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RESEARCH ARTICLE

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Minimizing dependency on internetwork: Is dew computing a solution?

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Abstract

Since the inception of the internetwork facility, it has been continuously serving as the fundamental backbone of existing aspects, such as cloud, fog, and edge computing. Several application perspectives are in practice that mandate the involvement of application domains including smart retail, transportation, and data analytics. However, the deployed service platforms do not conform to facilitate the minimal and/or internetwork-free orientation to current paradigms. Hence, to cater this approach, a dew computing paradigm that goals at bringing cloud, fog, or edge resources and services to the nearest of user's periphery without or minimal use of internetwork has been introduced. This article advocates the feasibility, applicability, and appropriation of dew computing while leveraging several real-life case studies with special attention to internetwork-free movement. From earlier published literary works, a taxonomy has been devised in the dominion of dew computing. Moreover, highlights are made on selective requirements that would be key to the advancement of dew computing. Finally, challenges are discussed to provide future research directions in the dew computing domain.

1 | INTRODUCTION

The recent era of human civilization has witnessed the rapid advancements through numerous computing domains, such as cloud, fog, and edge. Majority of the deployed applications is targeted toward the futuristic internet-based aspects. Examples of such applications include smart city, integrated surveillance, smart farming, and pervasive e-healthcare. However, most of the emerging applications solely depend on the stringent requirements of availability of internetworking support, ie, internet. Their internet dependency characteristic necessitates other inherent complexities such as incorporated high cost of service, robust network coverage facility, orientation with existing system-orchestration, and augmentation by cloud led provisioning. Existing cloud servers provide seamless dissemination of the distributed input storage, management, and access facilities through its virtualization attribute. A large portion of these distributed aspects are catered by the cloud platforms. Though, cloud servers are mostly appreciated for leveraging huge-range of contemporary digitalization efforts, they lack in delay-sensitive applications. Since a cloud server is normally accessed through a set of connected Wide Area Networks (WAN), thus converting current euphoria into an unavoidable problem. Scientists have proposed the fog computing to cater such delay-based applications in smarter way. However, it does not compromise with the issues like user mobility and context awareness that are affixed to the application's need. Fog computing is embarked as the intermediary between user and cloud infrastructure. It surely enhances delay-related issues but do not conform to the computational offloading perspective. Hence, a new approach came into the existence, ie, edge computing. The goal of edge computing is to minimize the access of cloud or fog resources by the processing of the frequently

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TABLE 1 Difference among cloud, fog, edge, and dew computing

Parameters	Cloud Computing	Fog Computing	Edge Computing	Dew Computing
Service location	Within the internet	Within the internet	In edge network	In edge network
Distance (number of loops)	Multiple loops	Multiple loops	Single loop	No loop
Latency	Very high	High	Low	Negligible
Jitter	Very high	High	Low	Negligible
Location awareness	No	No	Yes	Yes
Geo-distribution	Centralized	Semi centralized	Distributed	Highly distributed
Mobility support	Very limited	Limited	Semi supported	Highly supported
Data reroute attacks	Very high probability	High probability	Low probability	Very low probability
Target users	General internet users	General internet users	Semi mobile users	Purely mobile users
Service scope	Global	Semi global	Semi limited	Purely limited
Hardware	Scalable capabilities	Scalable capabilities	Limited capabilities	Very limited capabilities
User experience	Very normal	Normal	Good	Highly satisfactory
Internet dependency	Every access time	Every access time	Every access time	Not essential
Client–Server connectivity	Yes	Yes	Yes	No
Synchronization feature	Not essential	Not essential	Not essential	Always essential
Green energy compliant	Very Low	Very Low	Low	High
Delay tolerant	No	No	No	Yes
Computational offloading	Very Less	Less	High	Very High
Deployment scenario	Large enterprizes	SME	Router, gateway	PC, laptop, smart phone

accessed data at the edge of the user's current network (eg, router and gateway), thus enhancing the overall network security. However, edge computing fails to provide internetwork-free, extreme scalability, and point-of-call service to the user.[1] Several device-to-device communication schemes that complies with the energy-efficient content delivery and cellular traffic data offloading are recently proposed to cope up with the innovative content delivery mechanisms. The key purpose of these works is to leverage computational segregation among the centralized cloud or fog repository to end user devices. Although such solutions are quite promising in nature, they lack in providing proper justification and architecture on how the content delivery should be seamlessly aggregated and persuaded in larger scale. Despite of well demonstration against the proposed physical models, they do not conform to the miniaturization aspects of content delivery subsystems into reality.[2,3]

In this context, researchers have provided a new conceptual solution-dew computing to deal with billions of smart devices to run at the user's end with minimal affectionate toward internetwork. Similar to cloud, fog, and edge, dew computing also assists its user by providing minimal set of essential services.[4] The distinguishing characteristics of dew computing include very low dependency over internetwork, super flexibility in terms of user control, and proximity to end users. Dew computing aims at providing numerous facilities that may include (1) densely-distributed service, (2) location awareness, (3) support for heterogeneity, (4) minimization of network-service latency, (5) facilitation of any-time-any-how-access, and (6) energy efficient Quality of Service. It is also capable to provide flawless security services for multitude of applications, such as smart retail, e-healthcare, real-time data analytics, localized industrial automation, and smart sensing and actuation.[5] Table 1 presents the key differences between cloud, fog, edge, and dew computing.

