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KULTURA RUKOVANJA PODACIMA – ZABORAVLJENI ASPEKT INTEGRACIJE OBNOVLJIVIH IZVORA ELEKTRIČNE ENERGIJE

DATA HANDLING CULTURE – A FORGOTTEN ASPECT OF THE INTEGRATION OF RENEWABLE ELECTRICAL POWER SOURCES

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Trenutni trendovi poput digitalizacije, digitalne transformacije, industrije 4.0 i sličnog, koji su karakteristika savremenog društva u celini, nametnuli su svet podataka kao imperativ svih sfera ljudskog delovanja. U vrlo kratkom vremenskom roku probijene su sve ranije pretpostavljane barijere u trenutnoj količini podataka koja je u opticaju na globalnom nivou i koja se trenutno meri u desetinama zetabajta sa tendencijom kontinuiranog uvećanja u godinama koje slede. Trend povećanja količine podataka može se zabeležiti na svim nivoima, bez obzira da li posmatramo neki manji, lokalizovani uzorak, regionalni uzorak, ili, kao što je već navedeno, posmatramo globalni digitalni svet. Čak i ako nivo posmatranja svedemo na pojedinačnu instancu, gotovo da nema slučaja u kome ne možemo identifikovati neko povećanje količine podataka. Proporcionalno povećanju količine podataka, uvećala se i potrebna energija koju na različitim nivoima treba obezbediti za neku preduzetu radnju nad tim podacima, bilo da se radi o samom kreiranju tih podataka, skladištenju istih, nekoj vrsti obrade, umnožavanju ili nekoj drugoj adekvatnoj vrsti radnje nad tim podacima. Procenjuje se da već nekoliko procenata celokupne svetske proizvodnje električne energije odlazi na segment obezbeđenja neophodnih uslova za izvršenje neke od radnji nad podacima. U skladu sa tim, mnogi veliki centri za rukovanje podacima parcijalno ili u celosti prelaze na sisteme zasnovane na upotrebi obnovljivih izvora električne energije. Iako je taj transfer doneo niz prednosti i dalje postoji problem ekspanzije podataka na jednom dugoročnijem planu koji nova energetska rešenja treba da isprate. U radu će se pokazati kako se jednim racionalnijim rukovanjem podacima na različitim nivoima upotrebe može stvoriti daleko povoljnije energetsko okruženje na globalnom nivou i kako to okruženje može doprineti jednoj održivosti trenutno primenjenih rešenja koji se tiču upotrebe obnovljivih izvora električne energije u različitim segmentima upotrebe i rada sa podacima u modernom okruženju.

Ključne reči: *energija; obnovljivi izvori; održivost; podaci*

Current trends such as digitalization, digital transformation, Industry 4.0 and the like, which are characteristic of modern society as a whole, have imposed the world of data as an imperative of all spheres of human activity. In a very short period of time, all previously assumed barriers in the current amount of data in circulation at the global level, which is currently measured in tens of zettabytes with a tendency to continuously increase in the years to come, have been exceeded. Even if we reduce the level of observation to a single instance, there is almost no case in which we cannot identify any increase in the amount of data. In proportion to the increase in the amount of data, the required energy that needs to be provided at different levels for any action taken on this data has increased, whether it is the creation of this data, its storage, some processing, replication or some other adequate type of action. It is estimated that already few percents of the entire world production of electricity go to the segment of providing the necessary conditions for the performance of some of *the work on data. Accordingly, many large data centers are partially or completely switching to systems based on the use of renewable energy sources. Although this transfer has brought a number of advantages, there is still the problem of data expansion in a long-term plan that new energy solutions need to follow. The paper will show how a more rational data handling at different levels of use can create a far more favorable energy environment at the global level and how this environment can contribute to the sustainability of currently applied solutions for renewable energy in different segments of use and work with data in a modern environment.*

