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Dew Computing and Transition of Internet Computing Paradigms

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Abstract

The goal of this paper focuses on the development of dew computing, including its origins, research status, development status, and its impact on the transition history of Internet computing paradigms. By gathering and studying all the research papers related to dew computing that we are aware of, we found that these papers can be classified into three groups: dew computing early explorations, dew computing feature research, and dew computing application research. Commercial development in the dew computing area also has progressed fast recently; many dew computing products were developed and put into the market. To distinguish dew computing from other Internet computing paradigms and to reveal its essential features, we analyze the transition history of the Internet computing paradigms from information location and distribution aspects. Online impact and redundancy rate are two indices introduced to perform the analysis. The analysis reveals that dew computing is significantly different from other Internet computing paradigms.

Keywords

dew computing; cloud computing; online impact; redundancy rate; Internet computing paradigm

1 Introduction

Dew computing is a new computing paradigm that appeared after the widely acceptance of cloud computing. Obviously the natural cloud metaphor descends to the ground through the dew metaphor. Since its first appearance in 2015, the concepts of dew and dew computing have been explored by different researchers. Many different definitions and applications have been proposed. Researchers also tried to integrate dew computing into existing applications, such as Internet of Things (IoT) streaming, medical care, indoor navigation, and cyber-physical system. There is a lack of a systematic and comprehensive research on the development history and state-of-art of dew related activities. Additionally, dew computing, as a new Internet computing paradigm, has changed the way PC interact with the network and the cloud; a study regarding to the transition of Internet computing paradigms is needed.

Dew computing is positioned at the ground level in the architecture containing cloud computing, fog computing, and dew computing. The vertical, complementary and hierarchical division from cloud computing to fog computing and to dew computing satisfies the needs of high- and low-end computing demands in everyday life and work. The goal of dew computing is to fully use the potentials of personal computers and cloud services. The dew computing paradigm lowers the cost and improves the performance, particularly for concepts and applications such as the IoT and the Internet of Everything (IoE). In addition, the dew computing paradigm will require new architectural and programming models that will efficiently reduce the complexity and improve the productivity and usability of scalable distributed computing.

The contributions of this paper are: 1) systematically survey all the research activities and development activities in the dew computing area; 2) propose two indices to assist further analysis; 3) analyze the transition of the Internet computing paradigm to reveal the essential features of dew computing.

The rest of the paper is organized as the following: Section 2 covers the current status of dew computing research and dew computing applications. In this section, we try to provide a comprehensive survey of the research papers in the dew computing area; we also describe the development work and products related to dew computing. In Section 3, we analyze the Internet computing paradigms at different stages. We also introduce two indices to assist such analysis. Section 4 is the conclusions.

2 Dew Computing and Its Applications

In this section, we collect and study all the existing important research work in the dew computing area and classify these research works into three categories: early explorations, dew computing features research, and dew computing application research. In this way, we show to the readers the landscape of the dew computing research area. We also describe the progress of commercialized dew computing applications.

2.1 Early Exploration

The first group of research work in the dew computing area can be called early exploration. In this group, a few papers were published and the dew computing research area was formed. Cloud-dew architecture [1] was proposed as a possible solution to the offline data accessibility problem. Later, more work about cloud-dew architecture was performed [2]–[4]. Although we may consider cloud-dew architecture as the starting point of dew computing, we found out that dew computing applications started their existence years before the cloud-dew architecture was proposed. This is quite normal in real life: new concepts appear after new products appear; these new concepts generalize and enhance the features of the new products, promote and facilitate the development of broad range of similar products.

At the beginning, the scope of dew computing only includes web applications [1]. In other words, at that time, the proposed dew computing applications were all web applications. Later, a broader definition [5] was proposed. An important work in this area is that a scalable distributed computing hierarchy including cloud computing, fog computing, and dew computing was proposed [6]. Some other work includes the relationships among cloud computing, fog computing, and dew computing [7], the implementation of a horizontal scalable balancer for dew computing services [8], and a new definition and categorization of dew computing [9].