Current dew computing architecture is presented in Figure 1. Smart devices are attached with the dew servers so as to form a virtual dew cluster. User is able to access and modify the "internet-data" at any of the edge, fog, or cloud level based on existing internetwork facility. The four-tier model leverages user to opt-in for any layer of service at any point of time.

The contributions of this paper are as follows. (1) Possible use-case scenarios are presented; (2) a taxonomy is devised while creating a classification of currently available literatures; (3) identification of key attributes is made to express dew computing in more concrete way; and (4) several current issues are highlighted to realize the exploration of dew computing. Herein presented, the article also encourages dew computing application developers, dew engineers, and possible service providers to mitigate over the relevant landscapes that may minimize internetwork dependency while providing dew services to users. The selected requirements may aid in as a recommendation for guiding framework designers to incorporate vital features to execute the applications efficiently in the dew computing scenario. Similarly, the prescribed challenges alight future research pathways and directions. The aforementioned contributions are discussed in Sections 2-5, whereas the concluding statements are made in the Section 6.

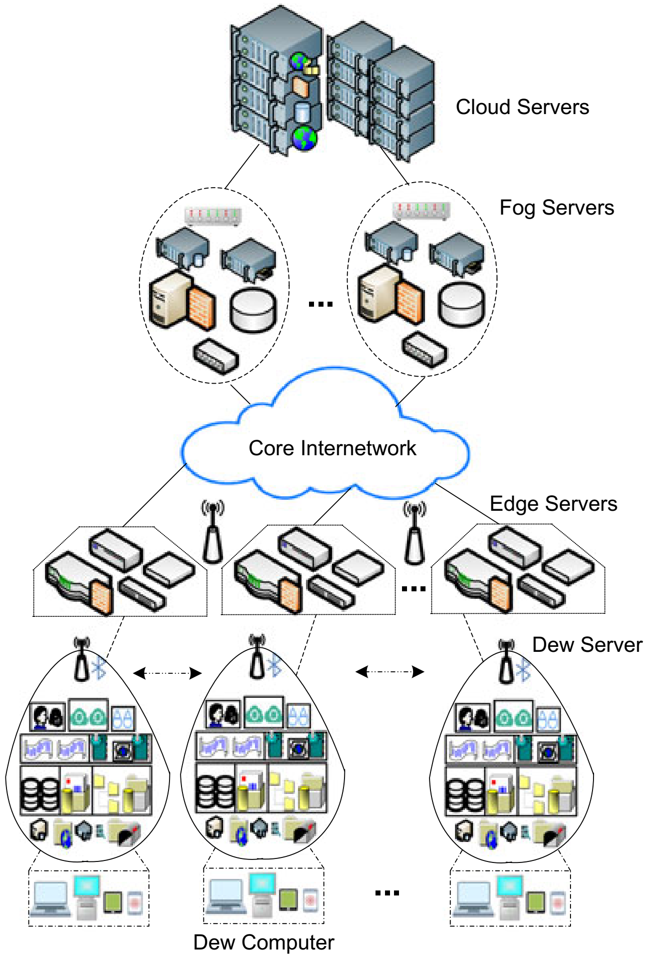

FIGURE 1 Dew computing architecture

2 | USE CASE SCENARIOS

This section describes few application scenarios in the domain of the dew computing. Dew computing can address several key issues in multiple scenarios, such as smart gaming, smart social networking, wearable e-healthcare, home automation, connected vehicles, and real-time data analytics.

2.1 | Smart gaming

Tony is fond of computer games. He goes for a vacation with friends to a sea beach where internet connectivity is often not stable. He wants to play a high-definition online game from his smart dew-phone formatted with dew computing services. He searches for internet but due to its unavailability, he starts finding a nearby dew-phone, which has a preimage of the game with similar facilities. His dew-phone seeks dew-permission to get started with the game borrowed from the other system. The game engine runs at offline mode from other system to his dew-phone. Upon instantiation of internet, his dew-phone performs a dew-synchronization to get aligned with the cloud-image of the game for saving the execution-logs for advancing to the next stages.

2.2 | Real-time image analysis

Tony's father Howard likes to tour places on the earth. He is now a visitor in China and wants to check the details of menu items of a restaurant written in Chinese. He captures the image of the menu by his smart dew-phone that has a preloaded local image of the character recognition tool. The tool works in correlation with internet connectivity to get executed with a more complex cloud solution. Suddenly, power goes off and the WiFi of the restaurant goes offline. In this context, the dew-phone starts the preloaded image-tool to translate the Chinese meaning out of the snapshot. The tool understands most of the characters but not all. Whenever internet is back, the dew-phone synchronizes with the character-recognizing cloud to get oriented with other necessary Chinese ascents or meaning into the dew-phone.

