along with VPN support;

- Integrated search support, which enables simultaneous search through files, media, applications and email;

- Gesture recognition supports – for example, shaking the device to undo the most recent action;

- Safari mobile browser;

- Integrated front – and rear-facing cameras with video capabilities;

- Direct access to the Apple App store and the iTunes catalog of music, podcasts, television shows and movies available to rent or purchase;

- Compatibility with Apple's cloud service, iCloud

- Siri personal assistant

- *Apple Pay* which stores users credit card data and allows them to pay for goods and services directly with an iOS device [14].

The research was performed on the mobile device iPhone 6 with OS version 10.3.3, which is also the latest version of the system. Version 10 is currently supported and supports the iPhone 5 models, and so on. With this version, it was announced that it was the biggest release ever, and has completely redesigned features to lock the screen with 3D touch-sensitive information, and a very simple camera and screen. SMS messages have been updated and enhanced, and now there are options for sending animations, different effects, and so on.

Also, the voice command Siri has also been enhanced in a way that enables developers to build support in their applications. In addition, Maps and Apple Music are also redesigned with a simpler interface, and Maps now have different proactive suggestions, and music has the ability to find songs better and easier, as well as better focus on the same [15].

3) Windows Phone operating system

Windows Phone is the OS for mobile terminal products developed by Microsoft. The design used in this operating system is Metro. As with the previous two operating systems, Windows can also install different applications and they are available through the application store called Microsoft Windows Marketplace for Mobile [16]. Windows Phone has only three versions and they are: Windows Phone 7, Windows Phone 8, and Windows Phone 8.1. Windows also has the fourth version called Windows Mobile 10, which is the latest version of the system.

The research in this paper was performed on a Nokia Lumia 535 mobile device that has a version of Windows Mobile 10 OS which is the latest version of the Windows system, and which focuses more on the user's experience and functionality. The OS on mobile devices is very similar to those on computers. Many apps have been enhanced, so the app of settings is completely reorganized and universal for all Windows 10 devices.

Also, top-of-the-list applications appear on recently-used apps, and it is making it easier to use a mobile device, and speeds up the time which takes to find a particular app [17]. It is possible to establish voice interaction by dragging the names from the phone book and knowing how to pronounce them. Consequently, it represents the best version so far, and allows all users who have Windows 8.1 ability to update.

IV. GENERATION OF DATA TRAFFIC

Data traffic is generated by the transmission of information in data form between the source and destination terminal device while using part of the capacity of the common resources of the public telecommunications network [18].

Devices generate a large amount of data traffic that users are not aware of, so when we load the Facebook page ten times on the home page, we are generating around 2 MB of data traffic. This amount of data traffic depends on the number of notifications on the home page.

The Google Maps app is linked to a huge system of informations about companies, roads and offers. With the access to the app and a search for a location, the app will generate around 150-200 kB at the searched location. Google provides voice over voice services. Google transmits voice samples to their end servers for transcription, and after transcription, they send the text back. When performing voice search and the average length of words, Google reduces the sound by generating about 20 kB for the entire operation, excluding loading the results page [19].

In 2016 data traffic increased by 63% compared to 2015. The reached level of data traffic on a monthly level for 2016 is 7.2 EB (*Exabyte*)[2], while for the year 2015 is 4.4 EB per month [20].

Over the past five years, data traffic has increased 18 times. Fourth generation networks have the highest usage of data traffic, or four times more data traffic than third-generation networks. 4G networks have generated 69% of total data traffic last year, which is a large number given that 4G networks last year accounted for only 26% of mobile connections. 3G networks compared to 4G networks in 2016 generated 24% data traffic to 33% of mobile connections. 60% of total mobile data traffic was generated through Wi-Fi networks. In 2016, 429 million new mobile devices and connections were added, and most of these devices are smartphones and M2M (*Machine To Machine*) devices [16].

On a global level smartphone represent 46% of all mobile devices and connections, and with the use of 3G and 4G networks accounted for 89% of mobile data traffic. In 2016 it was noted that the average smartphone generated 13 times more data traffic than a feature phone, but it should be noted that mobile network speeds in 2016 increased three times compared to 2015, a speed of 6.8 Mbit/s compared to 2 Mbit/s. More than half, about 60 percent of data traffic is generated by browsing video tracks.

