Energy Efficiency Study of Audio-video Content Consumption on Selected Android Mobile Terminals

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Abstract: Mobile devices are widely used by billions of users worldwide. Thanks to their main advantage, which is portability, they should be fully operational as long as possible, without the need to recharge or connect them to external power sources. This paper describes a study, carried out on four different mobile devices, with different hardware and software parameters, running the Android operating system. The research campaign involved several scenarios, including consumption of audio-visual content by different means of wireless communication (cellular and Wi-Fi), designed to best reflect the common daily use of a modern smartphone. Those scenarios were based on a user experience survey conducted at the beginning of the study. Obtained results illustrate user preferences as well as resource consumption of multimedia on different devices with varying distribution of the Android OS.

1 INTRODUCTION

Nowadays, almost everyone has at least one mobile device. The smartphone is basically a modern multi tool. It is utilized for a wide number of applications, e.g. communication and exchange of information between individuals, entertainment purposes, such as taking photos, recording videos, as well as listening to music and consuming multimedia content (Falkowski-Gilski and Uhl, 2020).

Mobile devices accompany us every day: at work, at school, at home, and on the move. Everyone can take advantage of the huge possibilities that this pocket computer can offer (Falkowski-Gilski, 2020). Manufacturers compete with one another in order to create the next hit, with cutting edge integrated technology. Yet, differences between individual models may be either very large or negligible. Often two separate devices have almost identical technical specifications. Nevertheless, they differ not only in brand, appearance, but also price. Of course, different users have different preferences. They may vary in a slightly different taste, needs and the way they use their smartphones. Consequently, functionalities can determine the choice of a user device.

The aim of this work was to test a number of mobile devices, in terms of their energy efficiency. We investigate the usage of resources, such as: CPU (Central Processing Unit) and battery lifetime. Tests, carried out during this experiment, will reflect the typical everyday usage of a smartphone, based on a user expectations survey.

2 USER SURVEY

The survey was carried out online using an interactive spreadsheet application. The questionnaire consisted of 3 questions, including both closed and open-ended ones. Provided answers could be chosen from a predefined list, as well as typed in by users themselves. They were organized as follows:

1) How many mobile devices do you use every day? (type in integer).
2) What do you usually take into account when choosing your smartphone? (select up to 2 answers).
3) What do you most often use your smartphone for? (select up to two answers).

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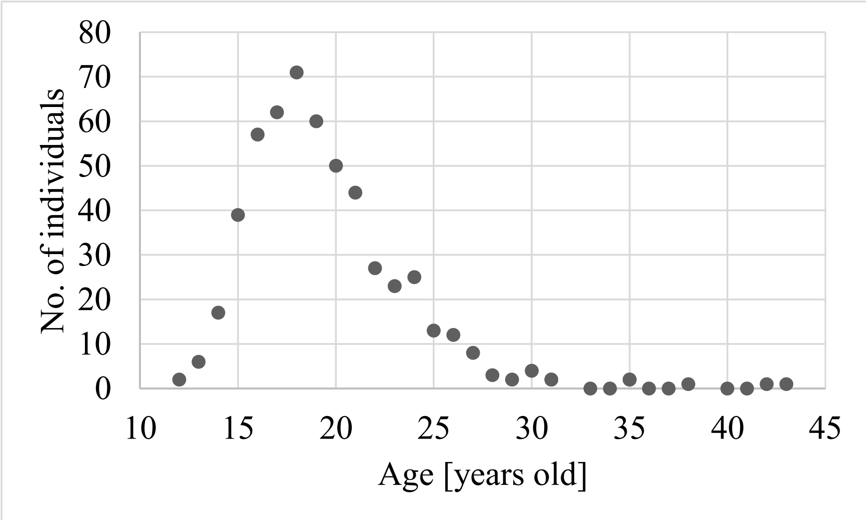

Figure 1: Age distribution of individuals participating in the survey.

The first question checked how "computerized" or "mobile" was each individual. Nowadays, a typical user has more than 1 mobile device. It is also interesting to learn how many users use a greater number of mobile terminals on a daily basis.

The second question allowed us to notice what features are most desirable among users. Thanks to this we could note their preferences. What makes a successful mobile device and what producers should pay special attention to.

The third question helped to determine which tasks smartphones are often used for. This part enabled us to design appropriate scenarios that could reflect realistic, everyday usage.

The fourth question pointed out which aspects and user expectations have not yet been met or fulfilled, as well as what characteristics of the device deteriorate over time.

The survey was posted on a social group called "Telefonawka" on Facebook, which associates over eighteen thousand people. It brings together users of mobile terminals, including different software and operating systems, IoT (Internet of Things) accessories, as well as manufacturers and other interested third parties. As a result, more than five hundred people replied. The age distribution of participants is shown in Figure 1.

The age of active participants ranges from 13 to 43 years of age. Most of the users participating in the survey are between 15 and 21 years old. Results of the survey, describing provided answers to each of the 3 questions, are shown in Figures 2-4, respectively.

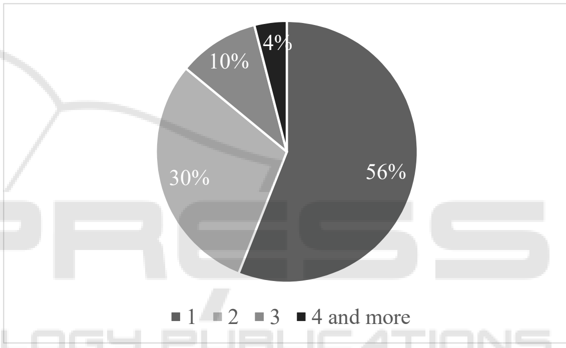

Figure 2: Number of mobile devices used everyday.

In the surveyed group, over a half of individuals use just one mobile device on a daily basis. Two devices are systematically used by approx. one third of them, whereas 14% of them use 3 and more devices every day.