2.2 Dew Computing Feature Research

After the early exploration stage, research work in the dew computing area can be classified into two groups. The first group, dew computing feature research, is discussed in this section; the second group, dew computing application research, is discussed in Section 2.3.

Dew computing feature research focuses on the overall features of dew computing. So far, these research works include the relationship between dew computing and fog computing [10], the implementation techniques of the cloud-dew architecture [6], [11], the relationship between dew computing and cloud computing [12], the relationship between cloud computing, fog computing, dew computing and possible unified framework [13]–[15], and model explorations [16], [17].

2.3 Dew Computing Application Research

Dew computing is not only a research area, but also an application area. Since dew computing is in its emerging stage, many researchers introduce dew computing into various new application areas. Till now, these areas include service and control technology [13], software delivery model [18], high-performance computing [19], life sciences and medical care [20], [21], legacy software language support [22], IoT streaming devices [23], indoor navigation [24], and relations to Cyber-Physical Systems [15], [25].

2.4 Dew Computing Commercial Applications

Dew computing is not only an emerging research area, but also an emerging application area. Some commercial applications already exist. Here we examine the status of dew computing applications through a few examples.

Flight entertainment systems play important roles during flight. While some airplanes have been equipped with screens for all seats, one airline has achieved good passenger satisfaction without these screens. This airline encourages passengers to download an app in their smart phones, tablets, or laptops; using this app, passengers can access free Wi-Fi during the flight. This Wi-Fi will connect passengers' devices to the system on board, and access flight information, movies, TV shows, and so on for free. This arrangement is also called Bring Your Own Device (BYOD) media streaming. Passengers can also access the Internet to surf websites and exchange information with outside world, but fees are normally involved. This on-board entertainment system is a typical dew computing system. It has an on-premises (on-board) dew server to provide services to passengers' devices. This dew server synchronizes with cloud-server (airport server) to get new movies and other information. Another kind of synchronization happens when passengers want to use paid Internet services and it will be accomplished through satellite links.

A few companies are providing series of products for bus Wi-Fi. It seems that these products are also dew computing products. For example, a company in UK, Mobile Onboard Limited, provides this kind of products.

Some music subscription services, such as Spotify, allow users to download music into local devices in a special format and play offline. Such services can also be considered as dew computing services.

The overall concept of dew computing refers to enabling content when there is no Internet connectivity. In early development stages this was initiated by introduction of small wearable devices (dew devices) such as iPod. Some services can be realized as simple downloads and having files on local repository, such as downloading a song, album or film by iTunes, Google play, Spotify, etc. This concept is extended to dynamically created content including maps or web sites. The idea is to enable offline web sites or web pages by providing functionality of a web application provider besides the content availability. For example, this means that the dew device needs to act as a web server, besides downloading static files, as realized by some applications for iOS and Android systems. Google has also implemented this concept on offline maps by realizing a map engine as application provider on the device. The other way of communicating the information is also implemented. Examples include features of uploading content on the web or postponed cloud service requests. In this case, the application will make a temporary copy of the cloud request that will be transferred when the Internet will become available. Shazam is such a service that depends on the Internet, and its later versions include temporal storage of a music sample until it is sent for analysis by an Internet service when the Internet is available. Some existing software packages have dew computing features. For example, open source package Gobby is a collaborative editor. Users can perform editing without the Internet, and the changes made by different users can be synchronized when an Internet connection is available.

It is hard to determine if there is any link between these dew computing applications and the dew computing concept and methodology. One thing is certain: dew computing applications are what users need and have huge potentials. Dew computing research could lead to useful concepts, techniques, frameworks, and platforms; these results will in turn facilitate the further development of dew computing applications.

2.5 Dew Computing Implementation

There are a few efforts on the design and implementation of a dew or the cloud-dew system architecture. Among them, the work in [11] explores the implementation of a dew structure on user's PC and proposes a cloud-dew architecture that features the interaction and collaboration of the cloud and the dew.

