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Definition and Categorization of Dew Computing

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ABSTRACT

Dew computing is an emerging new research area and has great potentials in applications. In this paper, we propose a revised definition of dew computing. The new definition is: Dew computing is an on-premises computer software-hardware organization paradigm in the cloud computing environment where the on-premises computer provides functionality that is independent of cloud services and is also collaborative with cloud services. The goal of dew computing is to fully realize the potentials of on-premises computers and cloud services. This definition emphasizes two key features of dew computing: independence and collaboration. Furthermore, we propose a group of dew computing categories. These categories may inspire new applications.

TYPE OF PAPER AND KEYWORDS

Visionary paper: *dew computing, cloud computing, cloud-dew architecture, on-premises computer, dew computing categories*

1 INTRODUCTION

With the rapid progress in cloud computing [11], a new research area, dew computing [18] [2], is emerging. Cloud computing brings in many benefits, such as universal access and scalability, but it also introduces a new challenge: all resources are far from user's premises and far from user's control. If an Internet connection is lost, the user will not be able to access the user's own data. Cloud-dew architecture [16] [17] [8] was proposed as a possible solution to this problem. In this architecture, newly-introduced dew servers make installed websites always available to users and synchronize with cloud servers when possible. The occurrence of the cloud-dew architecture was the first time when the meteorological terminology, *dew*, was associated with computing. From the terminology point of view, we may consider cloud-dew architecture as the starting point of dew computing; from the application point of view, we found out that the starting point of dew computing can be traced back to 2005 or earlier (see Table 1). The exact year when the first dew computing application was available may need special study, but definitely it will go back to many years ago.

At the beginning, the scope of dew computing only includes web applications [16]. Later, a broader definition [18] was proposed. In this definition, dew computing was defined as a personal computer software organization paradigm. The major features of dew computing are that local computers provide rich functionality that are independent of cloud services and the local computers collaborate with cloud services.

Some other work in the dew computing area includes the relationships among cloud computing, fog computing, and dew computing [19], a scalable distributed computing hierarchy including cloud

computing, fog computing, and dew computing [15], and the implementation of a horizontal scalable balancer for dew computing services [14].

In a new research area such as dew computing, it is vital important to clearly define the key terminology of this area so that researchers can have a common understanding in their discussions. The existing definition of dew computing [18] played an important role and its main idea is still valid, but some aspects of this definition are not easy to apply and too restrictive. For example, this definition links dew computing with personal computers. Thus it excludes dew computing to be applied to mobile devices and servers, and such limitation is unnecessary. This definition also requires dew computing to provide rich functionality, and the richness is hard to determine.

To solve the above-mentioned problems and to pave the way to future progress in dew computing research, in this paper, we will analyze and revise the definition of dew computing proposed in [18], and propose a new definition. We will also explore the categories of dew computing and the contributions of some existing dew computing applications in the past years, although the exploration is far from complete.

2 DEFINITION OF DEW COMPUTING

In this section, we will revise the definition of dew computing proposed in [18]. We put the existing definition here and discuss the revisions need to be made from different perspectives.

"Dew Computing is a personal computer software organization paradigm in the age of Cloud Computing. Its goal is to fully realize the potentials of personal computers and cloud services. In this paradigm, software on a personal computer is organized according to the Cloud-dew Architecture; in this paradigm, a local computer provides rich functionality independent of cloud services and also collaborates with cloud services."

First, the involved computing devices in this definition were personal computers. While personal computers are dominant nowadays, we do not need to exclude other types of computers, such as mainframe computers, servers, and mobile computers. Instead of personal computers, we propose to use the term *on-premises computers*. On-premises computer is a terminology used in cloud computing. Generally speaking, on-premises resources are equivalent to non-cloud resources. Using the term on-premises computers shows the connection between cloud computing and dew computing.

Second, dew computing was defined as a software organization paradigm. While software is the major concern, we might need to include hardware as well.

Third, dew computing was defined with two key features: "a local computer provides rich functionality independent of cloud services and also collaborates with cloud services." Using the term "rich functionality" may give readers an impression that dew computing is only possible when the local computer and its applications are powerful enough, but this is not true. For example, a simple cell phone has a very simple app on it: to keep track of the user's personal schedule on the phone regardless of the phone's connections, and to keep the schedule synchronized with a cloud service when a cell phone connection or a Wi-Fi connection is available. This simple app may be not rich enough, but we still consider it a dew computing application. One of the key features of this dew computing application is that the cell phone is able to provide schedule service even when the related cloud service is not available. In general cases, one of the key requirements of dew computing is independence instead of richness. Thus, we may remove the richness requirement and just keep the independence feature.