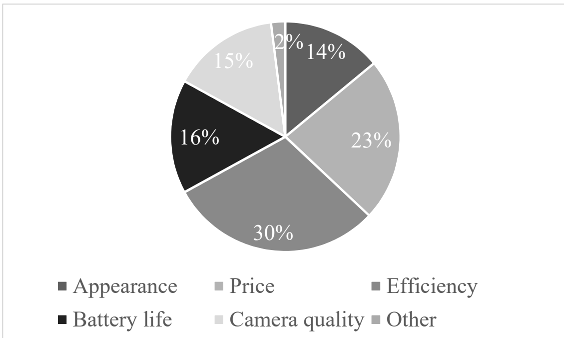

Figure 3: Factors taken into account when choosing a mobile device.

For most people (30%), efficiency (performance) is the most important factor. The second place is price, as many of them take into account the price-quality radio when choosing a smartphone, etc. Battery life came in third place, as it allows to enjoy the aforementioned performance. Whereas, the quality of photos and videos and the appearance of a device (dimensions, screen size, weight, etc.) were slightly less important. Other parameters included, among others, the operating system, support for updates, as well as waterproof and dustproof features.

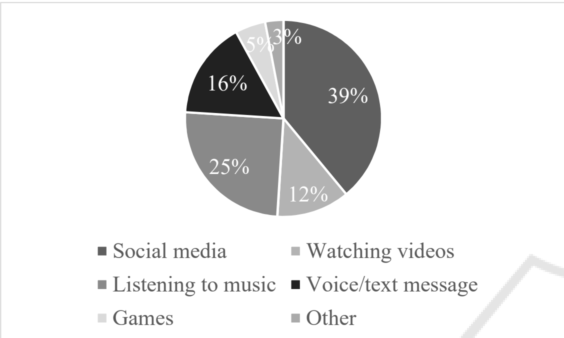

Figure 4: Main activities with a mobile device.

When it comes to the main activities, the most frequently chosen answer were social media. It should be noted that this survey itself was realized with the aid of a social media platform. The second and third place was playback of multimedia (audio and mixed audio-video). Whereas activities related with voice calls and text messaging came next. Surprisingly, only a small percentage of responders declared their interest in games. Undeniably, console or computer games are still more popular. Other activities included the ability to take pictures, record movies and navigation purposes. A related study, carried out in Portugal, may be found in (Horta et al., 2016).

3 ENERGY EFFICIENCY

There are many mobile device available on the market and the number of smartphones launched each year continues to grow. From a user's perspective, it is highly desirable to own a device that is both powerful and resource efficient (Ferroni et al., 2014). As our survey shown, battery lifetime is one of those parameters particularly important to a wide group of recipients.

The battery capacity itself is limited, due to the size and weight of a portable device (Abdelmotalib and Wu, 2012). Today's smartphones have a lot of different functions and applications. In order to understand which factors can affect the energy efficiency of a mobile device, one must determine which parts of the operating system or daily routine consume the largest amount of energy under different circumstances.

A regular cell phone that does not use smart applications can operate for several days on a single charge. With modern smartphones, handling multiple applications in the background, the device needs to be charger every one or two days (Segata, Bloessl, Sommer and Dressler, 2014). It is worth mentioning that smartphones consume more energy compared to regular cell phones even if their smart applications are rarely used. While the smartphone's battery capacity has increased, battery lifetime proved to be shorter compared to regular cell phones (Kim, Yun, Lee and Choi, 2012).

Additionally, graphical capabilities of smartphones in the last few years have grown significantly. The progress was possible thanks to the development of GPU (Graphical Processing Unit) chipsets. More powerful GPUs increase battery consumption. Today, smartphones have large, high resolutions screens that enable to process and present more demanding graphic data.

Of course other factors can affect battery lifetime, such as: build-in sensors, enabled wireless modules, services (applications) running in the background, brightness of the screen, and of course type of operating cellular standard or data transfer technology (Perrucci, Fitzek and Widmer, 2011; König, Memon and David, 2013; Schlichting and Sawin, 2017).

4 TESTED MOBILE DEVICES

There are many mobile device available on the market and the number of smartphones launched each year continues to grow. From a user's perspective, it is highly desirable to own a device that is both powerful and resource efficient. As the survey shown, battery lifetime is one of parameter particularly important to a wide group of recipients. The technical specification of 4 tested mobile devices is described in Table 1.

These smartphones come from various different manufacturers, they differ in both hardware and software parameters. The oldest of them (Smartphone 3) comes from 2012, and was a flagship model at that time. Smartphone 4, from 2016, is an unusual model, not intended for the European market. Smartphone 2 was manufactured in 2017, it is a mid-range phone,

Table 1: Technical specification of tested mobile devices.

		Smartphone 1 (Alcatel 3)	Smartphone 2 (Xiaomi Redmi 4X)	Smartphone 3 (Samsung Galaxy S3)	Smartphone 4 (Freetel Musashi)
Network	2G	GSM: 850 900 1800 1900	GSM: 850 900 1800 1900	GSM: 850 900 1800 1900	GSM: 850 900 1800 1900
	3G	UMTS: 850 900 1900 2100	UMTS: 850 900 1900 2100	UMTS: 850 900 1900 2100	UMTS: 800 900 2100
	4G	LTE: 800 900 1800 2100 2600	LTE: 850 1800 1900 2100 2300 2500 2600	-	LTE: 800 900 1800 2100
Screen	Type	IPS TFT	IPS LCD	Super AMOLED	TFT
	Dimensions	5.5’’	5.5’’	4.8’’	4.0’’
	Resolution	740 x 1440	1080 x 1920	720 x 1280	480 x 800
Battery	Capacity	3000 mAh	4100 mAh	2100 mAh	2000 mAh
Platform	Operating system	Android 8.0	Android 4.4	Android 4.0	Android 5.1
	CPU	MediaTek 6739 1.28 GHz 4 Cores	MediaTek 6797 2.30 GHz 10 Cores	Exynos 4412 1.40 GHz 4 Cores	MediaTek 6735M 1.0 GHz 4 Cores
	GPU	PowerVR GE8100 570 MHz	Adreno 506 650 MHz	Mali-400 440 MHz	Mali T-720 650 MHz
	RAM	2 GB	4 GB	1 GB	1 GB

very popular among consumers. Whereas, Smartphone 1 was produced in 2018, as a low-price model, with dual-SIM capabilities.

