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Original Article

Demystifying Dew Computing: Concept, Architecture and Research Opportunities

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Abstract *- Over the last decades, the IT world has witnessed paradigm shifts from conventional client/server networks to Cloud computing, providing organizations opportunities to reduce capital expenditures (CapEx) and Operational Expenditures (OpEx). Other technologies such as Fog computing, Edge computing addresses some of Cloud computing challenges such as high latency, real-time process, security, and location awareness. Unfortunately, all technologies mentioned above are prone to service outages and interruption due to their dependency on the Internet. Dew computing filled the gaps by providing users with offline usage capabilities. During outages or service interruptions, Dew computing makes data accessibilities archivable through two distinct features interdependency and collaboration. Copies of original data saved on the local machine are available to serve offline requests, and all modifications synchronize with the Cloud server when the communication signal is restored. This paper explains the Dew computing concepts, architectural design, and open research opportunities.*

Keywords *- Cloud Computing, Dew Computing, Edge Computing, Fog Computing, Server.*

1. Introduction

Cloud computing revolutionalized IT resources deployments by reducing the considerable cost of service deliveries such as hardware, software, and networking in the conventional client/server infrastructures. Other paradigms like Fog and Edge computing complements Cloud services by providing better latency, real-time process, location-awareness, and mobility support [1][2][3]. Despite all these benefits of the aforementioned technologies, their dependency on the Internet for service deliveries to users remains a huge consign for academia and industry. Also, the underutilization of users' on-premise devices' for computation, storage, and processing pose concerns for hardware manufacturers, since most of the computations, storage and processing are done in the Cloud [4][5]. Dew computing addresses the drawbacks of dependency on the Internet and underutilization of on-premise Cloud computing devices and their associates. The technology added interdependent and collaboration functionalities to network communications. The interdependent functionality provides local or on-premise devices offline capabilities during service outages or interruptions, while collaboration provides synchronization with the cloud server when the communication signal is restored. Among other achievable advantages of Dew computing are; self-healing, self-augmentation, user programmability, users flexibility, and scalability [6][7].

The contributions of this paper state:

1. Review of Dew Computing supporting paradigms
2. Better explanation of Dew computing supported with examples
3. The architecture of Dew computing with Cloud.
4. Challenges of Dew computing and open research areas.

2. Dew Computing Supporting Paradigms

The emancipation of the Internet of things (IoT) devices and an upsurge in the computational needs of network users pose a challenge for conventional client/server architecture. Numerous paradigms like Cloud, Fog, and Edge computing surfaced over the last decade to address the challenges [8]. This section gives an account of recently deployed technologies.

2.1. Cloud Computing

Cloud computing provides users with computational needs such as hardware, software, and networking from remote locations over the Internet on a pay-as-you-use method. This technology differs from the conventional client/server due to resource scalability and measured service [1][2][9]. Cloud computing adoption increases as organizations explore other benefits such as low CapEx and OpEx. With Cloud computing, users can migrate computational burdens such as networking, storage, and process from individual local machines to bigger servers in remote locations. However, Cloud computing faces challenges like security, high latency, real-time processing, and location awareness [1][2][3]. Figure 1 depicts the Cloud architecture.

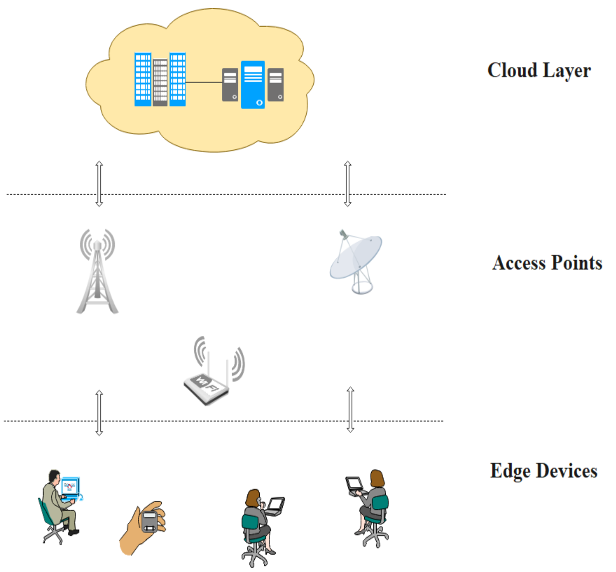

Fig. 1 Cloud Computing Architecture

2.2. *Fog Computing*

Fog computing places intermediary nodes between the edge devices and cloud servers to address high latency, real-time process, and location awareness challenges in Cloud computing [10]. CISCO networks introduced Fog computing in 2012 to support Cloud functionalities [8]. Few computations need, such as storage and data processing, are achievable on Fog nodes, rather than pushing such responsibilities to the Cloud server, as shown in Figure 2