The level of generated data traffic is different from device to device, but the highest data traffic is generated by the use of smartphones, so in 2016, their usage increased by 38%. The average amount of data traffic on a smartphone for the past year was 1 164 MB per month, which is an increase of 70% compared to 2015. Each year there is an increase in the number of accomplished connections to the terminal device, so in the last year there was an increase in the connection of tablet devices by 26%, and personal computers by 8% [20].

By 2021, an even greater increase in data traffic is anticipated. Mobile data traffic will reach 49 EB per month, and it will reach an amount of 0.5 ZB (*Zettabyte*)[3]. Based on this, technology development will continue, and because of the further growth in technology it is anticipated that each resident will have an average of 1.5 mobile devices, which is a number of 11.6 billion worldwide mobile devices. It will also record the development of M2M devices that will exceed the world population.

By 2021, also the development and use of 5G network is foreseen. It is assumed that the 5G network will have a theoretical 10 Gbit/s transmission rate, while the actual transfer rates will be greater than 20 Mbit/s [20]. Figure 4 shows the increase in the use of terminal devices in 2017.
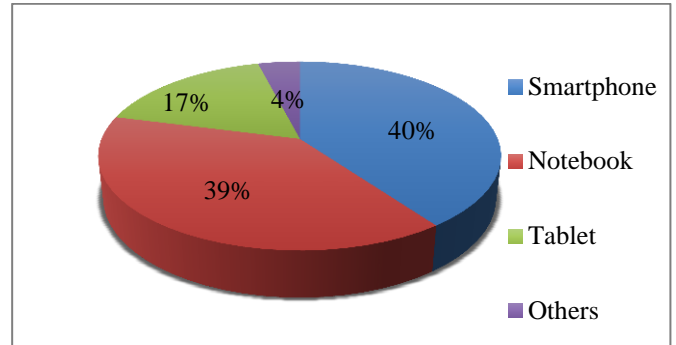

Figure 4. Overview of increased use of terminal devices in 2017. [21]

Also, large capacity networks and advanced devices enable the growth of data-intensive applications. Users migrate from existing 2G networks to 3G and 4G connections to benefit from advanced mobile devices with greater functionality and higher data rates offered by these networks. LTE network users tend to almost double the data transmission compared to users of other mobile network data traffic generations [22].

LTE network has a higher data transfer rate than other mobile network generations. The higher the data transfer rate is, the higher the amount of generated data traffic will be.

The amount of data traffic generated by a user who has access to a larger network generation with higher speeds significantly exceeds the amount of generated data of a user who had access to previous generation networks. This is proven because Android smartphones with the ability to access 4G networks have downloaded 13.1 GB of data traffic per month, while Android users with only 3G access can generate 5 GB of data traffic per user in the same month [22].

Assuming this 4G network growth, it is expected that 2/3 of the total amount of MDT in 2019 will generate 4G networks, as can be seen in Figure 5.
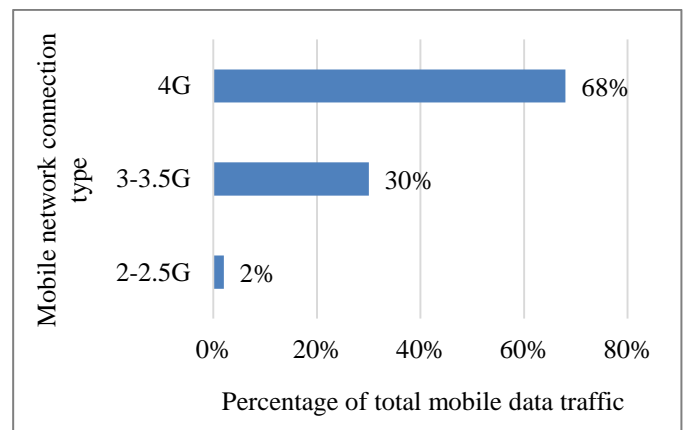

Figure 5. Prediction of generated MDT per connection type in 2019, globally [22]

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[2] The unit of 1 EB is one billion GB (*Gigabyte*).

[3] One zettabyte amounts toone trillion GB.

V. RESULTS OF RESEARCH

In recent years, there has been a huge increase in data traffic generation as well as in the use of various OSs. However, each OS differs in the generation of data traffic where each of its components already has different applications that have different usage of data traffic. Each application generates traffic differently depending on which type of content is being used.

In the research conducted on the generation of data traffic according to the OS, OS of computers and mobile OS are measured. OS of computers which were used are Windows and Mac OS, while mobile OSs are: Android, iOS, and Windows Phone.