Fig. 1 illustrates a conceptual dew structure and the interaction among its components. Note that in some specific applications, more components may be needed. The entire dew structure on the local PC is formed into a dew virtual machine (DVM), an isolated environment for the dew server to be executed on the PC. DVM contains the following components.

- Dew server (DS). The DS is the representative of web servers in the cloud on the local PC. It interacts and periodically synchronizes with web servers and provides customized virtual web service to the user of the local PC.
- Dew analytics server (DAS). Dew analytics server is a local version of the web analytics server, which analyzes data generated when user uses the dew server, viewing dew sites. In this case, user data can be pre-processed before sent to the cloud to the web analytics server.
- Artificial intelligence of the dew (AID). The AID component collects analytical results from the DAS, and uses it to guide the operation of the dew server, customizing the dew server to better serve the local user.

A multi-DVM dew architecture is also proposed in [11], where for each web server the dew interacts, there is a DVM initiated. This design may potentially improve the performance decline caused by the one to fit all scheme. For example, Facebook server and YouTube server may use different database systems. Different settings in the two DVMs to work with them will increase the system performance.

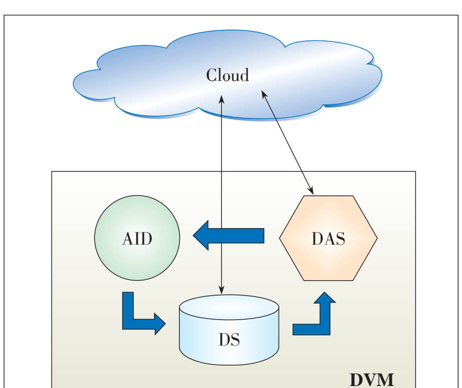


Figure 1. Dew components.

3 Transition of Internet Computing Paradigms

In this section, we try to reveal the essence of dew computing through analyzing the transition of Internet computing paradigms.

In terms of general computing paradigms, we may list batch paradigm, time-sharing paradigm, desktop paradigm, network paradigm, and so on. If we concentrate on the Internet, the network paradigm can be further classified from different perspectives. In this paper, we focus on information and the way that information is distributed, propagated, collected, and interacted among the end users through the Internet. Let us briefly review the history of the Internet computing paradigms.

- When ARPANET, the predecessor of the Internet, started in 1960's, there were only 4 nodes. All of them were mainframe computers. At that time, information was saved in each node and the connections between nodes were email and other simple communications.
- With time goes by, personal computers became dominant on the Internet, client-server architecture was proposed, and websites were created. Moreover, cloud computing has pushed the client-server architecture to the extreme: software, platforms, and infrastructures are all placed on the server side; client side local computers are merely terminals to access the Internet. The Internet's architecture has changed significantly since the mainframe computer stage.

- When more and more dew computing applications are developed, the Internet computing paradigm is changed again. Terminal devices, such as laptops, desktops, smart phones, and tablets, are not only terminals any more; they can also provide significant services to the users.

To summarize the above brief review, the early form of the Internet computing paradigm was that information existed in mainframe computers and these mainframe computers communicated with each other through email, File Transfer Protocol (FTP), and other protocols. With the development of the Internet, its architecture changed to websites and cloud computing, communicating via Hypertext Transfer Protocol (HTTP) and FTP like protocols exchanging Extensible Markup Language (XML) structured files. Since dew computing emerged, the Internet's computing paradigm has entered a new stage, where the computers work as conventional web services, or as dew services and directly communicate via XML oriented services and protocols. To simplify our analysis, we only consider these three stages in the development of the Internet computing paradigm: the mainframe stage, the website/cloud computing stage, and the web service/dew computing stage, as presented in **Fig. 2**. Three generations are classified by the information storage locations and level of information exchange.