Key words: *data; energy; renewable sources; sustainability*

1 Introduction

In the beginning, there were data, and then, from that data, information was created. That newly created information leads to the creation of certain knowledge about something, in order to take a certain action based on that knowledge. The result of that action is the creation of some new values. This is how the modern society of today could be described in the shortest way, it daily creates some new values from the data found and generated in its environment. It can be said without exaggeration that digitization and digital transformation have become one of the key backbones of modern activity in all spheres of human life and work. As confirmation of what has been said, we can take an extremely challenging and difficult period in which the world is found itself from the moment of the declaration of a global pandemic caused by the appearance of the new corona virus (the disease designated as COVID-19), from the beginning of 2020. Many claim that it is digitalization that enabled humanity's adequate response in difficult pandemic conditions, and there are also the most extreme statements that digitalization is exactly what prevented the cataclysm that could have occurred due to the spread of a new virus across the planet. Certainly, the previous period has largely indicated that we are a society that creates data, knows how to recognize that data in an appropriate way, to process it and based on the results of that processing to act in a timely and appropriate manner in different areas of human work, in different environments and various restrictions. In a survey conducted on several hundreds of global manufacturing companies, 94% of respondents answered that it was the foundations of Industry 4.0 that enabled them to carry out business in challenging pandemic conditions, while 56% of respondents answered that undertaken digital transformation was the one that was crucial in the response to the newly created pandemic conditions [1, 2].

Since data is of great importance in the implementation of various operations in human life and work, data should be handled in an adequate manner. Taking into account the enormous growth in the speed with which data is generated, the volume of data, the variety of data and similar, the amount of energy that needs to be provided in order to satisfy the various aspects of handling that data has also increased. When we say different aspects of data handling, here we do not mean only the energy needed for example to power network equipment, data storage devices and the like. Here, a broad picture should be taken into account in order to understand the complexity in terms of the amount of energy that needs to be provided when performing various operations on and with data. If we were to look at a classic data center, a little more than a third of the required energy (36%) would be used for various equipment in the form of servers, storages, network infrastructure and similar devices. Half of the energy (50 %) would be intended for the realization of cooling processes, while the rest of the energy (14 %) would be intended for some other processes, for example the realization of lighting, or some conversion processes and similar. Significant energy consumption by IT equipment is observed, but there is also significant energy use by infrastructure facilities [3].

In 2020 data centers globally used 200-250 TWh while data transmission networks are used 260-340 TWh of electricity [4]. That means that data centers globally used about 1 % of global electricity and data transmission networks used between 1.1 and 1.4 % of global electricity regardless of exponential growth of internet traffic and data centers workloads. Key technological giants increase the share of renewable sources of electricity in their operations constantly from year to year, whether it is starting their own production, or purchasing electricity that is based exclusively on the use of renewable sources of electricity. Also, many companies, by switching to the use of services in the cloud, reduce the use of energy by tens of percent, and the energy used in the future to provide services becomes based on renewable sources of electricity [5]. Although these trends seem very encouraging, they should still be taken with a certain amount of reserve, since there is already mentioned exponential growth of key factors that affect the increase in the required electrical energy necessary for the realization of basic tasks related to some segment of work with data. Some forecasts predict that, already in 2025, 20% of the world's electricity production will be spent on various operations related directly or indirectly to the operation of data centers around the world [6].

In accordance with the above, the search for new ways of improving the energy efficiency of data centers must be continued in the future. This will certainly enable the creation of a more favorable climate for the introduction of renewable sources of electricity in this segment of work and business, as well as the possibility that existing solutions will be adequately and optimally used. In the following, we will review several potential solutions in the field of data handling that can contribute to reducing the consumption of electricity in this field, increasing energy efficiency, and thus creating additional space for the introduction of the use of electricity based on renewable sources.

2 Energy consumption differences

Each data center expresses its energy efficiency through a measure called Power Usage Effectiveness (PUE). The PUE value is expressed through the following formula [7]:

$$\mathrm{PUE} = \frac{\mathrm{TCE_{DC}}}{\mathrm{TCE_{ITEQ}}} \quad (1)$$

PUE is defined as the ratio of the total consumed energy of the data center (TCE_{DC}) which represents sum of consumed energy of all systems which participates in data center operations (cooling, lighting, network, server, storage etc.) and the total consumed energy of the IT equipment (TCE_{ITEQ}) which represents sum of consumed energy of various hardware (servers, storages, network devices etc.).