Own OS surveys were performed using various applications to determine the generation of data traffic. There are different applications because each OS does not support the same program that allows measuring of data traffic.

Measuring was performed while browsing video tracks on YouTube to determine how much data was on downlink and on uplink in the period when the video track was viewed. The experiment was repeated multiple times on each operating system to determine the accuracy of the results. During the experiment, other applications did not make any communication. In addition, the app that showed the total amount of data traffic usage had possibility to show the percentage for each app separately, as well as for the YouTube where the measurement was performed.

A. Generating data traffic on computer operating systems

The measurements were performed on the Windows OS and on Mac OS. Figure 6 shows the obtained results on both operating systems. The results were obtained while browsing the video track on the YouTube application in a time interval of 11:10 minutes. These results are shown in the Figure 6.
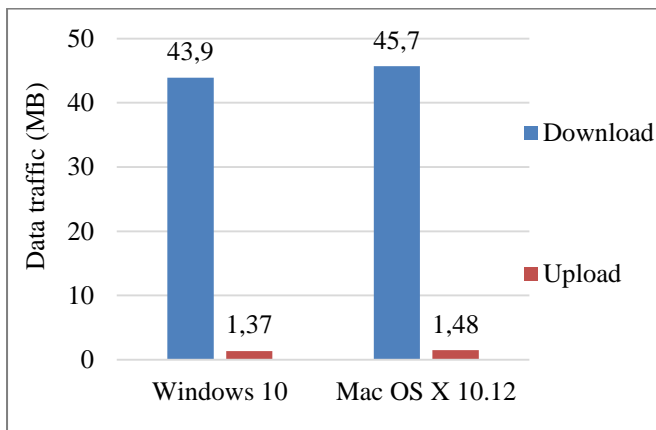

Figure 6.   Overview of the generation of data traffic between the OS of computers on data in downlink and uplink

Windows OS 10 on the terminal device Acer Aspire E1-532 generated 43.9 MB (megabytes) of data in downlink, while in uplink the device generated 1.37 MB which would mean that they totally generated data traffic was 44.46 MB. MacBook Pro which was used in this measurement has Mac OS X 10.12 version and it generated a larger amounts of data in downlink

and uplink than Windows OS 10. On the downlink 45.7 MB of data was generated and on uplink that number was 1.48 MB which is approximately like Windows and makes totally generated data traffic equivalent to 46.56 MB.

It has been shown that while using the same application and the same content, different OSs do not have the same usage of data traffic.

B. Generating data traffic on operating systems of mobile devices

On the mobile OS data traffic generation was measured using the same video track on the YouTube app in 11-minute interval. Measurements were obtained on mobile devices while they were connected to mobile networks (3G and 4G) and to the Wi-Fi network. The OSs on which data traffic is measured are: Android 6.0.1, iOS 10.3.3, and Windows Phone 10. The Android device which was used is the Samsung Galaxy A5 2015, and the iOS device is the iPhone 6 and Windows Phone is Nokia Lumia 535.

When data generation was measured, the My Data Manager application on Android and iOS was used, and the Daily Data Sense application was used on the Windows Phone. The applications have the same purpose, which is to enable data traffic measurement across different networks. Traffic generation measurement can be displayed at specific intervals or by different applications.

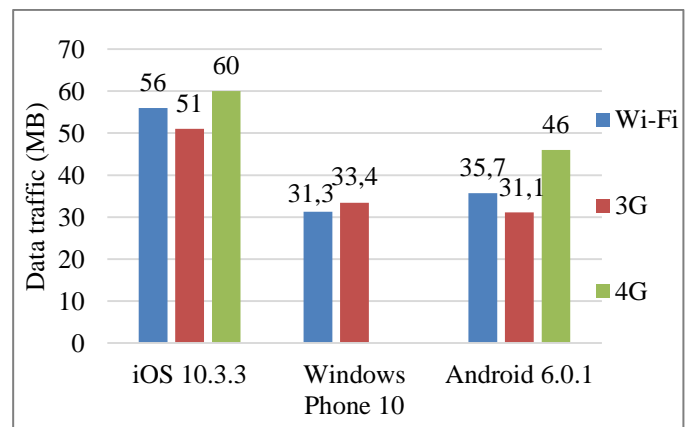The measurement results can be seen in Figure 7.