The initial setup as well as testing procedure is described in Table 2. The utilized benchmark application was Trepn Power Profiler from Qualcomm (Qualcomm, 2021), a power and performance profiling application, designed to identify applications that are CPU-intensive, data consuming, or simply drain the battery. This application can be run on any Android-powered device with version 4.0 or higher. The app has two modes of operation: preset and advanced mode.

The predefined preset mode enables to monitor:

1) CPU speed – displays the speed of CPU cores on the screen.
2) Mobile data – detect which applications are using cellular/Wi-Fi data.
3) Performance – a plot of CPU and GPU load.
4) CPU usage – generates the percentage of usage.
5) CPU load – a plot of CPU cores load.
6) Network activity – including the status related to the operating networks.

The advanced mode allows to select a set of parameters that one is interested in. Of course the availability of respective data depends on the manufacturer of the chipset, which sometimes may not be available. For the purpose of this study, we have selected 2 parameters, namely: battery power [mW], CPU load [%]. Those factors were monitored during the use of both cellular and Wi-Fi data transfer, as well as lowest and highest brightness settings.

Table 2: Initial setup and testing procedure.

Stage	Step	Description
Initial setup	Step 1	Device is fully charged and powered on
	Step 2	Screen brightness is set to lowest/highest level
	Step 3	Cellular/Wi-Fi data transmission is enabled
	Step 4	Testing, custom and evaluated application are launched
Testing procedure	Step 1	Launching all applications and configurations
	Step 2	Audio/Video playback over a period of 3 minutes
	Step 3	Ending all actions, saving results to .csv file
	Step 4	End of procedure

The execution of each step, as described, was automated by our custom-build software, which was later used to gather and handle obtained data.

5 RESULTS

Since watching videos and listening to audio proved to be one of the most common activities with a smartphone, we have performed a study concerning: battery usage and CPU load. Our scenarios included two types of data transmission (cellular and Wi-Fi), as well as different screen brightness level (minimum and maximum). Results of this study are shown in Figures 5-16. Those related with consumption of video content, particularly YouTube application, are shown in Figures 5-12, whereas those focused on audio content, namely Spotify application, are shown in Figures 13-16, respectively.

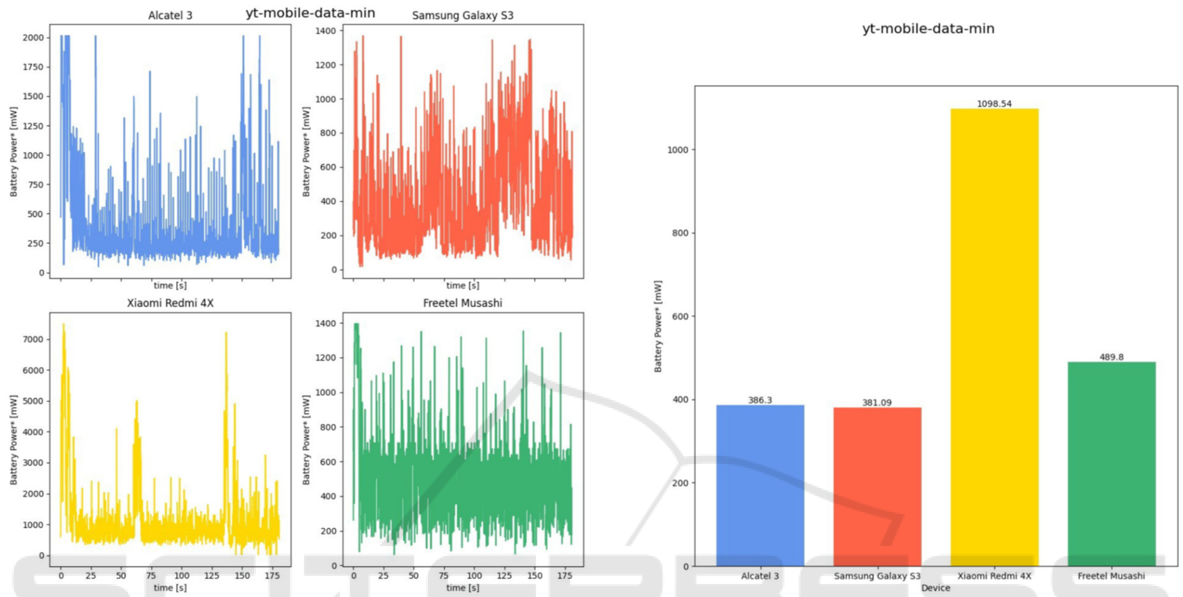

Figure 5: Battery power consumption while watching YouTube videos with cellular data at lowest brightness level: instantaneous value (left), averaged value (right).