Of course, the ideal value of PUE would be equal to 1, which would indicate that the entire energy used in the operation of the data center is used only for IT equipment, but in practice this is not possible to achieve, so the aim is to these values are accomplished as close as possible to the value 1. Some of the lowest achieved and recorded PUE values are around 1.2, but there are also indications that certain technological giants in their data centers managed to achieve even lower values around 1.1 [7,8]. However, attention should be paid here as well, because the data centers operations becomes more complex year by year due to the constant expansions in the world of data and it is necessary to constantly work on the implementation of new mechanisms that would keep PUE values at minimum acceptable values for achieving the highest degree of energy efficiency in work. If we look at the above from the point of view of the use of renewable sources of electricity, of course, lower PUE values are extremely favorable for the transfer to a higher degree of use of renewable sources, so essentially, if we look at the reduction of the carbon footprint, we can say that it is extremely important to find new ways that in the very fast world of data, it will enable maintaining the energy efficiency of data centers.

One of the key factors here is precisely the IT equipment that represents the basis of the operation of all data centers, since it figures in both the denominator and the numerator of the formula (1) by which the PUE value is expressed. In addition, there is a direct influence of IT equipment on the energy consumption of certain other systems, especially the cooling system. That is why it is of essential importance to reduce the load on IT equipment, and accordingly we have a whole series of different hardware and software upgrades of IT equipment from year to year. However, the question arises whether it is possible to produce the same results with the same equipment, and at the same time reduce the load on it in some other way. This will be discussed later in this paper. However, we will first familiarize ourselves with some aspects of energy consumption by IT equipment through several tests that we have conducted on several typical servers that performed standard tasks used when working with data.

All tests were performed in a controlled environment in which the ambient temperature was kept constant with a maximum value of 24 ^{O}C in accordance with existing research and recommendations [9,10]. Some of the characteristics of the tested equipment are shown in Table 1.

Table 1. List of tested servers

Label	Server Type	CPUs	Memory	Used Controller	Disks	OS
S1	Rack	2xIntel Xeon E5410 2.33 GHz	8 GB	SAS	2x73 GB SAS 15k rpm 2x146 GB SAS 15k rpm	Linux
S2	Tower	Intel Xeon E3120 3.16 GHz	4 GB	SATA II	500 GB SATA II 5400 rpm	Linux
S3	Rack	2xIntel Xeon 3.06 GHz	2 GB	SCSI Ultra320	2x36.4 GB SCSI Ultra320 15k rpm	Linux
S4	Tower	Intel i7-2600 3.40 GHz	8 GB	SATA III	128 GB SSD 550/500 MB/s 1 TB SATA III HDD 7200 rpm	Linux

The tests consisted in monitoring the maximum recorded power during various operations performed with the help of the equipment shown in table 1, since there is a direct proportionality between power and energy (energy can essentially be expressed as a product of power and elapsed time) [3]. The consumption was observed in a switched off state, during system booting, during idle state, during the downloading data and during the extraction of downloaded data on the corresponding server, which covers some of the most common operations that are carried out in production environment. The obtained values are shown in table 2

Table 2. Maximum measured power values during various operations

Server	Off	Booting	Idle	Downloading	Extracting
S1	12 W	242 W	183 W	200 W	218 W
S2	8 W	110 W	90 W	95 W	123 W
S3	27 W	211 W	151 W	176 W	198 W
S4	1 W	95 W	60 W	81 W	92 W

All servers used in this test environment have the same operating system (OS), the same OS modules, the same OS configuration parameters. Also, they performed the tasks using the same parameters, working conditions, and what is most important, they performed the same operations on the same file using identical software. However, although the procedures for the implementation of predefined tasks are identical, although the software environment is also identical, there is still a difference in the hardware configurations of the used servers. As expected, different hardware configurations when performing the same tasks will have different energy characteristics that can vary significantly.

We saw that each of the servers achieved a unique energy signature when performing the same tasks on the same processing object. Accordingly, the question arises as to how to find the appropriate unique pattern for reducing energy and achieving a higher degree of energy efficiency. What is the factor that we can change and whose change will result in a reduction of energy consumption in all observed systems without changing the characteristics of the system itself and whose change would not violate the consistency of those systems.