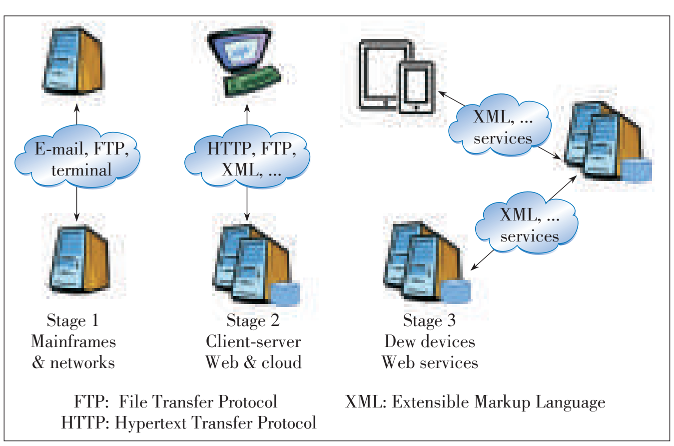
To explore the features of the Internet and the trend of its computing paradigms, we create two indices: online impact and redundancy rate. We will use these indices to describe the Internet computing paradigms and to find the regularities in the transitions of these paradigms.

3.1 Online Impact

In this paper, we consider online impact as an index that measures the importance or impact of the Internet to a node on the Internet. It is defined as

$$I = \log_2 \frac{U}{V}, \quad (1)$$

where I is the online impact of a node on the Internet; U indicates the amount of information available to a node if this node is online; V is similar to U except that when the node is offline.



▲**Figure 2. Development stages of Internet computing paradigms analyzed by information distribution.**

In the above definition, U and V are information amounts, but we did not specify how to determine the values of U and V. The basic way to determine an information amount is to find the size of the related storage in bytes. For example, if a cell phone has 16GB storage and the storage is almost full, we may estimate that $V = 2^{34}$ bytes.

Now, we use an example to show how to calculate online impact I. The first question we have to solve is how to calculate U, that is, how to determine the total amount of available information when a device is online. Note that we are not talking about the total amount of information that has ever produced and saved on the Internet; we are talking about the amount of information that is publically available and relevant. Also, the accuracy of this number does not matter much because it is only used in an example. For these reasons, we chose a simple number as the base of our estimation: the sum total of data held by Google, Amazon, Microsoft, and Facebook is at least 1200 petabytes [26]. For easy estimation, we assume that the sum total of all available data held on the Internet is 8192 petabytes, i.e., $U = 2^{63}$ bytes. Next we need to estimate V. We assume that the node in question is a personal computer and it has 1TB storage; the storage is almost full. Under these assumptions, $V = 2^{40}$ bytes. Thus the online impact

$$I = \log_2 \frac{2^{63}}{2^{40}} = 23. \quad (2)$$

In some special situations, we may also calculate the online impact using other information estimation methods, not the basic one discussed above. For example, a user is interested in a special group of programs, say games. Suppose there are 1000 such programs on the Internet, and there are 8 such programs on the local node. We may use the number of available programs to estimate the available information amounts: $U = 1000$ and $V = 8$. This node's online impact would be

$$I = \log_2 \frac{1000}{8} = 7. \quad (3)$$

For the same node on the Internet, we may get different online impact numbers using different information amount estimation methods. The reason we define the online impact in such an indefinite way is because it is a subjective index: for the same node, when the Internet becomes not available, it could have a great impact to one user but have a less severe impact to another user.

Although the online impact is defined in an indefinite way, it does not prevent us from using this index to perform comparisons and other analysis because online impact numbers are comparable as long as they are all calculated using the same method. The freedom of choosing information amount estimation method makes the online impact meaningful in different situations. Once an information estimation method is chosen, this method should be applied consistently so that this index would be comparable.

Now we try to estimate the online impact values for different stages of Internet development: the mainframe stage, the cloud computing stage, and the dew computing stage. In the following analysis, basic estimation method is used.

In the mainframe stage, major computing tasks were done by each node. The Internet (ARPANET) provides email, telnet, and similar services. Since these services were low-efficient, they cannot drastically change the size of the available information. We can estimate that the amount of the available information when a node was online could be more than the amount of the available information when this node was offline, but would not be more than doubled. Thus, the online impact would not be more than 1. Generally speaking, in the mainframe stage, the online impact was pretty low.