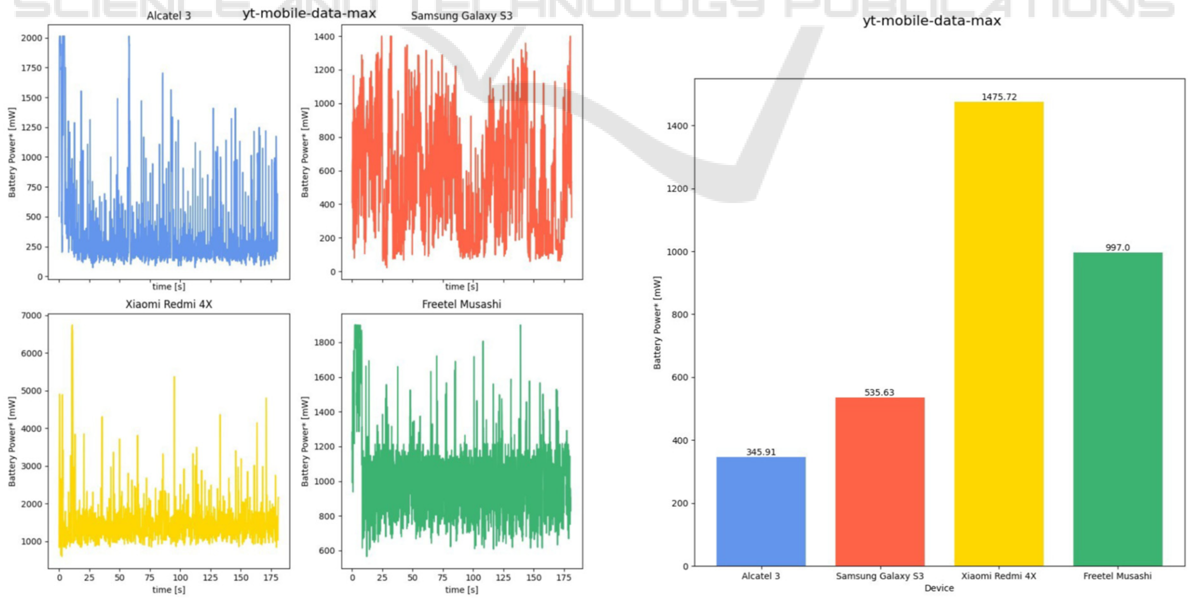

Figure 6: Battery power consumption while watching YouTube videos with cellular data at highest brightness level: instantaneous value (left), averaged value (right).

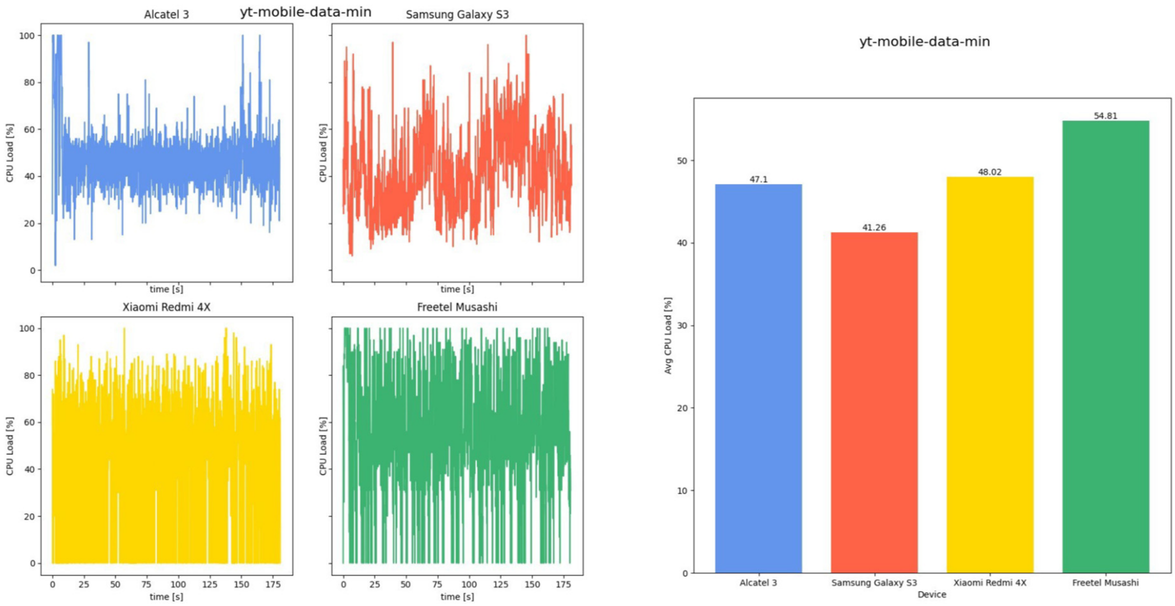

Figure 7: CPU load while watching YouTube videos with cellular data at lowest brightness level: instantaneous value (left), averaged value (right).

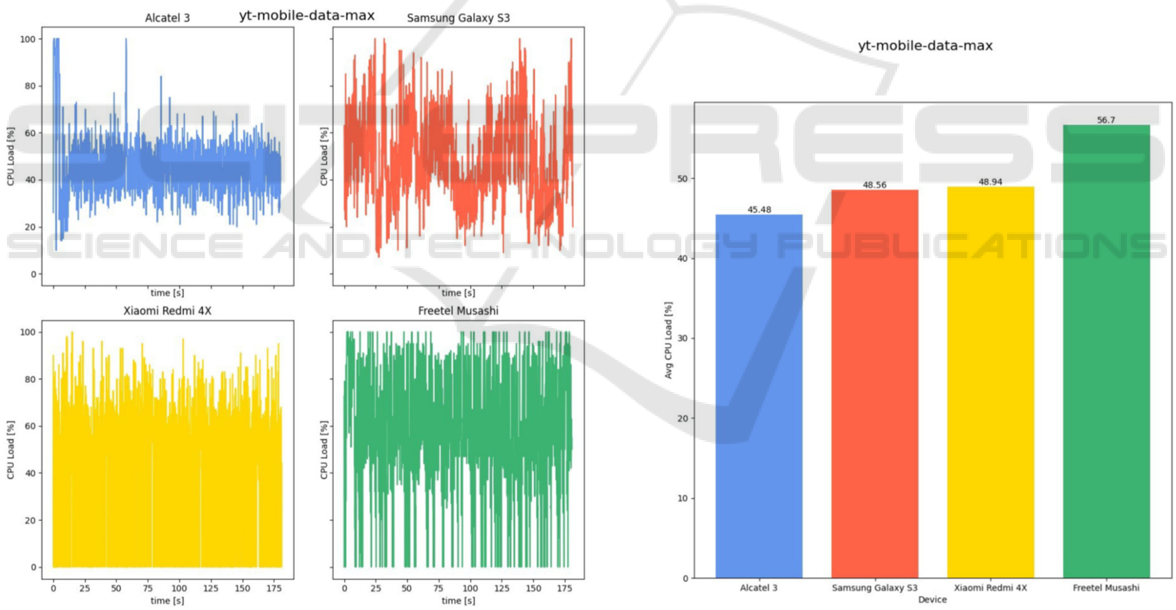

Figure 8: CPU load while watching YouTube videos with cellular data at highest brightness level: instantaneous value (left), averaged value (right).

When watching movies using the mobile Internet, the brightness of the screen is of great importance, especially among the older models. Alcatel 3 (Smartphone 1) obtained similar power consumption in both variants at approx. 350-380 mW, whereas other devices recorded a higher difference of approx. 150 mW (Samsung Galaxy S3), 400 mw (Xiaomi Redmi X4) and 500 mW (Freetel Musashi).