We come to the conclusion that the only factor that we can move out of the environment without disturbing the environment is the data itself. Accordingly, in order to achieve better energy efficiency, the focus should be on the data itself, so the following will show how the usual traditional practice of handling data should be changed in order to reduce the required amount of energy.

3 Improving data handling improves energy efficiency

Generally, when a change to the data itself is considered, there is a fear that such a change will damage the integrity of the data itself and with their later processing we will not get accurate and purposeful results. It is true that this can be the case if the change is made in an inadequate way so that there is a certain risk of an error occurring. However, when analyzing any process that in some way includes work with data, there is always a risk of errors to a greater or lesser extent, but in most cases this is not a reason not to carry out the given process. On the contrary, the practice is to analyze the existing risks, to enable their control and to implement such mechanisms to minimize the given risks and to disable them partially or completely. The same applies here, the perceived risks are not left to chance, the exact way of dealing with them is known.

Below will be presented three possibilities of using certain actions that include the use of data in order to maintain or improve energy efficiency, depending on the individual cases of application. All three presented possibilities imply such processes that will not threaten the integrity of the data itself and that will not make certain data sets unusable or lead to inadequate results of analyzes on them.

3.1 Reducing the amount of data

The first approach that can be achieved with data in order to increase energy efficiency when working with it is to reduce the amount of data that is processed in relation to some initial amount of data without violating a certain data set and the potential information which that dataset brings to the user who processes it. At the same time, as our researching in controlled conditions have shown, there is not necessarily a reduction in the power exerted during data processing, but the time required to perform various operations can certainly be reduced. Since, as already mentioned, in the most general case, the energy required for this type of processing is expressed through the product of power and the specific time required for that processing, reducing the processing time as one of the factors leads to a reduction in energy consumption related to the same processing. In some cases, there are significant reductions, which in total, in the case of very big data center loads, can represent significant savings in the energy balance.

During our researches, three subtypes of reducing the amount of data are identified and they will be presented using use cases which are realized through our experiments.

In the first example, a continuous recording of the memory usage in the computer was performed for a period of 5 minutes and in real time the data was recorded in a corresponding text log file that contained the recording date, recording time and recorded memory usage. In several recording series, recorded file sizes of around 100 MB were obtained. Then the content of each recorded file was analyzed. What was observed with each of the files was the existence of many repeating values for recorded memory usage. The existence of repeating values of the recorded memory states enables the reduction of each of the recorded files according to the principle shown in Figure 1.

The shown principle of reduction is reflected in a very simple replacement of a series of data containing a repeated value with the calculated number of repetitions. In doing so, the first identified data containing the repeated value is retained in the original in order to maintain the time sequence, and after it the calculated number of repetitions is written, followed by the first identified data containing the changed value in the original. In this way, we do not lose the integrity of the entire data set because we can unambiguously establish a time sequence based on the retained data, as can be seen from the example shown in Figure 1.

The next sub-type that we take into consideration concerns the existence of files that can be characterized under certain conditions as duplicates and is most often applied when working with image galleries. We called this principle "*it's not the same but it's the same*". It is most often manifested when generating images using mobile phones, which is an everyday phenomenon today that has a continuous expansion, so the next example that we will consider is related to this.

Depending on the recorded data, that is, on the number of changes made, different results of applying this method are possible. The best result that was achieved in our controlled test environment is the reduction of the log file from the size of 100.3 MB to the size of 1.9 kB. Of course, these results generally represent extreme values and are difficult to repeat in practice and production environments. Here it is assumed that there were a lot of idle states, so the number of repeated values is extremely high, which in practice may not be the case. However, although not extreme, savings are achievable using this method of tracking changes of values.