2.3 | Wearable e-healthcare

Tony's grandfather resides in a lonely environment. One day, while he got up in the morning, he suddenly falls down on the floor. Fortunately, a wearable dew-watch was worn around his wrist. The dew-watch instantaneously compares the current accelerometric and heart pulse data with the preloaded set of vital-data. If required, it provides necessary piezo pressure on his hand nerve or create chirping sounds to provide external stimulus to wake him up. Such tasks may be carried away with or without intervention of cloud support, ie, internet connectivity. Otherwise, the dew-watch is capable to push the health-log to the remote health-cloud for leveraging appropriate services when the internet is sustained. Furthermore, it checks for the nearest available dew server or other dew-phone, which is attached with internet connectivity for possible borrow of the data service for the processing of the current health data in real time. Another option could be the checking of the nearest dew-phone for the dissemination of appropriate machine learning solutions that may be helpful at the moment.

2.4 | Smart social networking

Michael, who is Tony's sister, goes for a party to friend's location. She tries to post selfies on a social networking site. Due to unavailability of internet, she fails to post such pictures. She discovers that her dew-tablet is prefixed with dew computing services and prompts for the necessary actions out of it. The dew-tablet had earlier stored her social profile as a local copy in the system. The pictures are hereby posted on the local social profile, which is later synchronized with the dew-shadow of the website's cloud repository for accessible to global viewers.[6]

2.5 | Real-time retail service

John, a family friend of Tony, runs a multipurpose shop. The account system of the shop is subscribed by an instance of the salesforce. A customer buys some items from his shop and approaches for payment. Suddenly, the internet connectivity goes offline, but John keeps some smile and proceeds with a successful transaction because his local system had a localized copy of salesforce cloud image at his shop's computer.[7] When the local internet is restored, the local copy is updated with the salesforce's central account repository.

2.6 | Smart transportation

Dew computing can drastically improve the current scenario of road services through deployment of smart transportation facilities that are already in use. For instance, dew computer of an ambulance may directly communicate with nearby dew-server positioned at the traffic light post to clear the road prior to physically reach at the jam. Similarly, smart street lights can be equipped with dew-services so as to sense the information to detect the presence or absence of pedestrians and then switch on/off the light. Such information can be propagated with the nearest dew server for establishing communication with smart city cloud server.

2.7 | Smart multimedia streaming

Multimedia streaming has become a habit for the modern age people in day-to-day life. Youtube, Netflix, Hulu, and Amazon videos are leading this race. It is true that multimedia streaming facilitates a huge portion of current internet users with a handful videos of entertainment in their leisure time or educational purposes or spreading business campaigns of any product.[8] In this respect, dew computing can also act as key enabler of multimedia stream provider to the dew user. The subscribed, liked, or shared channels of multimedia streams could be initially saved into the dew computer. Moreover, the multimedia files may be played in the user's dew computer when no internet is there. This would be possible in conjunction to other dew-computers that contain similar video files that are recommendable in some way. Herein, the presented scenario may require sophisticated data-borrowing facilities to be sorted out by the dew server itself.

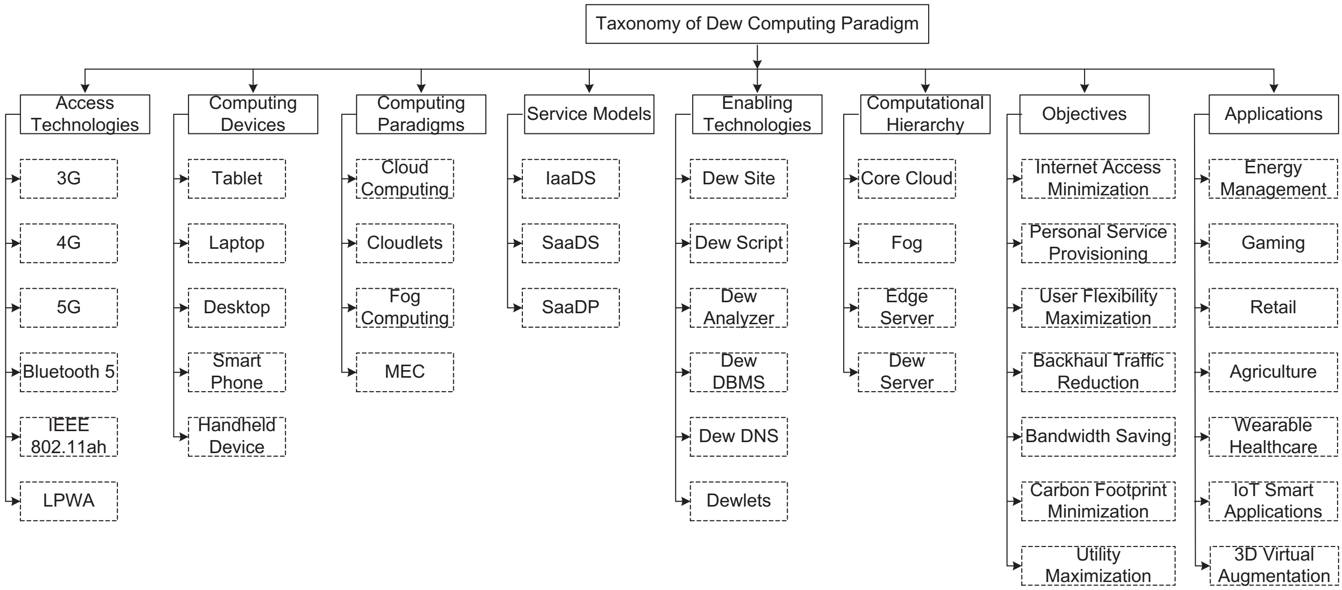

FIGURE 2 Dew computing taxonomy

3 | TAXONOMY

A taxonomy on dew computing paradigm is presented in Figure 2. The taxonomy is classified in the following key areas, such as (1) access technologies, (2) computing devices, (3) computing paradigms, (4) service models, (5) enabling technologies, (6) computational hierarchy, (7) objectives, and (8) applications. The rest of the section briefly discusses each of the taxonomical-attributes.