What is interesting, CPU load did not vary depending on the brightness level of the screen.

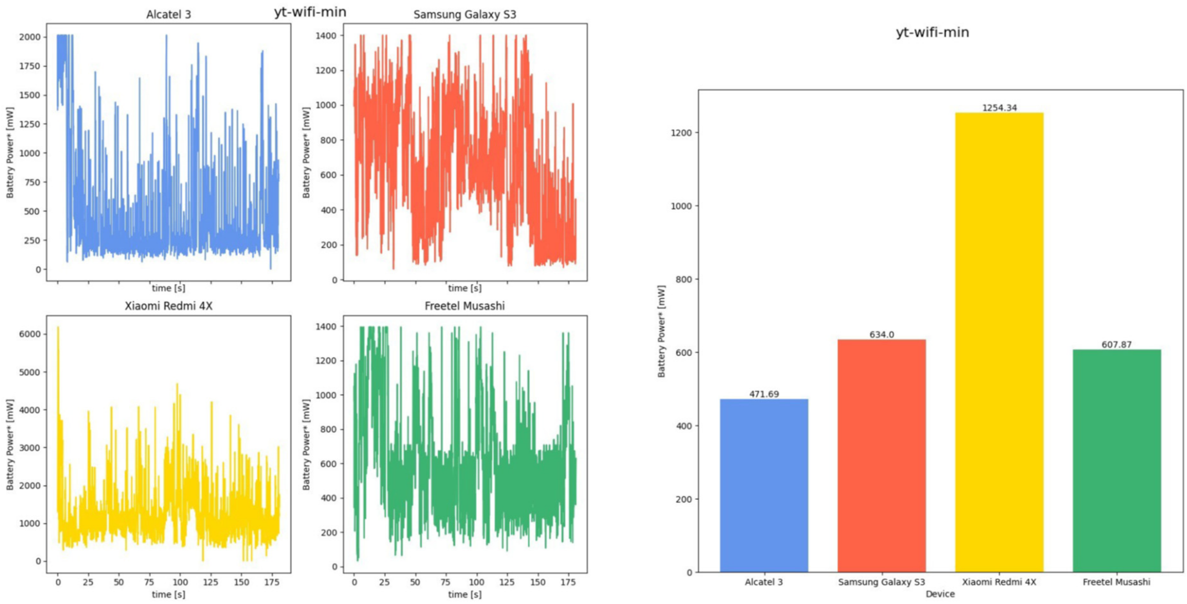

Figure 9: Battery power consumption while watching YouTube videos with Wi-Fi data at lowest brightness level: instantaneous value (left), averaged value (right).

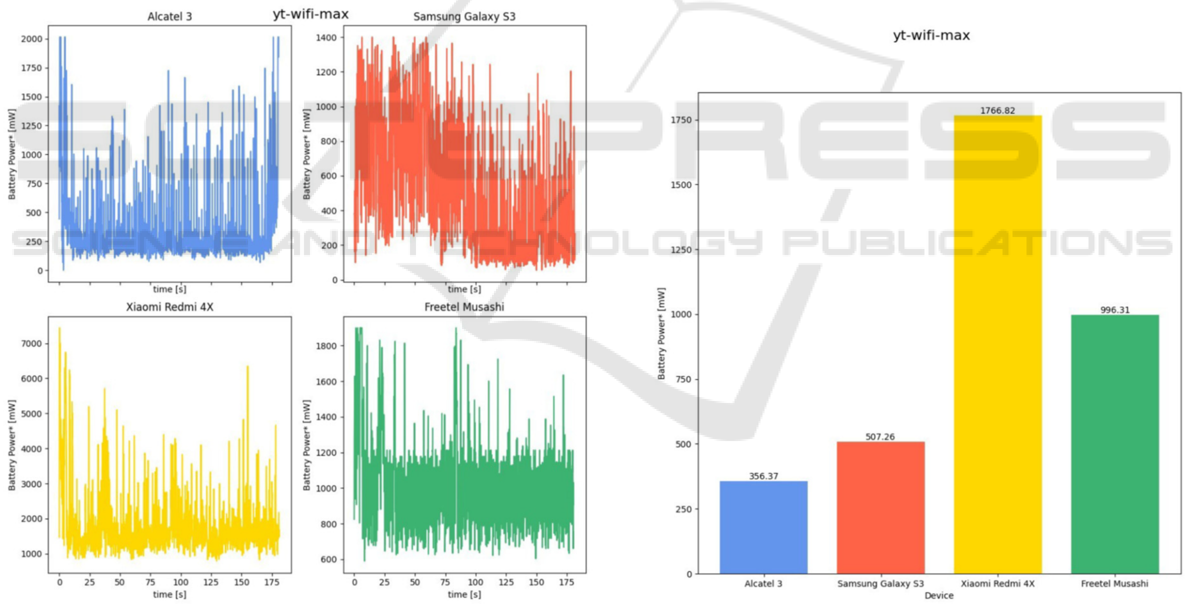

Figure 10: Battery power consumption while watching YouTube videos with Wi-Fi data at highest brightness level: instantaneous value (left), averaged value (right).

Comparing obtained results it can be seen that in the case of Redmi Note 4X and Freetel Musashi with brighter screen, power consumption increased drastically (by 500 mW and 400 mW, respectively), as did when using mobile Internet. Alcatel 3 and Samsung Galaxy S3, on the other hand, achieved better results with a higher screen brightness (reduction of consumption by 120 and 130 mW).