1,05.09.2022.,09:32:29,25.7G
2,05.09.2022.,09:32:30,25.7G
3,05.09.2022.,09:32:31,25.7G
4,05.09.2022.,09:32:32,25.7G
5,05.09.2022.,09:32:33,25.7G
6,05.09.2022.,09:32:34,25.7G
7,05.09.2022.,09:32:35,25.7G
8,05.09.2022.,09:32:36,25.7G
9,05.09.2022.,09:32:37,25.7G
10,05.09.2022.,09:32:38,25.7G
11,05.09.2022.,09:32:39,25.7G
12,05.09.2022.,09:32:40,25.7G
13,05.09.2022.,09:32:41,25.7G
14,05.09.2022.,09:32:42,25.7G
15,05.09.2022.,09:32:43,25.8G

a)

1,05.09.2022.,09:32:29,25.7G
2,05.09.2022.,09:32:30,25.7G
3,05.09.2022.,09:32:31,25.7G
4,05.09.2022.,09:32:32,25.7G
5,05.09.2022.,09:32:33,25.7G
6,05.09.2022.,09:32:34,25.7G
7,05.09.2022.,09:32:35,25.7G
8,05.09.2022.,09:32:36,25.7G
9,05.09.2022.,09:32:37,25.7G
10,05.09.2022.,09:32:38,25.7G
11,05.09.2022.,09:32:39,25.7G
12,05.09.2022.,09:32:40,25.7G
13,05.09.2022.,09:32:41,25.7G
14,05.09.2022.,09:32:42,25.7G
15,05.09.2022.,09:32:43,25.8G

b)

1,05.09.2022.,09:32:29,25.7G
13
15,05.09.2022.,09:32:43,25.8G

c)

Figure 1. Illustration of the applied principle of reduction
a) Originally recorded values b) Identified repeated memory values c) Reduced dataset

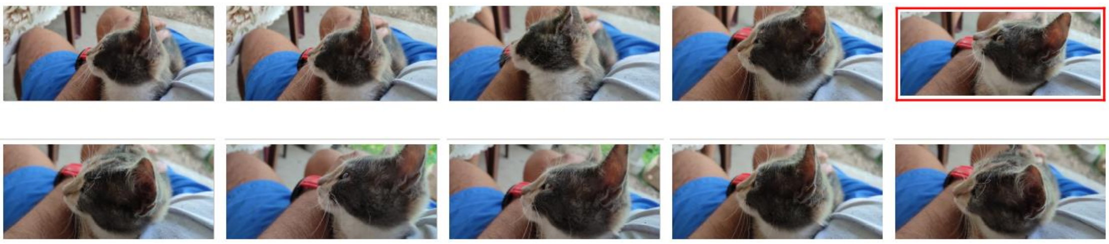

Figure 2. Illustration of the principle "it's not the same but it's the same".

Most users, when capturing a certain moment using a mobile phone camera, take several photos of the same frame to make sure that they have captured the frame in the appropriate way. Users do this either by taking individual pictures or by using some of the available options offered by modern software on mobile phones where the software automatically takes a series of pictures. Then, from the obtained set of images, users generally choose one image that meets their criteria (adequate sharpness, appropriate arrangement of elements, color, etc.). However, after selecting that one "successful" image, hardly any of the users discard the other images of that type, but save them together with the selected one and upload them all together to a destination, which is most often in the cloud today. Therefore, an additional load is produced, because, in addition to storing and processing relevant material, storage and further processing of material that is no longer relevant for the user is also performed.

The basics of the mentioned principle is illustrated in Figure 2. We have a set of ten pictures of one cat. From the whole set, one picture was selected, which is marked with a red frame. This practically means that the other nine images are no longer relevant for the user. All images are provided as jpeg images with a resolution of 4000x1800 pixels and the entire set of images occupies 45.2 MB, while only the selected image occupies 5.1 MB. This practically means that if we do not discard other, irrelevant images, we will have almost nine times more engagement for storage, transfer and other related operations. From picture 2, you can see why we called this approach "it's not the same but it's the same". When we take a closer look at the displayed images, we notice that each of them is slightly different from the previous one, but in general they all show the same frame, trying to capture the same moment, so in a certain approximation they can be treated as "identical" images and therefore, in most cases, user can choose one picture and discard the others without fear of missing the desired captured moment.

In order to make a more representative example of this method, with the consent of the user, we transferred all the images that he currently had in his mobile phone and analyzed them. In the period from May 1 to May 25, 2022, the user recorded a total of 6,697 images that occupied a total of 31 GB. After the analysis, it was discovered that there are a total of 401 images that are unique, representing approximately 6% of the recorded material. The rest of the material consisted of images representing shots that were taken multiple times (at least twice). After applying rejection of "duplicates", the total amount of images was reduced to 12.3 GB. The new set of images was then shown to the user, where after viewing it, he did not make any significant remarks about the irreversible loss of material and the like.