Based on the above discussions, we propose the new definition of dew computing in the following:

Defnition (Dew Computing): *Dew computing is an on-premises computer software-hardware organization paradigm in the cloud computing environment where the on-premises computer provides functionality that is independent of cloud services and is also collaborative with cloud services. The goal of dew computing is to fully realize the potentials of on-premises computers and cloud services.* □

The key features of dew computing reflected in the definition can be summarized as *independence* and *collaboration.*

Independence means the on-premises computer is able to provide such functionality without cloud services and an Internet connection. In other words, it means this application is not a completely-online application or cloud service. For example, a browser is not a dew computing application because it cannot provide an independent service without an Internet connection. The independence feature advocates using on-premises resources as much as possible before sending requests to cloud services, aiming to fully realize the potentials of on-premises computers.

Collaboration means the dew computing application has to automatically exchange information with cloud services during its operation. Such collaboration includes synchronization, correlation, or other kinds of interoperation. For example, most desktop applications, such as Microsoft Office, are not dew computing

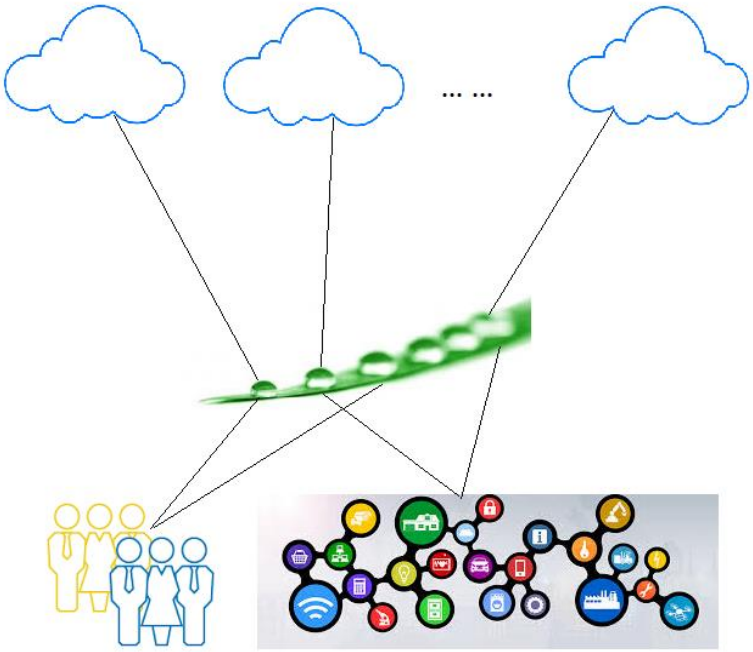

Figure 1: The structure of Dew Computing

(Explanation: This figure describes the essential idea of dew computing. The green leaf represents an on-premises computer. The dew drops on the leaf represent some applications that are running inside the on-premises computer. These applications have two features: they provide services to users and/or devices independent of cloud services and they collaborate with cloud services.)

applications. The collaboration feature requires that all dew computing applications use cloud services; this feature realizes the potentials of cloud services by promoting the use of cloud services together with on-premises computers.

These two features precisely describe the nature of dew computing applications. Independence indicates that this application is inherently distributed; collaboration indicates that this application is inherently connected.

Figure 1 shows the essential idea of dew computing. The green leaf represents an on-premises computer. The dew drops on the leaf represent some applications that are running inside the on-premises computer. These applications have two features: they provide services to users and/or devices independent of cloud services and they collaborate with cloud services.

Dew computing is a computer science's response to cloud computing. It tries to answer the following question: how do we organize non-cloud components in the cloud environment?

3 THE CATEGORIES OF DEW COMPUTING

As a generic paradigm, dew computing can be applied in different areas. In other words, dew computing has many categories. We use a pattern **X in Dew** to describe these categories, where X is a kind of resource or service. Here we list some of the possible categories and their existing or possible applications.

3.1 Web in Dew (WiD)

Web in Dew is a dew computing category where an on-premises computer contains a duplicated fraction of World Wide Web or a modified copy of that fraction. To reach this goal, a Web server should be started and the involved websites should be created in the on-premises computer. Because this fraction of Web is contained inside the on-premises computer, it satisfies the independence feature of dew computing. This fraction of the Web in the on-premises computer synchronizes with the Web, and thus it satisfies the collaboration feature of dew computing. The architecture of WiD is described in [16] and is called the cloud-dew architecture.