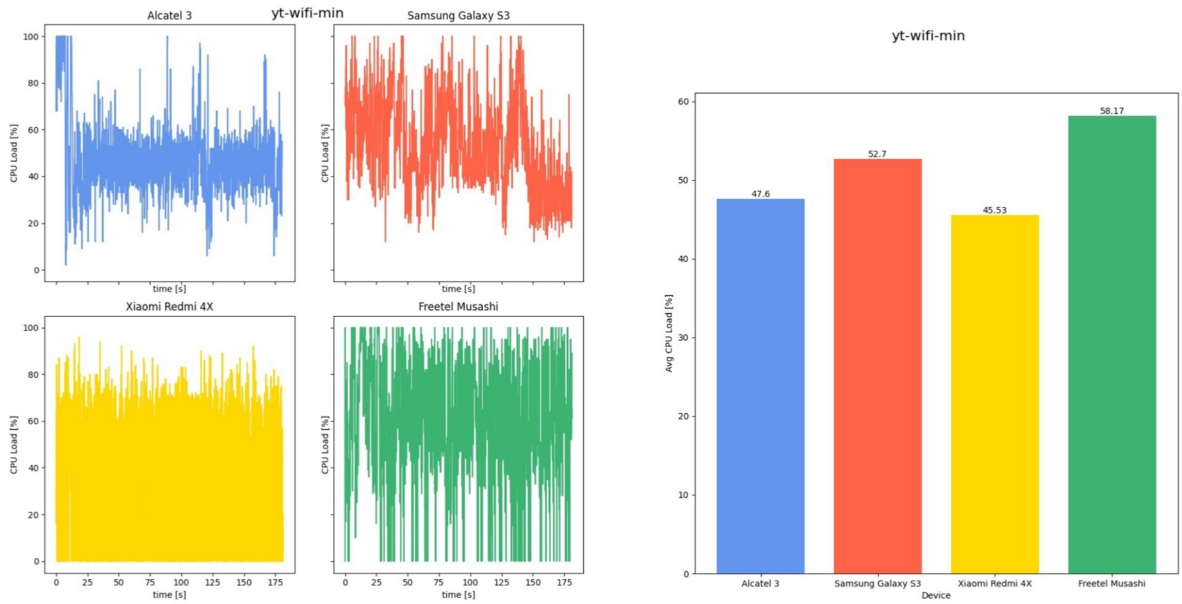

Figure 11: CPU load while watching YouTube videos with Wi-Fi data at lowest brightness level: instantaneous value (left), averaged value (right).

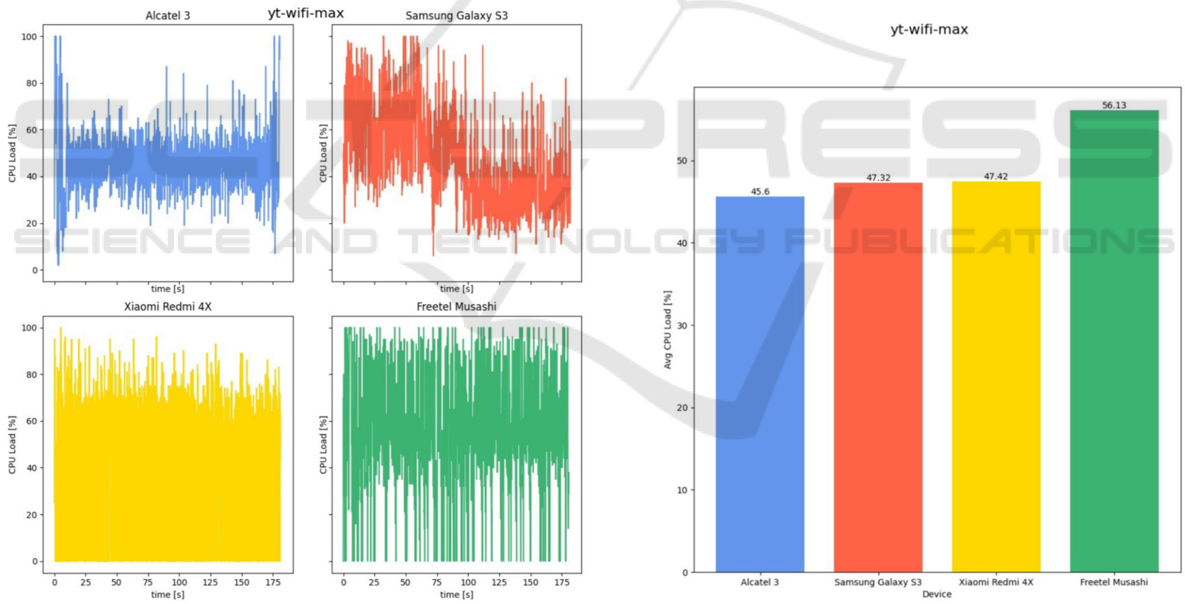

Figure 12: CPU load while watching YouTube videos with Wi-Fi data at highest brightness level: instantaneous value (left), averaged value (right).

As shown, the brightness of the screen does not affect CPU usage. The load is at a similar level as in the analogous test when using mobile Internet.

During this scenario, on the two latest phones (Alcatel 3 and Xiaomi Redmi X4), one can notice that the use of mobile data required much more battery power (470 mW compared to 355 mW in case of Wi-Fi). The difference between cellular and Wi-Fi data transmission in case of Samsung Galaxy S3 and Freetel Musashi was lower, yet it favored the Wi-Fi connection as well (27 compared to 124 mW).