We will only briefly explain the third mentioned subtype, and it concerns the possibility of limiting the duration of files. Practically, this means the implementation of such a mechanism, which in certain cases will allow the definition of a deadline during which a certain file or collection of files will exist, and after the expiration of that deadline, they will be permanently destroyed (deleted). In this way, "unnecessary excess" content can be removed. Some such mechanisms have already been integrated and are used for the treatment of various temporary files marked by the system as such, however, it was observed that the spectrum of use should be expanded at certain moments.

An example from practice will be given, from a production server. The user compressed into an archive (single file) one site that occupied a total of 53.5 GB of space. The size of the resulting archive was about 35 GB. The user then downloaded that archive to his personal computer in order to have a copy to work in the development environment, but left that archive on the server. After two years, the content of the site (about 61 GB of data) was transferred to a new server from the old one. Because of the forgotten old archive, an additional 35 GB of data were transferred that were not needed, so the total transfer amounted to almost 100 GB of data.

In such cases, the existence of the previously mentioned mechanisms that would enable a wider spectrum of limitation of the duration of certain contents would be of enormous importance, since it would prevent the unnecessary use of additional resources, that is, the focus would be on those data that are really necessary.

As seen in the previous presentations, in all three subtypes we reduce the amount of data to more reasonable amount. The question arises, what does this specifically mean in the field of energy and energy efficiency. During our research, we cannot say that there is a significant reduction in the required power when performing tasks in cases where we reduced the amount of data in one of the ways. However, the time required to complete a certain task is significantly reduced, which results in significant energy savings. Specifically, in our cases, when performing file copying operations, the power peaks increased by an average of 20-23 W, while during file deletion operations, the power peaks increased by an average of 7-8 W, whether there were smaller or larger amounts of data. When the factor of time, which is significantly reduced by reducing the amount of data, is inserted into the whole equation, energy consumption is also reduced.

3.2 Other good practice

In the previous presentation, we were based on some possibilities to reduce the amount of data used, by which we can also reduce the required energy consumption. However, it must be noted that these are not the only examples of good practice that lead to significant energy savings.

In recent years, there has been a tendency in the digital world to use once obtained data multiple times, that is, whenever possible, to enable the reuse of obtained data instead of recreating it in an identical or similar way. The initiative to create open data sets that are available for use by a wide range of people, instead of limited data sets that are mainly intended for narrow corporate circles, also contributed to this.

Solutions based on the reuse of data realize various economic benefits, however, if we look strictly from an energy point of view, here too we can see several benefits that are realized. By using existing data, there is no use of energy required for their generation and for various elements of processing on them in order to realize usable data sets. In accordance with that, infrastructure needs are also reduced, which again reduces the required energy [11]. In accordance with the above, the reuse of already obtained data is shown to be a good practice towards achieving better energy efficiency.

4 Conclusion

A few decades ago, conditioned by the great limitation of resources and digital technologies available at the time, we treated data much better. With the expansion that has entered the entire digital world, we have largely given up some traditional culture related to the handling and processing of received data. The great availability of resources, content, geographical unlimitedness have made us more likely to become those who will grab a lot of data in as little time as possible, while at the same time largely forgetting the way in which that data should be properly treated. As one of the effects of the aforementioned tendencies, the problem of energy consumption required for data operations on a global level arose. Although efforts have been made to keep energy efficiency at an acceptable, set level, in recent years, the question of whether this energy efficiency will be able to be maintained in the future due to further growth in the amount of data has been raised.

That is why some approaches were presented in the paper, which are not new in the world of data, but have been largely forgotten, and which may be crucial in the future in establishing a more rational energy approach in the sphere of working with data. The described approaches also are suitable for the greater implementation of renewable sources of electrical energy in the sphere of data handling, as well as the sustainability of already implemented solutions in recent years.

It can be expected that in the foreseeable future trends regarding energy consumption in the sphere of working with data will return these solutions to the forefront as a matter of priority, so that we will treat working with data, at least from an energy point of view, like we used to do, culturally and expedient.

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