At one point, WiD was considered as the whole dew computing, but now it is only one category of dew computing. Cloud-dew architecture was advised based on Web applications so that it is suitable for WiD applications. The structure shown in Figure 1 is essentially the same with the cloud-dew architecture, but the Web application assumption has been removed. Thus, we may call the structure shown in Figure 1 as *general cloud-dew architecture*.

No applications in WiD category had existed before the cloud-dew architecture was proposed. WiD has great potentials in many areas, including Internet of Things (IoT) [13] [1] applications.

3.2 Storage in Dew (STiD)

Storage in Dew is a dew computing category where the storage of an on-premises computer is duplicated in a cloud service and the on-premises computer storage is automatically synchronized with its cloud copy.

A typical existing STiD service is Dropbox [4]. First, the files/folders in Dropbox are available to users at any time so that it satisfies the independence feature. Second, these files/folders are automatically synchronized with cloud services so that it satisfies the collaboration feature.

Many other similar applications also exist. Google Drive [5] is another one we want to analyze briefly. Apparently, it satisfies the collaboration feature, but it does not satisfy the independence feature because a file cannot be opened if Google Drive service is not available at that moment. Thus Google Drive is not a STiD application. On the other hand, Google Drive Offline [6] is a STiD application.

3.3 Database in Dew (DBiD)

Database in Dew is a dew computing category where a database on a cloud service and a database on an on-premises computer serve as backup to each other. There are many different ways to implement DBiD. Users may decide which database is the main database and which one is a replicated backup. There are also different ways to perform the backup: real-time database replication, real-time log backup, and periodic log backup.

DBiD will make DBA's job much easier and the databases much safer. Apparently, DBiD satisfies the independence and collaboration features.

3.4 Software in Dew (SiD)

Software in Dew is a dew computing category where a user's ownership to a piece of software is not only reflected by the software's existence on the user's on-premises computer, but also reflected by the ownership and settings information recorded in a cloud service. SiD should also make sure the user can re-download this software if necessary. The mechanisms in Apple's App Store [3] [9] and Google Play [7] are examples of SiD.

3.5 Platform in Dew (PiD)

Platform in Dew is a dew computing category where (1) a suite of software supporting the development and operation for specific purposes is installed and running on an on-premises computer; (2) the settings and application data of this software suite are dynamically synchronized with a cloud service.

Various kinds of Software Development Kits (SDKs) are candidate PiD applications. An installed SDK itself is not a PiD application; synchronization is needed. Synchronization includes development data online backup and system deployment. GitHub [10] is an existing application that satisfies PiD requirements.

3.6 Infrastructure as Dew (IaD)

Infrastructure as Dew is a dew computing category where an on-premises computer is dynamically supported by cloud services. IaD can be in different forms. At least the following two forms can be used: (1) An on-premises computer can have an exact duplicate virtual machine instance in the cloud, and the virtual machine instance is always kept in the same state as the on-premises computer; (2) An on-premises computer can have all its settings/data saved in cloud services. Such settings/data not only include system settings/data, but also include each application's settings/data.

If IaD is fully implemented, data and devices can be completely separated. If a laptop or a cell phone is lost or damaged, the user only needs to buy a new device and all the settings/data will be completely recovered in the new device. Currently, some cell phone companies provide backup/restore functions, but not all application settings/data can be restored. With the progress of IaD, such complete restore will become possible.

3.7 Data in Dew (DiD)

All the above categories have a common feature: some forms of data exist in an on-premises computer and are automatically synchronized with cloud services. Literally, Data in Dew could be defined as identical to dew computing, but such definition would not be very useful.

Table 1: Summary of Dew Computing Categories

Category	Resource in Dew	Key Function	Existing Applications
WiD	Web fraction	Access Web fraction without Internet connection	
STiD	Storage	Storage in dew has a cloud copy	Dropbox (2007) [4]
DBiD	Database	Local database has a cloud backup	
SiD	Software	Software ownership and settings have a cloud copy	Apple App Store (2008) [3][9], Google play (2008) [7]
PiD	Platform suite	SDK and projects have a cloud copy	GitHub (2008) [10]
IaD	Whole computer	On-premises computer settings and data have a cloud copy	
DiD	Data in forms other than above	Dew computing applications not in above categories	Novell Groupwise 7 (2005) [12]

What we need is a dew computing category where the above categories do not cover. Some applications do belong to this category. For example, Novell Groupwise email client [12] cannot be put into any of the above categories, but it is a dew computing application. Many cell phone apps are also dew computing applications, but are not in any of the above categories.