3.1 | Access technologies

A dew user can communicate with other dew users using low-powered next generation technologies, ie, IEEE 801.11ah (HEY-Low), is used to create a large group of dew base-stations and sensors to coordinate with the shared information among dew devices. Low Power Wide Area Network protocols are useful for establishing a peer-to-peer secure link between multiple dew-devices in a wide geographic area. Bluetooth5 provides location awareness and high speed to form an ad-hoc infrastructure between dew computers. Mobile dew users can adopt 3G, 4G, or low power 5G communication technologies for experiencing seamless features of dew-services.

3.2 | Computing devices

Unlike other computing paradigms, dew computing devices are deployed at the nearest proximity of a user such as PC, laptop, and smart phone. However, such devices lack several issues such as bandwidth, computational resource, and data storage. However, dew services can be deployed in a superhybrid cum distributed fashion by creating a virtual dew cluster.

3.3 | Computing paradigms

The main purpose of dew computing is to fetch existing remote computational resources at a near vicinity to the dew-user. Four trending paradigms are in this list, such as cloud computing,[9] cloudlets,[10] fog computing,[11] and mobile edge computing (MEC).[12] Cloud computing provides the best solution for large enterprize related issues through virtualization techniques. Fog computing and cloudlets bring cloud services closer to user, which is occasionally located at the end of the internet. The MEC leverages virtualized deployments of fog or cloudlets in the telecommunication network, preferably at the base stations or routers.

3.4 | Service models

Exiting cloud or fog service models include three key solutions, ie, Software as a Service, Platform as a Service, and Infrastructure as a Service. Dew computing is henceforth needed to be aligned with the current service trends but in modified forms as follows. The Infrastructure-as-a-Dew Service is used for facilitating user with a dew-infrastructure at local machine. In contrast to Infrastructure as a Service in cloud computing, the Infrastructure-as-a-Dew Service leverages infrastructural facilities in form of resources to the dew user; Software-as-a-Dew Service may be beneficial for impactful software-based service synchronization with the cloud-based Software-as-a-Service model. Furthermore, Software-as-a-Dew Service provides software service platform that may be subscribed by the individual dew user per dew computer; and Software-as-a-Dew Product is appropriate for on-premises software upgradation and executions facilities. Furthermore, the software packages such as dew server, dew data base management system, and dew synchronization are solicited to the dew user in terms of dew's own product.

3.5 | Enabling technologies

The assimilation of dew computing may be attributed to the recently proposed key enablers as presented as follows.

1. Dew site: It is a localized copy of actual web site that has complete read, write, append, and delete access to dew user. Every frequently visited or prompted web site should have a corresponding dew site at on-premises dew computer. For example, if www.abc.com is the actual web site, then its dew site may be designed wid.abc.com. Here, *wid* resembles to the *www* protocol, but in on-premises dew devices.
2. Dew script: It is a scripting tool available to dew user for possible modifications in the dew site placed at the dew device. For instance, user can change the formatting of *Instagram* personal profile, which is only visible to the dew user at the dew computer (wid.instagram.com). Upon accessing rights from user, the same could be synchronized with the actual web template for global visibility. If *partha* has user profile for *instagram*, then a remote shadow copy of local dew site could be positioned at the *Instagram* cloud, ie, partha.wid.instagram.com.
3. Dew analyzer: This is a software package meant to coordinate and control the overall task and assignments performed by dew script on a specific dew site. When a user does any changes in a file of a dew site, the dew client program activates the dew analyzer to create, delete, or append the local dew script file names like *file1.dewscript* in absence of the internet. When internet resumes, the modifications of *file1.dewscript* could be interleaved with the partha.wid.instagram.com. The authorization related issues could be solved by incorporating a master mapping table between dew site and actual web site.
4. Dew DBMS: As an original web site needs to have a set of database for storing and logging of activity records, the same is essential for the dew site. The dew database management system is essentially a personalized copy of personal database to provide personal dew site surfing experience in reality.
5. Dew DNS: It is assumed that a dew server will host multiple dew sites in one dew computer. Hence, a sophisticated and unique page naming mechanism is evitable. Dew domain naming service shall provide such on-device dew site searching and access features that can be achieved by the host-to-IP mapping. For example, if *wid* is mapped to *127.0.0.1*, then other dew sites could be mapped with *127.0.0.1*, ie, all local URLs could be mapped to local host, eg, wid.abc1.com, wid.abc2.com, … , wid.abc10.com to *localhost – 127.0.0.1*. Dew domain naming redirection (Dew DNR) could be another technique by which such redirection could be possible.
6. Dewlets: It is an extended dew service to a dew computer by which associated dew supported equipment could receive “let services.” In this context, multiple things of Internet of Things (IoT) could be associated with one or more dew computers.