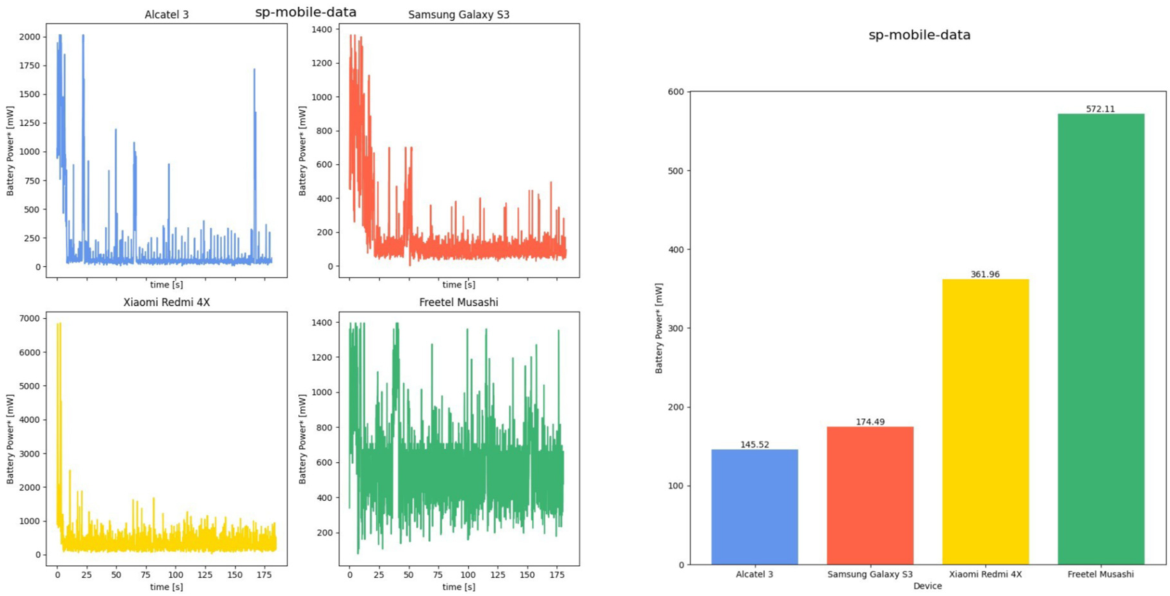

Figure 13: Battery power consumption while listening Spotify audio with cellular data: instantaneous value (left), averaged value (right).

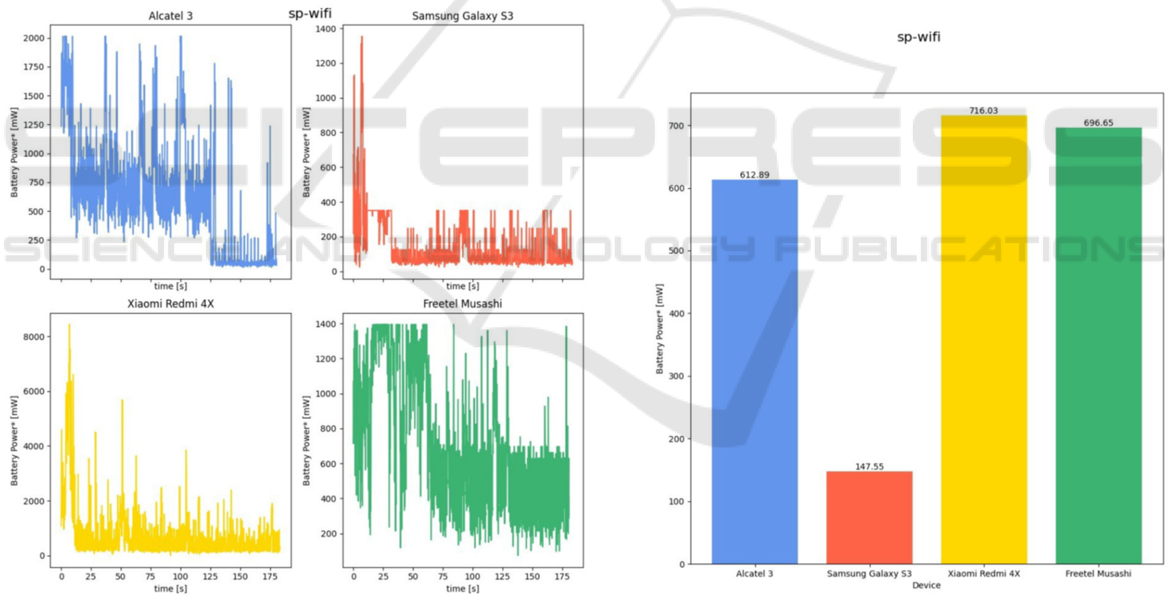

Figure 14: Battery power consumption while listening Spotify audio with Wi-Fi data: instantaneous value (left), averaged value (right).

The measured CPU loads partially coincide with the battery consumption for individual devices (Freetel Musashi and Samsung Galaxy S3). During the transfer via Wi-Fi they are characterized by higher load values compared to cellular data transmission. Automatically, this translates into higher battery usage.

6 SUMMARY

In the carried out study, the tested devices were subjected to typical user scenarios, in which their energy efficiency has been put to the test. It has shown that the degree to which the screen brightness is selected, the choice of data transfer technology affects the use of the battery and its rate of discharge.

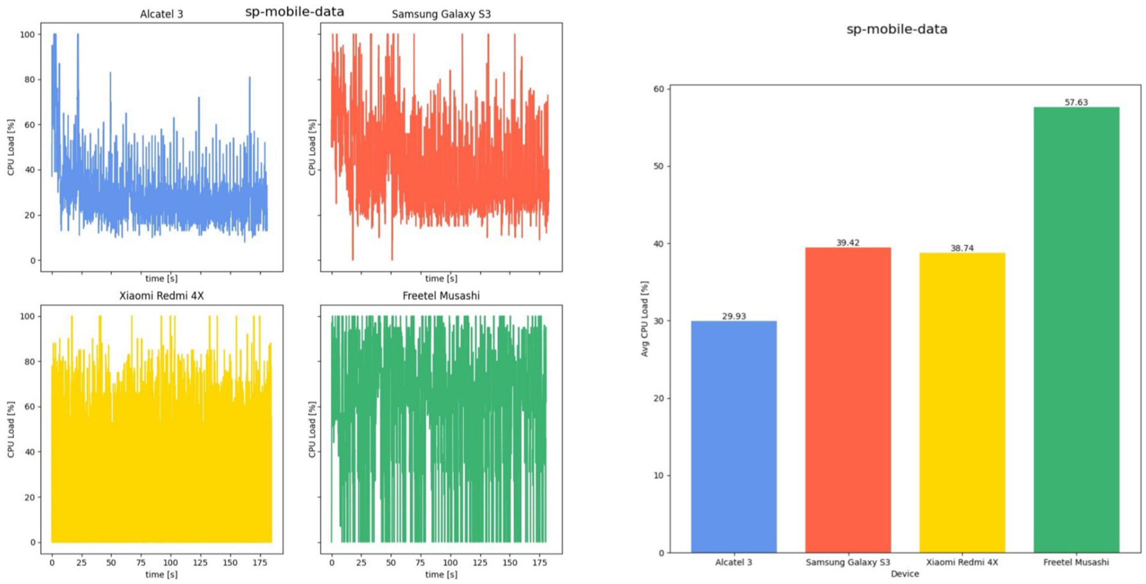

Figure 15: CPU load while listening Spotify audio with cellular data: instantaneous value (left), averaged value (right).