In the cloud computing stage, major computing tasks are done at the server side. In extreme situations, the node on the user side (user's device) is merely a terminal; no useful information is stored in the node. In these situations, the user expects the device is always online; when the device is offline, the user's device loses its connection and control to the cloud; although submitted jobs can still be processed, no more new jobs can be submitted. When we calculate online impact for the extreme situations, we will find that U is a big number and V is 0 or almost 0, which leads to an online impact that is infinity or a huge number.

In the dew computing stage, the dew server and related databases on a node provide useful information to the user. Apparently, the whole dew mechanism increased the V value, and thus decreased the online impact: either from infinity to a finite number or from a bigger number to a smaller number.

Next, we summarize the above three situations:

In the early mainframe stage, the online impact was very low; it shows that the Internet had not well developed and the Internet did not have vital importance at that time.

Currently, cloud computing is still the dominant form of the Internet computing paradigm. In other words, the Internet is still in the cloud computing stage. In this stage, a node's online impact is very high and, in theory, could be infinity. This fact reflects that the Internet has well developed; the Internet has vital importance to many users; once offline, some users feel they can do nothing.

In dew computing stage, the online impact is getting smaller. This is an interesting phenomenon. In the past, the online impact is getting bigger and bigger, which shows that the Internet is getting more and more important. Now the trend has changed: the online impact is getting smaller; it seems that the Internet is getting less important.

Does dew computing reduce the importance of the Internet? If we carefully analyze this issue, we will find that the answer to this question is no. Dew computing does reduce the online impact number; in other words, dew computing reduces the shock when an Internet connection is lost. However, this benefit is obtained based on the support of the Internet. We may notice that the dew computing components on a user device have collaborative relationship with cloud servers. In the past, a node's available information may have nothing to do with the Internet. If dew computing paradigm is adopted, a node's available information, i.e. the dew component, would be well organized and supported by the Internet. In this way, we may say that the Internet plays a more important role in the dew computing stage.

This brings in an important conclusion: dew computing reduces the online impact, thus it reduces the user's shock when an Internet connection becomes unavailable. Dew computing does not reduce the importance of the Internet; on the contrary, dew computing makes information on users' devices systematically organized and collaborative with the Internet. Dew computing enhances the Internet and cloud computing.

3.2 Redundancy Rate

The redundancy rate is an index that measures how much information on a node has a copy on the Internet.

Redundancy rate is defined as:

$$R = \frac{W}{V}, \tag{4}$$

where R is the redundancy rate, V is the node's available information amount, and W is the amount of information inside V that has a copy on the Internet. All the discussions in Section 3.1 regarding to the methods to determine values U and V are also suitable here for values W and V.

In the mainframe stage, major computing tasks were done by each node; programs and other form of information were also saved at each node. Redundancy copy may exist due to special arrangements, but there were no generally-available redundancy copies. The redundancy rate at this stage was very low.

In the cloud computing stage, major computing tasks are done at the server side; useful information is also saved on the server side. The node on the user side (user's device) is merely a terminal, no useful information is stored on the node; it is not necessary to make a redundant copy for such information. Even though important information is stored on the node, redundant copy of such information might be specially arranged; there is no systematic mechanism to perform redundant copying. Generally speaking, the redundancy rate at this stage is also very low.

In the dew computing stage, the dew server and related databases on a node provide useful information to the user. These dew components are supported by the cloud servers and synchronized with the cloud servers; these dew components all have redundancy copies on the Internet. If the node has completely adopted dew computing, all the available information in this node would be dew component information. Since all the dew components have redundant copies on the Internet, the redundancy rate would be 100%. If the node also contains information other than that related to dew computing, the redundancy rate could be less than 100%. We can conclude that dew computing significantly increases the redundancy rate. If dew computing components are dominant on the node, the redundancy rate could be close to 100%.