3.6 | Computational hierarchy

Computational hierarchy illustrates that the dew computing services can be executed at various hierarchical levels, such as remote cloud server, fog server, local or remote edge servers, and end-dew devices. Although then aim of dew computing is to perform user-concentric personalized applications while providing real-time, delay-tolerant, and context aware services, some part of the application might require to communicate with the cloud, fog, or edge for synchronization of localized data. It is worthy to note that the hierarchy depicts the computing capacity and other vital characteristics. The lower the level, the more the number of nodes but less the resource in terms of processing capacity and storage.

The intermediate nodes of hierarchy act as the superior service provider. The closest high-end service is received from the edge server, whereas the cloud provides the super set of service and data repository.

3.7 | Objectives

Dew computing brings the centralized core cloud services nearest to the user. The objectives of bringing complex computational part from the remote cloud platform to end-user are as follows.

1. Internet access minimization: Dew computing is envisaged to minimize the usability of internetworking facility such that user specific instantaneous supple service could be provided.
2. Personal service provisioning: Unlink other computing paradigms, dew computing handles the higher expectation of user services at user's end. Without or minimal use of internetwork facilitates user in form of a true personal digital assistant.
3. User flexibility maximization: Existing computing solutions provide predefined set of services to user. Dew computing benefits user with unlimited amount of user-willed performances.
4. Backhaul traffic reduction: In reality, the overloading minimization effort on the network backhaul depends on data-traffic in average duration. A dew user relies upon localized services that require minimum network intervention. Moreover, the dew computing paradigm encourages its user to stay with the user's prioritized data presaved as dew copy in local dew database. In most of the cases, dew user utilizes personalized data to surf over dew sites rather on real web sites. If a required data is not present in the dew computer, the dew server first fetches from nearby dew cluster upon a dew permission over local network communication protocols. Only when a data is not present in the dew machine as well as dew cluster, it may require access to remote cloud for which actual internetwork backhaul will be responsible. Thus, minimum usage of internetworking is needed in reality, resulting optimal access over existing network traffic.
5. Bandwidth saving: As dew computers impose over self-system–self-service notion, hence communication bandwidth is minimally utilized.
6. Carbon footprint minimization: Less implications over current network assets lower down dependency over physical establishments such as base stations, enterprize fog, and big-data centers. Indirect reduction of power consumption is thus evitable, which may proportionally help to minimize the carbon foot print.
7. Utility maximization: The Quality of User Experience can be improved. Dew computers can fetch and provide the information from low-end network hierarchy. Cloud and fog services can be effectively use dynamically with the requirement of information in real time.

3.8 | Applications

Application attributes prescribe the wide range of dew computing applications that can be hosted by the dew computes in local-proximity to user. Energy consumption in an office can be easily managed by the deployed dew server. A computer game parlor can attain customers and control the game selectivity by a dew-base game application server. In retail, a shop-keeper can track and transact item-specific disbursements in efficient manner. A farmer can use dew computer on the tractor to identify soil quality and diseases of plants. Elderly person can wear a dew-watch that helps in monitoring and diagnosis of requested vitals.[13] A large number IoT devices can be accommodated with a set of dew-computers for full-fledged distributed orientation in fields. Tourists can tap 3D virtual reality enabled glass on forehead to realize ancient historical activities before eyes. Automatic health and life-data analysis in breath gas and brain damage restoration may be sought by dew-cloud combination.[14,15] The overall activity diagram is self-explanatory, as presented in Figure 3.

4 | REQUIREMENTS FOR DEW COMPUTING

Dew computing drifts the utility services of centrally hosted cloud servers to highly-distributed and decentralized dew computing devices. Superior-hierarchical networks mitigate heavy-traffic applications per user's personalized need at the dew end. In this manner, larger computing services can be provided by the dew systems with minimal network latency and use of internetwork connectivity. However, the dew computing paradigm must ensure that it carries several requirements to penetrate into the IT utility domain. As of now, most of the IT utility market is covered by cloud and its subsidiaries,