Figure 7.   Overview of generated data traffic between OS on mobile devices

According to the measurements seen in the figure 7, it is apparent that the greatest amount of generated data traffic was on the Wi-Fi network by using iOS 10.3.3 or iPhone 6. That amount was 56 MB of data traffic. Android 6.0.1 device generated a total amount of 35.7 MB of data, and the last was the device using Windows Phone 10 with 31.3 MB of generated data traffic.

The order is slightly different by using 3G network. As well as on the Wi-Fi network, the iOS device generated the highest amount of data traffic, which was 51 MB, followed by Windows Phone 10, where the generation on the 3G network is similar to the Wi-Fi and it was 33.4 MB. The least device was mobile device using Android 6.0.1 with 31.1 MB of generated data traffic.

By using 4G network, only Android 6.0.1 and iOS 10.3.3 measurements were performed because device based on Windows Phone 10 did not support the connection to 4G network. A higher level of data traffic was generated on iOS 10.3.3 with 60 MB of data, while Android 6.0.1 mobile device generated 46 MB of data traffic.

C. Comparison of the gathered data

According to the own measurements in generating data traffic, a certain difference can be observed between OS of computers and OS of mobile devices. All OSs were tested by using the Wi-Fi network and because of that it is best to show comparison according to it.

Figure 8 shows how this comparison looks between OSs in generating data traffic while they were connected to the Wi-Fi network and while the same video track was playing on every of the device.
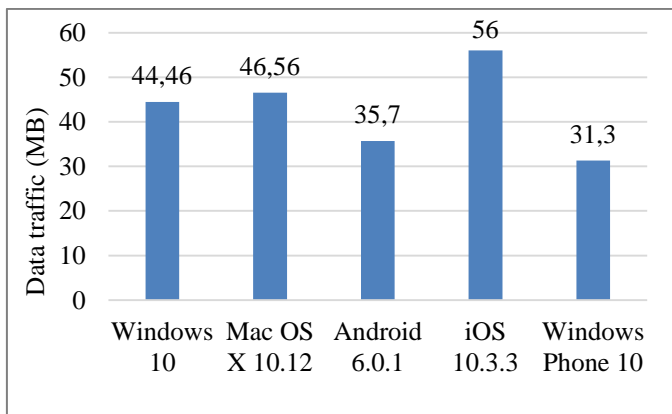

Figure 8. Comparison of OS by generating data traffic by using the Wi-Fi networks

Figure 8 shows the differences in generating data traffic while all of the devices were connected to the Wi-Fi network. It is shown that the Windows Phone 10 on the Nokia Lumia 535 generated the smallest amount of data traffic while iOS 10.3.3 on iPhone 6 generated the greatest amount of data traffic. Windows Phone 10 generated 31.3 MB of data, and iOS 10.3.3 generated 56 MB of data traffic, representing up to nearly double amount of generated traffic for the same video track.

VI. CONCLUSION

We live in a time where men's daily life without terminal devices became unthinkable. The use of terminal devices became a habit, but also a need, so during the day every human being uses at least two to three terminal devices.

Terminal devices could not provide different options without an OS who allows the functionality of all applications on them. The OS is actually used to allow the user to communicate with the desired applications. However, if the user wants to communicate with other people throughout their terminal device, he usually needs access to data networks. Today there are different networks, and the most often used are Wi-Fi, 3G and 4G networks.

The amount of generated data traffic is influenced by factors such as the OS that the terminal device applies, screen size, communication technology, etc. So, a device with a large display and resolution will generate a large amount of data traffic because it is able to show a large amount of high-quality data. Through the years, the development of mobile networks has been noted. With the development of mobile network technologies, the results show a higher amount of data traffic usage. Each mobile network generation has different transfer rates, so newer generations of mobile networks have higher data transfer rates.

Generating data traffic is not the same for all OSs, regardless of whether the same application is used on everyone. This can be supported by the results that show that the most data traffic is generated by iOS OS. While browsing the video track on Wi-Fi network, iOS has generated 56 MB of data. At the same time, using the same video track on the same Wi-Fi network, Windows Phone device generated 31.3 MB of data, which is much less than iOS.

Beside that some OSs use more data traffic when loading certain content, the overall amount of data traffic is affected by the fact that some OSs are more interesting with their applications, so the user is spending more time on the device and generates more data traffic. Also, the same applications on different OSs do not generate the same amount of data traffic. Although unaware of that, the terminal device generates background data as our application runs, or simply needs more data on one device to run than on other.

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