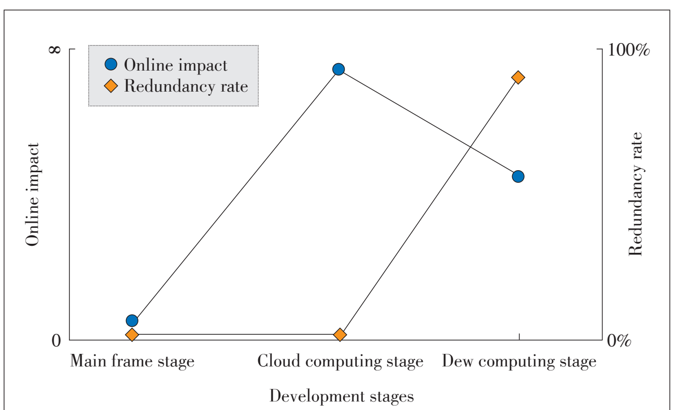
3.3 Analysis of Online Impact and Redundancy Rate

In the above two sections, we introduced two indices: online impact and redundancy rate. These two indices change over the three stages of Internet computing paradigm development: mainframe stage, cloud computing stage, and dew computing stage. We summarized these changes in **Fig. 3**.

We notice that the online impact has increased from almost 0 in the mainframe stage to a big number close to infinity in the cloud computing stage, and then decreased in the dew computing stage. The increasing portion shows that the Internet has developed greatly such that users heavily rely on it. Once the Internet is not available, the impact to users is very big. In some extreme situations, users feel nothing can be done without the Internet. While the high online impact number shows the greatness of the Internet, we should also notice the other side of the story: even if the Internet is just temporarily not available, we have to face some negative effects. The decreasing portion of the online impact line reflects the efforts to solve this problem.

In the dew computing stage, online impact is reduced because when the Internet becomes not available, the dew server can provide some services to the user so that the user will feel a less severe impact.

Let us further apprehend the meaning of the index online impact. Is it correct to say that the bigger the online impact, the better the Internet? This conclusion probably was right for the past few decades. To some extent, online impact is an index to measure the greatness of the Internet. With the development of the Internet, more and more data and services have been added to the Internet; users become more and more reliant to the



▲Figure 3. Online impact and redundancy rate change over major stages of Internet computing paradigm development.

Internet; the online impact becomes higher and higher.

In our daily lives, we rely on many resources, such as utilities, transportation, governments, and heroes. When some resources are not available, we will feel some impact on our lives. The bigger the impact is, the more important the resource is. For example, we heavily rely on electricity; we will feel a big impact when a blackout happens. While we all agree that electricity is vital to our lives, we feel unsafe if electricity is the only means we can count on. Homeowners may want to buy generators or propane tanks/stoves in winter as backup. In other words, homeowners want to reduce the impact when a blackout happens.

Generally speaking, people would like to use the resources that we highly rely on because these resources must be of great values, but people also want to have some backup options so that they would not get into a big trouble when these great resources become not available. In other words, people like resources that have great impact factors, but do not want these impact factors to be too big.

In the case of the Internet, users want devices on the Internet to have big online impact numbers, but they do not want these numbers to be too big. Dew computing is a solution to reduce the online impact: from infinity to a finite number or from a bigger number to a smaller number.

Analyzing the redundancy rate line in Fig. 3, we notice that the redundancy rate stays quite low in the mainframe stage and the cloud computing stage, and then increases to a high number close to 100% in the dew computing stage. The shape of this line shows that dew computing has brought in something new. This new feature can be described as user-aware (systematic) redundancy.

In computer science, redundancy is a widely-used technique to improve reliability and availability, but this technique was mainly used by developers and was often transparent to users. Dew computing systematically brings in redundancy technique to users. In a dew computing system, the user is aware that data and services are redundantly installed both in his/her own device and in the cloud servers; the user is also aware that his/her device will exchange data with cloud servers when it is possible and necessary.