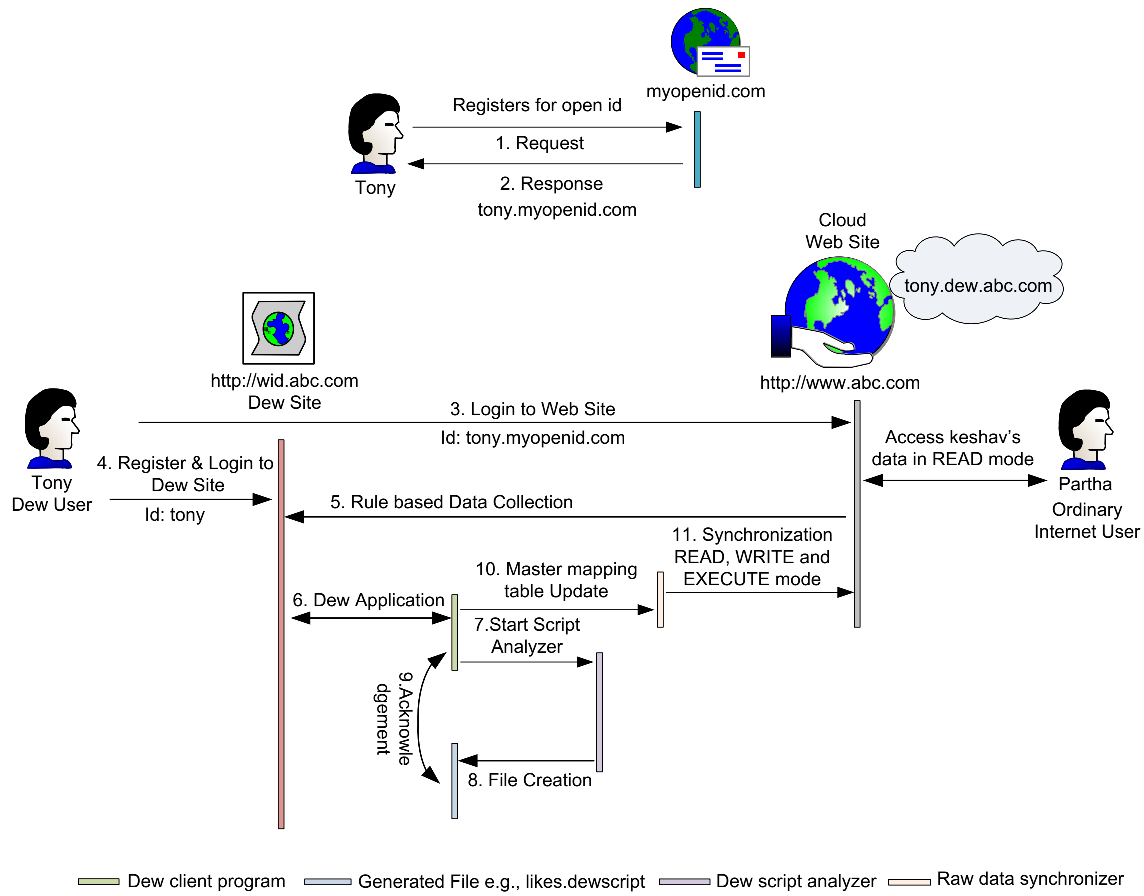

FIGURE 3 Activity diagram in de computing paradigm in internet-free scenario

such as fog, cloudlets, and MEC. Dew computing thus needs to ensure put more incentives to the utility model of existing cloud paradigm services. The listed necessitates to effective application of dew computing in both the cases of unitary functioning as minimal-cloud and interact with the cloud specifics. The rest of the section lists the essentials of dew computing as follows.

4.1 | Synchronization

How will dew computing provide internetwork-free like services while implying advanced synchronization technique?

Certainly, to work in internetwork-free environment, a sophisticated synchronizing mechanism is evitable. By synchronization, it is meant that two or more copies of data-files stored in distributed locations are in coherence with each other that further provides data-integrity. In dew computing paradigm, synchronization is the key for maintaining the sustainability of the system. For example, a user wants to access https://onedrive.live.com/. User must first authenticate own identity with the live.com cloud database. The user will next authenticate own dew identity with personal dew server. Later on, the user will access the local copy of cloud data in dew computer. If any modifications are done, the same can be synchronized with the live.com file handler. It can be done in two ways, ie, (1) process synchronization, where multiple distributed processes come together to join as a complete process for processing a single task; and (2) time stamp, where each of the updated files will be processed per their time-stamps of modifications. A preassigned synchronizer tool may take the responsibility to upload or download the user's files to or from cloud or dew computer.

4.2 | Transparency

How will dew computing provide transparent services to user such that data-corruption can occur?

Transparency is defined as the process of hiding of high-level constructs from low-level implications. In this context, dew computing needs to opt-in for two types of transparency models, such as data replication and data distribution.

In the data replication model, dew user will have two options to access the data, either localized dew-data or remote cloud or fog or edge data. While accessing the data, a dew user must not be aware of what copy of data he is currently accessing. Similarly, in the data distribution model, a dew user must not be able to know about the distribution pattern of data access. The model will seamlessly provide data-access transparency to the dew user without any difficulty. Now, comes the next question, ie, whether the transparency will provide exact services to the dew user? The answer could be given in two ways, ie, (1) dew service-wise, no discrepancy will be there; but, (2) context-wise, yes. However, some changes in dew browser and implications of mutual consistency technique might improve the situation drastically. Now, mutual consistency mechanism may be applied in two orthogonal ways, such as (1) high priority update and low priority update.[16] In high priority update, data replication or update first happened in remote cloud server. In low priority scenario, local data update follows the global or remote data update process. If cloud is considered as core (ie, master copy) and dew as distributed (ie, local copy), then four options are available to dew server, such as (1) high core priority, (2) high distributed priority, (3) low core priority, and (4) low distributed priority. As dew computing is specified for application in the internetwork-free situations, low priority update seems to be more suitable. The best choice is low distributed priority where local copy at dew computer is asynchronously gets updated, followed by the core-master copy. However, several security and communication protocols need to be aligned appropriately.