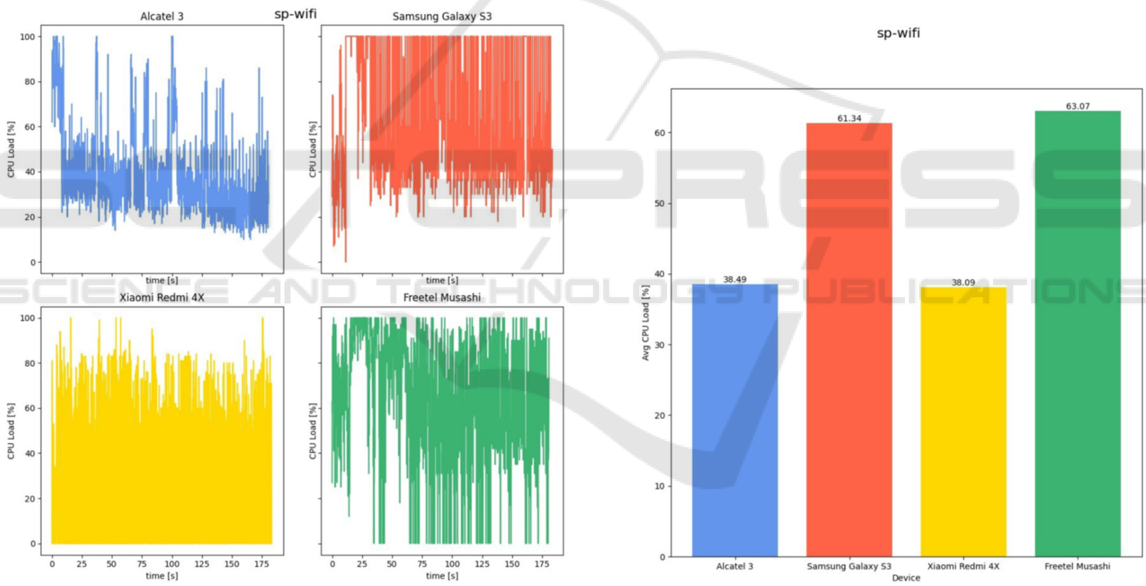

Figure 16: CPU load while listening Spotify audio with Wi-Fi data: instantaneous value (left), averaged value (right).

Current mobile communication includes transferring and handling huge amounts of data containing high-quality sound and image, which must be processed and properly displayed on the device. Hence, newer phones offer higher hardware investments.

As shown, generally speaking mobile data transmission (cellular connection) required much more battery resources than Wi-Fi data transmission. As expected, video playback proved to be more demanding than just single audio. Whereas, screen brightness should be also taken into account when designing energy effective solutions. Additionally, results clearly show that newer devices, both considering hardware (build-in components) and software (distribution of the operating system), have a noticeable advantage over older devices. However, this does not mean that there is really a necessity to change one's mobile device every year (The Climate Group, 2008).

Still, the topic of energy efficiency and battery consumption of mobile devices and related systems and services remains open. Future studies may and should include a broader range of user activities as well as hardware and software platforms, including a single or multiple operating systems and user devices, not to mention network optimization methods and algorithms. It would be also interesting to evaluate various playback accessories, including loudspeakers and headphones, both wired and wireless. A source of inspiration may be found in (Coughlin and IEEE Consumer Electronics Society Future Directions Committee, 2014).

REFERENCES

Abdelmotalib, A., Wu, Z. (2012). Power consumption in smartphones (hardware behaviourism). *International Journal of Computer Science Issues*, *9*(3), 161.

Coughlin, T., IEEE Consumer Electronics Society Future Directions Committee. (2014). A Moore’s Law for mobile energy: Improving upon conventional batteries and energy sources for mobile devices. *IEEE Consumer Electronics Magazine*, *4*(1), 74-82.

Falkowski-Gilski, P. (2020). On the consumption of multimedia content using mobile devices: A year to year user case study. *Archives of Acoustics*, *45*(2), 321-328.

Falkowski-Gilski, P., Uhl, T. (2020). Current trends in consumption of multimedia content using online streaming platforms: A user-centric survey. *Computer Science Review*, *37*, 100268.

Ferroni, M., Cazzola, A., Trovò, F., Sciuto, D., Santambrogio, M. D. (2014). On power and energy consumption modeling for smart mobile devices. In *EUC’14*, *12th IEEE International Conference on Embedded and Ubiquitous Computing*, 273-280.

Horta, A., Fonseca, S., Truninger, M., Nobre, N., Correia, A. (2016). Mobile phones, batteries and power consumption: An analysis of social practices in Portugal. *Energy Research & Social Science*, *13*, 15-23.

Kim, M. W., Yun, D. G., Lee, J. M., Choi, S. G. (2012). Battery life time extension method using selective data reception on smartphone. In *ICOIN’12*, *International Conference on Information Network*, 468-471.

König, I., Memon, A. Q., David, K. (2013). Energy consumption of the sensors of smartphones. In *ISWCS’13*, *10th International Symposium on Wireless Communication Systems*, 1-5.

Perrucci, G. P., Fitzek, F. H., Widmer, J. (2011). Survey on energy consumption entities on the smartphone platform. In *VTC’11*, *73rd IEEE Vehicular Technology Conference*, 1-6.

Qualcomm. (2021). Trepn Power Profiler. https://developer.qualcomm.com/forums/software/trepn-power-profiler [accessed: 15.07.2021].

Schlichting, M., Sawin, J. (2017). Modeling the effects of independent components on mobile device charging times. In *FiCloud’17*, *5th IEEE International Conference on Future Internet of Things and Cloud*, 142-147.

Segata, M., Bloessl, B., Sommer, C., Dressler, F. (2014). Towards energy efficient smart phone applications: Energy models for offloading tasks into the cloud. In *ICC’14*, *IEEE International Conference on Communications*, 2394-2399.

The Climate Group. (2008). Smart 2020 – Enabling the Low Carbon Economy in the Information Age.