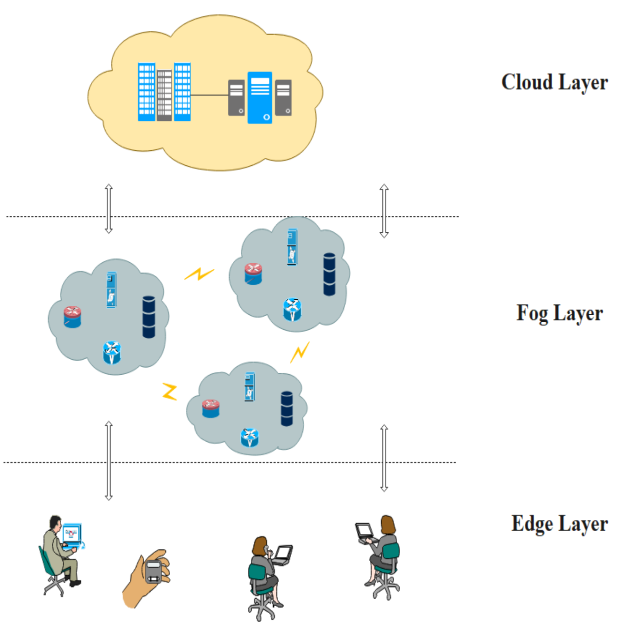

Fig. 2 Fog-Cloud Computing Architecture

2.2. Edge Computing

Edge computing performs tasks like data processing, application platforms, and storage in proximity to the data source, unlike Fog computing which is only a closer extension of Cloud computing [11]. This technology deploys a decentralized architecture by using the intelligence of local devices like IoT gateways, Edge servers, and other intelligent devices in performing computations. Edge computing reduces response time and bandwidth for real-time applications such as self-driving cars, home automation systems, and smart cities. Figure 3 shows an intelligent security camera that uses an in-built motion detector to sense human motions and transfer the footage to a Cloud server for image processing, unlike the conventional security camera that keeps sending footage even when motion is not detected. The intelligent security camera illustration saves network bandwidth and latency because it performs some processing (image detection) right at the data source, as shown in Figure 3.

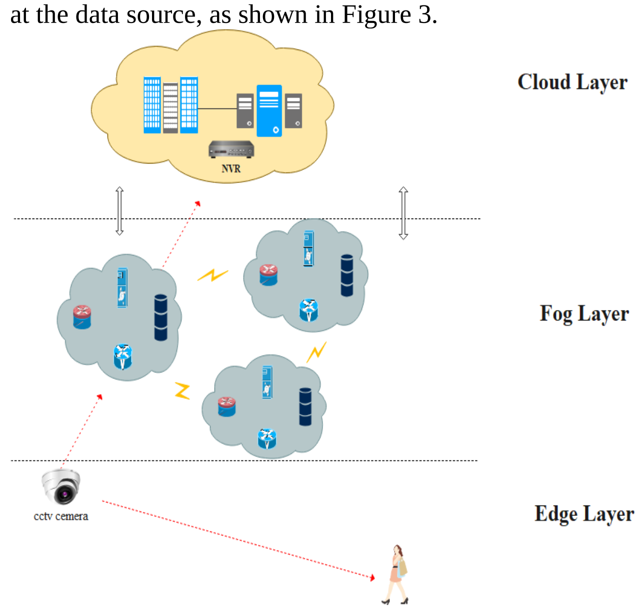

Fig. 3 Edge Computing

3. Dew Computing Concepts

Dew computing is still at the elementary stage, many researchers defined Dew computing, but a consensus definition is unavailable. Two important features: 'interdependency" and "collaboration," distinguish Dew computing from other paradigms but can't deploy in isolation. Instead, it coexists with other allied technologies like Cloud, Fog, and Edge networks [4].