4.3 | Reorigination

What will happen to dew data or files if they are destroyed due to vulnerable activities?

Dew computing paradigm is based on a well-defined metaphorical idea that resembles the dew computer with a “drop of dew” while the cloud as “floating cloud in the sky.” It is apprehended that a drop of dew is negligible per weight with respect to a set of cloud in the sky, thus dew computing is light-weight. A dew drop is placed over an entity; hence, dew computer should facilitate one end-user at a time. Dew computer stores only most frequently accessed data in its dew database. A dew drop is tiny; thus, dew computing should store minimal amount of data with it. Dew drop is easily destroyable as in dew computer's data is prone to several fatal errors like malware, virus, or system damages. Lastly, a dew drop is evaporable, thus a dew data set. However, a dew drop is recreated when it rains from cloud. It means a dew data is recoverable. Whenever any mishaps occur to local data-set, the same could be reproduced from the cloud-stored data. This metaphor clearly depicts the relationships between a natural dew drops with a digital version.

4.4 | Rule-based data collection

How will dew computer store the user′s personalized data in dew database?

Dew systems will be smart enough to probabilistically estimate, predict, and prepare the most possible set of data to user that are frequently accessed. Existing machine learning techniques are capable to cater this need. The aim of such process is to store and manipulate knowledge to infer information in a convenient way. It can be achieved in three ways, such as (1) dew site browser, appropriate fuzzy-based rule engine is to be integrated with dew site browser so that it can automatically understands the pattern of data access by the dew user; (2) content personalization, where custom landing pages could be created that may help in displaying both the versions of dew and cloud counterpart, furthermore, various segmentations could be perceived while including web, database, and behavior attributes; and (3) expert system, available expert system-engines are another avenue where rules for web-data collection and restructuring are possible.

4.5 | Scalability

How will dew computing scale to sparse applications, mobile end users, and constrained bandwidth scenario?

To be scalable, dew computing must penetrate into sundry networks, vigorous end user machines, and vibrant dew-system assemblies and disseminate a prominent sensor-aware performance in case of a sudden growth in the dew end users and applications. Dew computing can be scaled by (1) allowing dewlets among nondew systems; (2) defining virtual dew cluster (geographic expansions); and (3) utilizing cloud or fog or edge interplay. While the interplay with other computing paradigms can tip to outlying myriad scalability for all entities, the impartial functioning of dew computers requires preassessment because of the inadequate means of dew devices. Dew should ensure severance of resources in case it acts as an autonomous minimal-cloud, as it would happen. Intelligent controlling of the scalability opportunities in diverse consequences is perilous to the functioning of dew computers.

4.6 | Heterogeneity

Given the exaggerated heterogeneity of dew devices, systems, protocols and methodologies, how will dew computing support interaction and interoperability with own sphere?

Dew computing require to assimilate higher degree of interoperation and interconnects among multiple heterogeneous machines ad service formulations. In dew computing, heterogeneity is a special issue that arises from varieties of device specifics, network protocols, and system architectures. However, dew devices must support the heterogeneity. In near future, dew computing should define interoperability standards so that seamless dew-data altercation could be made among several network players. Moreover, hybrid peer-to-peer communication is an essential component of dew computing. Existing standards need to be revised for overall implications to all network devices. Efficient management of interoperability is also a key in congealing IoT systems and smart sensor-based devices toward dew computing paradigm.[17,18]

4.7 | Reliability

How will dew computing facilitate utmost reliable services in occasions of dew server failures?

Dew computers are usually very dynamic and surfacing in nature. Moreover, such dew devices are most of the time disconnected from the internetwork. Therefore, a fail-tolerant blueprint must be obtainable for end user services for instances of unexpected change in bewildered situations. A reliable dew computing perspective entrusts fail-over contrivances in pitfalls, such as (1) catastrophe in individual dew computer, (2) restrictions in network stipulations due to unavailability and limitations of the associated networks, and (3) failure between dew network and access network platforms. In cloud, fog, or edge network, the reliability of user service is entrusted by data repudiation or replication of respective servers. Dew server resides inside a dew computer; hence, a new dew server cannot be immediately affixed with a dew computer. Dew session logs can be saved in the edge, fog, or cloud servers so that possible data regeneration is done during a failed environment. Moreover, some patches can be integrated to advance the dew-reliability aspects, such as (1) asynchronous rescheduling of suspended tasks, (2) duplication of dew servers and dew services in a number of scattered locations, and (3) periodic maintenance of resume-points in dew devices.

5 | CHALLENGES

This section highlights vital most challenges that inhibit the success of dew computing aspects. The discussions on the identified challenges facilitates research pathways for further investigations in the field of dew computing.