Dew computing is not only a technique to implement applications; it also brings in a new feature, user-aware redundancy, to the users and familiarizes users to use this new feature. In this sense, dew computing brings in significant changes to the Internet computing paradigm.

To summarize the whole analysis using these two indices, online impact and redundancy rate, we obtain the following observations:

1) Dew computing is a new form of the Internet computing paradigm, which is significantly different from previous Internet computing paradigm forms.
2) Dew computing enables users to feel a less severe impact when the Internet becomes not available.

3) Dew computing brings in a new feature, user-aware redundancy, to users.

4 Conclusions

Since the first group of papers related to dew computing were published in 2015 and early 2016, dew computing research work can be roughly classified into three major groups: early exploration, dew computing feature research, and dew computing application research. Considering the short time since this research area was started, it is amazing that so many papers have been published already. It is worth to note that among the recently published papers, 7 papers were related to the overall features of dew computing, but 10 of them were related to dew computing applications. This phenomenon indicates that dew computing application is the current focus of dew computing research.

To be consistent with the above dew computing research focus, commercialized dew computing applications have also progressed pretty fast recently. Many dew computing products have been developed and put into the market. This fact further indicates that dew computing is needed by the society and the market.

Dew computing has been going through fast progress in both research and development, but we still need to answer the following questions: what are the essential differences between dew computing and other Internet computing paradigms? What are the special features of dew computing? The Internet computing paradigm transition analysis was performed to answer these questions. Online impact and redundancy rate are two indices introduced to perform such analysis.

The analysis revealed the following two features of dew computing: 1) Dew computing enables users to feel a less severe impact when the Internet becomes not available; 2) dew computing brings in a new feature, user-aware redundancy, to users. These two features indicate that dew computing is significantly different from other Internet computing paradigms.

References

[1] Y. Wang, "Cloud-dew architecture," *International Journal of Cloud Computing*, vol. 4, no. 3, pp.199–210, 2015. doi: 10.1504/IJCC.2015.071717.

[2] Y. Wang and Y. Pan, "Cloud-dew architecture: realizing the potential of distributed database systems in unreliable networks, " in *21st International Conference on Parallel and Distributed Processing Techniques and Applications (PDPTA' 15)*, Las Vegas, USA, Jul. 2015, pp. 85–89.

[3] D. Bradley. (2016, May 8). Dew helps ground cloud services [Online]. Available: http://sciencespot.co.uk/dew-helps-ground-cloud-services.html

[4] Z. Kang, "A new method to implement ldns in the cloud-dew architecture, " University of Prince Edward Island, Canada, CSIT Research Rep. CS-21, , Nov. 17, 2005.

[5] Y. Wang. (2015, Nov. 10). The initial definition of dew computing, dew computing research [Online]. Available: http://www.dewcomputing.org/index.php/2015/11/10/the-initial-definition-of-dew-computing

[6] K. Skala, D. Davidovic, E. Afgan, I. Sovic, and Z. Sojat, "Scalable distributed computing hierarchy: cloud, fog and dew computing, " *Open Journal of Cloud Computing (OJCC)*, vol. 2, no. 1, pp. 16–24, 2015.

[7] Y. Wang. (2015, Nov. 12). The relationships among cloud computing, fog computing, and dew computing, dew computing research [Online]. Available: http://www.dewcomputing.org/index.php/2015/11/12/the-relationships-among-cloud-computing-fog-computing-and-dew-computing

[8] S. Ristov, K. Cvetkov, and M. Gusev, "Implementation of a Horizontal Scalable Balancer for Dew Computing Services," *Scalable Computing: Practice and Experience*, vol.17, no. 2, pp. 79–90, 2016.

[9] Y. Wang, "Definition and categorization of dew computing," *Open Journal of Cloud Computing (OJCC)*, vol. 3, no. 1, pp. 1–7, 2016.

[10] T. Mane. (2016, Jul. 2). Fog-dew architecture for better consistency [Online]. Available: https://eye3i.wordpress.com/2016/07/02/adressing-inconsistency-in-dew-computing-using-fog-computing

[11] D. E. Fisher and S. Yang, "Doing more with the dew: a new approach to cloud-dew architecture," *Open Journal of Cloud Computing (OJCC)*, vol. 3, no. 1, pp. 8–19, 2016.