This paper introduced a more straightforward definition by blending understanding across different works of literature.

Dew Computing is an interaction between local machine resources and cloud infrastructures. The local machines provide functionalities such as (edit, create, store, and delete) independent of the Cloud when offline and automatically synchronize and update all modifications done in the offline mode with the Cloud when network connectivity is restored.

[6] characterized Dew computing with six distinct characteristics: Rule-based data collection, Synchronization, Scalability, Transparency, Re-origination, and availability.

1. **Rule-based data collection**: This ensures simple, seamless, and strategic data exchange between the local machine and the Cloud server at both online and offline states.
2. **Synchronization:** Dew computing ensures that all data modifications carried out in the offline mode are automatically updated to Cloud servers when network connectivity is restored without compromising the CIA's data confidentiality, integrity, and availability.
3. **Scalability:** Dew computing provision mechanism can switch between upgrade and downgrade resources according to users' needs, such as switching between multi-core and single-core processors.
4. **Transparency:** Dew computing duplicates users' data without their awareness, and such data are available both at the local machine and Cloud server.
5. **Re-origination**: Dew computing put in place a data loss recovery mechanism during synchronization
6. **Availability**: The resources of Dew computing are available anytime with or without the Internet. The technology is not constrained by connectives such as outages, signal fluctuations, or loss.

Dew computing offers various service models, as stated in [12].

1. **Infrastructure-as-a-Dew (IaaD):** A local device dynamically coexists with the Cloud services in this model. Either store all settings and data on the Cloud server or use a Dew virtual machine DVM to create dual setting and storage instances (both on the local machine and Cloud server). The Apple iCloud is an example of IaaD, allowing users to store documents, music, and pictures on remote servers and later download them to any device.
2. **Software-as-a-Dew (SaaD):** This model provisions software for users both at online and offline states such that the configuration and ownership of the software reside on the Cloud servers. All user's installed applications are available on the user's account, and such applications can be accessed with any device simply by the login. The most common example is the Google play store, Amazon store, and Apple store.
3. **Platform-as-a-Dew (PaaD):** Unlike the platform-as-a-service (PaaS) available on Cloud computing, the PaaD mandates application developers to install a copy of software development that suits SDS on their local machine. All settings and application data synchronize with the Cloud server for activities such as online backups and system development data.
4. **Storage-as-a-Dew (SaaD):** This model enables users to partially or fully duplicate data contents such as documents, pictures, and videos on both local machines and Cloud storage, while such contents are available both in online and offline states. A mobile application like Dropbox can allow users to view content in an offline state and synchronize and update users' content when online.
5. **Web-as-a-Dew (WaaD):** This model enables users to access web resources like Email access personal accounts through an offline version or replica of the website. All modifications carried out offline also collaborate with the cloud server at the online state. Yahoo mail app installed on mobile devices is an example in this class. Users can access the inbox, draft, sent mail, and spam messages through the app while offline or logging into their account through a domain name (www.yahoomail.com) online. Also, users can compose messages using the Email App while offline and press the send button when in an online state. This app satisfies both the independency and collaboration features of Dew computing.

Table 1. Comparison of Dew and other paradigms

Features	Cloud	Fog	Edge	Dew
Latency	High	Better	Low	Very Low
Real-time	Poor	Good	Excellent	Excellent
Location-Awareness	No	Yes	Yes	Yes
IoT support	Yes	Yes	Yes	Yes
Internet Dependency	Yes	Yes	Yes	No
Bandwidth	High	Low	Low	Low
Cost Saving	Good	Better	Excellent	Excellent
Power Requirement	High	Low	Low	Very Low
Efficiency	Good	Better	Better	Better

4. Dew Computing Architecture

Dew computing architecture consists of different components needed to establish a connection with the Cloud server. The Dew Virtual Machine DVM is required to archive the Cloud-Dew services. The DVM components stated in [5] are the Dew server, Dew artificial intelligence, and Dew database management software DBMS, as shown in Figure 4.