Based on the above discussions, we propose the following definition for Data in Dew: Data in Dew (DiD) is a dew computing category where all its applications satisfy the independence and collaboration requirements, but they do not belong to any of the above categories.

Table 1 is a summary of the proposed dew computing categories. These categories are not meant to be exhaustive. New categories might be proposed. Some categories might be refined. From this table, we can see that some categories already have existing applications, while other categories do not have existing applications. These categories may inspire new applications.

4 DISCUSSIONS

In Section 2, we introduced the new definition of dew computing; in Section 3, we introduced the categories of dew computing. Here in this section we will discuss the impact of the new definition and the categories.

Although the revised definition of dew computing seems similar to the previous definition, the difference is quite significant when we examine the details.

First, replacing personal computers with on-premises computers does not only expand the scope of involved devices, but also makes the definition logically complete: on-premises computers and cloud computers (servers) are complementary to each other; the new definition involves all the computers that are not in the cloud. Practically, on-premises computers include personal computers, tablets, cell phones, servers, clusters, and so on. All computers that are not in a cloud service are on-premises computers and are covered by dew computing.

Second, replacing software organization paradigm with software -hardware organization paradigm does not only mean some hardware features may be added for dew computing purposes, but also means dew computing organization should be studied from the system viewpoint. If dew computing is just a software organization paradigm, only programmers will be needed to propose new software applications. Because dew computing is a software -hardware organization paradigm, researchers and designers may design and improve each dew computing system from the whole system perspective; new devices and systems might be proposed.

Third, removing the richness requirement from the definition given in [18] eliminates the impression that dew computing is only possible in powerful devices. The key merits that make dew computing attractive are the independence and collaborative features instead of the powerfulness of a device. This change extends the scope of dew computing to cover cell phones and may further promote the development of dew computing applications in cell phones.

With the new definition of dew computing in place, we would like to go one step further to explore the research area of dew computing. The categories of dew computing reflect such efforts. In one hand, these

categories are helpful in shaping this area; on the other hand, these categories pose more open questions to us. Here we try to briefly examine the open questions we can think of for each category.

For the WiD category, the following open questions need to be answered: How do we realize multiple website synchronization efficiently? How do we install a duplicated website (dewsite) on an on-premises computer easily? For the STiD category, there are already some existing applications, but much work still needs to be done in this area, such as reducing the cost of STiD.

DBiD can be implemented with mature technology, but one form of DBiD, a database running on an on-premises computer has its backup in the cloud, seems to be a new application. For many reasons, people may want to run a database locally. DBiD provides backup for such applications so that the database can be restored even though the on-premises computer is damaged or lost. Normally database replication involves special firewall setup for special ports, but many on-premises computer users are not able to or not allowed to setup firewalls. One of the questions in this area is: How do we implement database replication or backup in a way that no firewall settings need to be changed?

SiD is a category that has already been implemented in some products. SiD may need to contain not only the ownership information, but also user settings for the software. It might be necessary to incorporate SiD function into Operating Systems. Although some PiD-like applications do exist, it is desirable that we have an open PiD framework so that PiD applications can be developed easily. IaD category presents an open question to us: How do we separate data from device in an on-premises computer? If the separation can be done, it won't be a big problem anymore if a laptop or a cell phone is damaged or lost.

Probably the biggest open question regarding to the categories is: Can we find more categories? The categories listed in this paper are neither exhaustive, nor permanent. New categories might be proposed and the existing categories might be altered. The changing of these categories reflects the progress of dew computing.

5 CONCLUSIONS

In this paper, the definition of dew computing has been revised. The new definition connects various kinds of on-premises computers with dew computing; the new definition defines dew computing as a software-hardware organization paradigm in the cloud computing environment; the new definition emphasizes two key features of dew computing: independence and collaboration; the new definition points out that the goal of dew computing is to fully realize the potentials of on-premises computers and cloud services.

Based on this new definition, a group of dew computing categories have been proposed. These categories are helpful in further explaining the connotation and denotation of the dew computing concept; these categories may inspire new applications.

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