[12] A. Rindos and Y. Wang, "Dew computing: the complementary piece of cloud computing," in *IEEE International Conferences on Big Data and Cloud Computing (BDCloud), Social Computing and Networking (SocialCom), Sustainable Computing and Communications (SustainCom)*, Atlanta, USA 2016, pp. 15–20. doi: 10.1109/BDCloud-SocialCom-SustainCom.2016.14.

[13] Z. Šojat and K. Skala, "Views on the role and importance of dew computing in the service and control technology," presented at Distributed Computing, Visualization and Biomedical Engineering Conference, Part of the 39th International Convention on Information and Communication Technology, Electronics and Microelectronics (DC VIS 2016) , Opatija, Croatia, 2016.

[14] Z. Sojat and K. Skala, "The dawn of dew: dew computing for advanced living environment," in *DEWCOM 2017*, Opatija, Croatia, May 2017, pp. 375–380.

[15] M. Frincu, "Architecting a hybrid cross layer dew-fog-cloud stack for future data-driven cyber-physical systems," in Proc. *MIPRO DEWCOM 2017*, Opatija, Croatia, May 2017, pp. 427–431.

[16] P. Brezany and F. Khan, "Cloud-dew data provenance framework," presented at DEWCOM 2017, Opatija, roatia, May 2017.

[17] Y. Wang, "An attempt to model dew computing," presented at DEWCOM 2017, Opatija, Croatia, May 2017.

[18] Y. Wang and D. LeBlanc, "Integrating SaaS and SaaP with dew computing," in *IEEE International Conferences on Big Data and Cloud Computing (BDCloud), Social Computing and Networking (SocialCom), Sustainable Computing and Communications (SustainCom)*, Atlanta, USA, 2016, pp. 590– 594. doi: 10.1109/BDCloud-SocialCom-SustainCom.2016.92.

[19] G. Oparin, V. Bogdanova, S. Gorsky, and A. Pashinin, "Service-oriented application for parallel solving the parametric synthesis feedback problem of controlled dynamic systems," in *Proc. MIPRO DEWCOM 2017*, Opatija, Croatia, May 2017, pp. 381–386.

[20] Y. Gordienko, S. Stirenko, O. Alienin, et al., "Argmented coaching ecosystem for non-obtrusive adaptive personalized elderly care on the basis of cloud-fog-dew computing paradigm," in *Proc. MIPRO DEWCOM 2017*, Opatija, Croatia, May 2017, pp. 387–392.

[21] P. Brezany, T. Ludescher, and T. Feilhauer, "Cloud-dew computing support for automatic data analysis in life sciences," in *Proc. MIPRO DEWCOM 2017*, Opatija, Croatia, May 2017, pp. 392–398.

[22] N. Crnko, "Distributed database system as a base for multilanguage support for legacy software," in *Proc. MIPRO DEWCOM 2017*, Opatija, Croatia, May 2017, pp. 399–402.

[23] m. gusev, "A dew computing solution for IoT streaming devices," in *Proc. MIPRO DEWCOM 2017*, Opatija, Croatia, May 2017, pp. 415–420.

[24] D. Podbojec, B. Herynek, D. Jazbec, et al., "3D-based Location Positioning Using the Dew Computing Approach for Indoor Navigation, Proceedings of MIPRO 2017," in *DEWCOM 2017*, Opatija, Croatia, May 2017, pp. 421–426.

[25] T. Lipic and K. Skala, "The key drivers of emerging socio-technical systems: a perspective of dew computing in cyber-physical systems," presented at *DEWCOM 2017*, Opatija, Croatia, May 2017.

[26] G. Mitchell. (2017, Jun. 10). How much data is on the internet? [Online]. Available: http://www.sciencefocus.com/qa/how-many-terabytes-data-are-internet

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