5.1 | Data storage facility

Dew computers are entitled to host partial amount of data at dew database in contrast to cloud′s perspective. Such partial data should be synergized with the cloud or fog′s main repository, without which the lost dew-data cannot be recovered. Dropbox is such a utility, which provides 24x7 data storage and access facilities to its users even when internet connectivity is not present. More similar products are available in IT market, which are not all popular. Hence, those have never got attention of IT developers. The example of Dropbox is an instance of dew-like computing. It indicates that applications on dew computing is readily existing, without having been conformed to actual orientation. Dew users will be mainly dependent on on-premises local copy of dew data, which will be frequently searched, accessed, and modified. Thus, a robust file storage technology is required, which would suffice the dew applications. Storage-in-Dew (SiD) is such a concept that will change the practicality with novel conjunctures while employing the solid-state driver technology and the smart data handling mechanism.

5.2 | Business model

Dew computing has to compete with other market players, such as dew developers, edge analytics, fog SMEs, and cloud enterprizes. An appropriate business model is henceforth ready to be responsible to account, monitor, and possibly bill the usage of dew services in conjunction with other services. One option could be similar of pay-as-you-go model currently in practice with cloud and fog solutions. Moreover, how dew players will segregate the payment among own sphere and how dew providers participate in the incentive-aware advertising campaign will also have to be thought of. Furthermore, cost–benefit analysis of dew-based subsystems will be an issue that might have direct effects on the reachability of dew computing paradigm in offices, universities, and corporate sectors. Heterogeneous charging granularity may be an issue for dew computing.

5.3 | Lightweight security and privacy

In comparison to cloud, fog, and edge computing, dew computing is inherently most secure paradigm. The reason is minimal mitigation and migration of tasks through open internetwork. It is expected that a dew computer will be used by one user as personalized digital assistant. In this context, if network securities are assumed to have minimal effect on dew computing, localized privacy and authentication challenges will trouble dew computing to settle down. Lightweight security and privacy means will be an essential part of dew devices as they are prone to restricted resources.[19] For example, shortage of battery power, biometric authentication, and private files may be intruded by external entity or dew users at any point of time. On other hand, diverse network configurations and complex data synchronization will make security and privacy issues vulnerable ones.

5.4 | Utility modifications

Dew computer necessitates integration of novel components like, dew server, dew dbms, dew site, dew analyzer, and dew dns. Dew user is assumed to be oriented toward utilizing of frequently accessed data in a personalized manner. In that case, browser configuration should be changed in such way that, whenever a user surfs some web sites, the visited pages and other legacies should be monitored and analyzed per user's activity pattern. Next time, when the user tries to fetch the preaccessed data, he could easily be vetted with required pages, even though the internet is down. Operating system play the most vital role to make a dew computer follow its principles. As opposed to the ordinary network model, dew computer hosts a dew server within, thus an efficient constrained-server mechanism should be in place. Dew sites are often modified by user. Hence, the dew scripting technique may be revised and possibly get aligned with the existing Linux-based scripting notions. Similarly, processors in dew computer should not be high end in nature. Commonly used ARM processors or INTEL processors would do the job. If more power is required, task offloading could be made or more processing capability could be borrowed from infrastructure as a service, provided by cloud and fog platforms.

5.5 | Social collaboration

It is expected that various dew vendors will provide different flavors of support and services in the deployed dew computers. To enable, social collaboration among different dew devices originating from a number of vendors, some unified analytics could be developed. Standardization and competitions are the key leg-pullers that impede the collaborative communication.[20] Contemporary dew providers, who leverage heterogeneous services, create problems for dew users to get socially colligative into reality. Thus, social collaboration within dew paradigm remains a challenging task that must be resolve to get open up in efficient dew-data analytics.

5.6 | Personal high productivity

Dew computing paradigm is proposed to cater user′s personalized needs to be solved in purely personal way. However, dew computers are meant to reside at the bottom most layer of computing architecture, resulting into minimal performance by personal high productivity-wise issue. As envisaged, dew computer may be the chance to be less utilized than what in the cases of cloud, fog, and edge paradigms. To facilitate dew as a personal centric service provider, necessary change in productivity policy is mandatory. For example, Distributed High Productive Information Processing (DHPIP) is such an alternative that may be incorporated with the existing computing hierarchy. It will be possible if super-hybrid-peer-to-peer communication link is achieved between dew peers. A large chunk of information then could be executed by using Giga, Tera, Peta, or Exaflop computing facility.

6 | CONCLUSION

Dew computing brings the centralized service models of cloud, fog, or edge computing closer to the user. Dew computing is conceptualized as a novel computing paradigm where dew server provides personalized services to the user, even when internetwork connectivity is unstable. Thus, the extension of the dew model with existing models is a trivial task. This study presented herein is formulated with the aim of exploring dew computing paradigm.

In this paper, dew computing is highlighted while given special attention to the significance on user-centric flexible approaches in real-life scenarios. Moreover, existing dew computing literature has been categorized and classified and a taxonomy has been devised based on pertinent parameters. Several requirements are identified and delineated that should be met to empower dew computing. Furthermore, key challenges that endure to be addressed are expounded as future research guidelines. Finally, we may provide the conclusive remarks as follows. Although the dew computing paradigm inherits some fascinating characteristics, such as internetwork independency, ultralow latency, end user flexibility, super-heterogeneous, and context awareness, the paradigm is at its nascent stage of evolvement. Thus, substantial effort should be given for solving the identified challenges to expedite the intrusion of dew computing in futuristic IT domain as a key enabler.

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