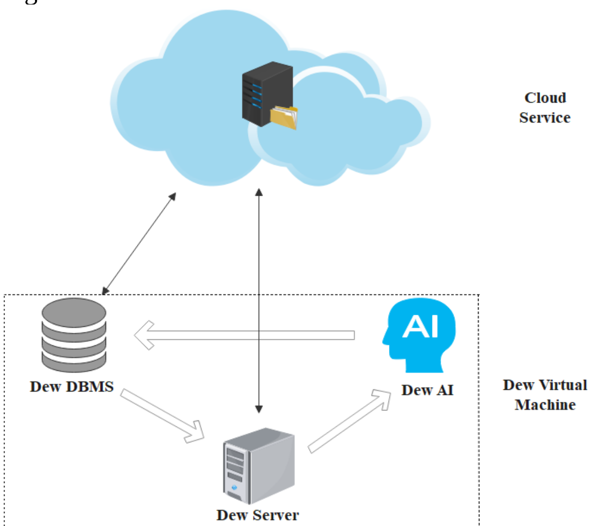

Fig. 4 Dew-to-Cloud server Architecture

Dew Server performs the functions of the Cloud services on the users' local machine and periodically interacts and synchronizes user data with the Cloud service. The architecture of the Dew server is provided in figure 5.

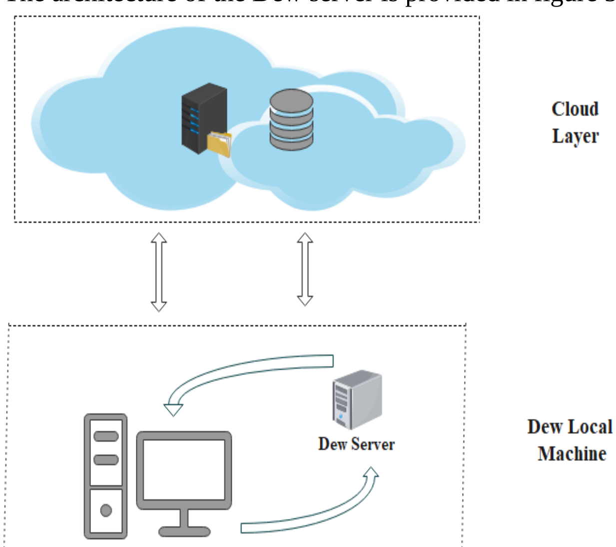

Fig. 5 Dew Server Architecture

Dew analytical server imitates the functions of an analytical web server in the conventional network environment, which helps monitor, collect, analyze, and report users' activities on the Dew server for easy understanding and efficiency. The Dew artificial intelligence component uses the data produced by the Dew Analytical server to make intelligent decisions and guide the operations of the Dew server.

5. Dew Computing Open Research Areas

Like other technological paradigms such as Cloud, Fog, and Edge computing, Dew computing has no silver bullet against challenges. This section discusses some Dew challenges and possible research opportunities.

5.1. Energy Management

The power requirement of Dew computing is shallow. Still, developing an energy-efficient task scheduling algorithm to switch between idle, busy, and sleep states of the Dew server can further minimize the energy requirements of the Dew local machines.

5.2. Processor Utility

Cloud computing services are scalable, as users can automatically upscale or downscale computing resources when needed by deploying a scalable mechanism on the Dew local machines to switch between single-core and multi-core processors.

5.3. Data Storage

Dew devices are mostly intelligent devices with limited memory space, making storing large files unachievable. Also, since Dew computing is an on-premises infrastructure, its imperative to provide a suitable resource sharing mechanism and security to prevent an insider attack.

5.4. Data Security

Security challenges have been a significant research focus among all network communication paradigms. Attacks like DoS and DDoS are well known to compromise users' data integrity, confidentiality, and availability, leading to numerous attack defenses such as packet filtering and intrusion detection system. Also, the dew computer is not immune to the security challenges mentioned earlier, as data on the on-premises hardware are exposed to insider attacks. Providing a security measure to protect data accessibility becomes an open research area.

5. Conclusion

Dew Computing facilitates interaction between local machine resources and cloud infrastructures. The local machines provide functionalities independent of the Cloud network when offline and automatically synchronize and update all modifications done offline with the Cloud when network connectivity is restored. The paper explains different paradigms supporting Dew computing, its concepts, and architectures. Also discussed are selected dew computing research areas like data security and storage, efficient processor utilization, and power management.

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