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Edge Computing : A Review

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Abstract - The Edge computing concept has gained traction in academic and corporate circles in recent years. It serves as a key part for many future technologies like 5G, Internet of Things (IoT), augmented reality and vehicle-to-vehicle communications by connecting cloud computing services to the end users. Delay-sensitive applications benefit from the Edge computing paradigm's reduced latency, mobility, and location awareness. Significant research has been carried out in the area of Edge computing, which is reviewed in terms of latest developments such as Cloudlet, and Fog computing, resulting in providing with more insight into the existing solutions and future applications. This article is intended to be an overview of huge progress in Edge computing, with a spotlight on the most important applications.

***Keywords* – *Edge Computing*, Cloud Computing, fog Computing, Cloudlets.**

1. Introduction

Edge computing is a relatively new development in the computing world. It brings cloud - based services and utilities closer to the end user and is distinguished by fast processing and application response time. The current developed applications using internet such as surveillance, virtual reality, and real-time traffic- monitoring require fast processing and quick response time . End users generally run these applications on their resource-constrained mobile devices and the core service and processing are performed on cloud servers. Leveraging services of cloud by mobile devices result in high latency and mobility-related issues . Edge computing fills the above-mentioned application requirements by making the processing to the edge of the network. The cloud computing issues can be resolved through the different Edge computing models such as Cloudlets, Fog computing and Mobile Edge computing .

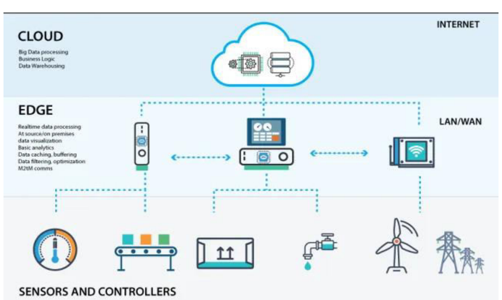

Fig. 1 Edge Computing.

2. Background

This section explains the fundamentals of cloud computing and how it differs from edge computing.

2.1. Cloud Computing

Cloud computing is a computing paradigm that offers on-demand services to the end-users through pool of computing resources that includes storage services, computing resources and so on. The main services that Cloud computing offers includes infrastructure as a service(IAAS), platform as a service(PAAS) and software as a service (SAAS) . All these services provide on-demand computing services like storing and data processing . Besides offering the above mentioned services, the Cloud computing also look on dynamic optimization of shared resources among multiple users. For example, a Cloud computing resource (such as email) is assigned to a western user according to his or her time zone. The same resource is allocated to Asian users via Cloud computing based on their time zone.

2.2. Edge Computing

Computational data, applications, and services are directed away from Cloud servers to the network's edge with edge computing. The content providers and application developers can use the Edge computing systems by offering the users services closer to them. Edge computing is defined by high bandwidth, ultra-low latency, and real-time access to network data that can be used by a variety of applications. By granting Edge users access to new apps and services, the service provider can make the radio access network (RAN) available to them. Edge computing opens several new services for enterprises and consumers . The use cases of Edge computing are augmented reality, video analytics, and data caching. Thus, these new Edge computing standards and deployment of Edge platforms become key part for new revenue streams to vendors, third-parties, and operators.

2.3. Main Differences between Cloud and Edge Computing

- The total number of operations required to reach and again transfer data from server is much less in edge computing than cloud computing. Edge computing decrease the operations by distributing data process to the different locations,This help it in making the data deliverable to the nearest node and process it at the edge.

- But, when it comes to being powerful in terms of processing, cloud infrastructures are always preferred over edge computing.

- Another key difference lying between edge and cloud is that the cloud gives a centrally managed platform. In the case of edge computing, only the initial processing is done by the edge network while rest is done by a Centrally Managed System which makes the initial processing more time redundant and efficient.

- When it comes to data retrieval in Cloud Computing, files or applications are directly accessed from main the server. In the case of edge computing processing done on the edge network with the help of Internet of Things (IoT).

- The exposure to the nearest access of the data can make the data more vulnerable to malicious actions which can be a big “NO” for the data security, but it is less unlikely to happen.

- Edge Computing is used for the real-time monitoring and analysis, where Cloud Computing is used for the back-end data access that might be in Cloud Computing. Cloud Computing offers data security with some additional security layers to protect the customers data

3. Edge Computing Characteristics

3.1. Dense Geographical Distribution

Edge computing brings the Cloud services closer to the user by deploying multiple computing platforms in the edge networks. The infrastructure's dense geographical distribution helps in the following ways:

a) The network administrator can support location-based mobility services without having to traverse the entire network.

b) Big data analytics can be done more quickly and with more precision.

c) The Edge systems enable the real-time analytics on a very large scale.

Examples include sensor networks to monitor the environment.

3.2. Low Latency

Edge Computing concepts bring processing resources and services closer to the users, lowering latency in service access.

Edge computing's reduced latency allows users to run resource-intensive and delay-sensitive applications on resource-rich Edge devices (e.g. router, access point).

3.3. Mitigating bandwidth limits

The ability to move workloads closer to the end users or data collection points reduces the effect of limited bandwidth at a site. This is especially advantageous if the service on the edge node eliminates the need to send large amounts of data to the core for processing, which is common in IoT and NFV workloads. Data compression and local processing can result in more responsive apps as well as a reduction in the expense of transferring terabytes of data across great distances.

4. State-of-the-Art on Edge Computing

This section aims to critically analyze the literature available on Edge computing paradigms, including Fog computing, Cloudlets, and Mobile Edge computing.

4.1. Fog Computing

Fog computing refers to a network fabric that extends from the point where data is created to the point where it will be kept, whether in the cloud or in a customer's data center.

Fog is closely associated with cloud computing and the internet of things (IoT) and is another layer of a distributed network environment. the edge is where data from IoT devices is created. One can think cloud vendors as a high-level, global endpoint for data.

“Fog provides the missing link for what data needs to be pushed to the cloud, and what can be analyzed locally, at the edge,” explains Mung Chiang one of top researchers on fog and edge computing.

According to the OpenFog Consortium, a group of vendor and research organizations advocating for the advancement of standards in this technology. fog computing is

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"a system-level horizontal architecture that distributes resources and services of computing, storage and networking everywhere along the continuum from Cloud to Things."

4.1.1 Benefits of fog computing

The development of fog computing frameworks open different choices for processing data where it is most appropriate to do so to organizations. For some applications, data need to be processed as quickly as possible – for example, in a manufacturing where connected machines need to respond to an incident as soon as possible.

Fog computing can able to create low-latency network connections between devices and analytics endpoints. This structure in turn reduces the amount of bandwidth needed compared to if that data is to sent to a data center or cloud for processing. It can also be used in cases where there is no bandwidth connection to send data, so it must be processed close to point it is created. Users can also add security elements to a fog network, such as split network traffic and virtual firewalls, as an added bonus.

4.1.2 Applications of fog computing

Fog computing is the stages of being rolled out in formal deployments, but there are different types of use cases that have been identified as potential idea for fog computing.

Connected Cars: The arrival of semi-autonomous and self-driving cars will increase the large amount of data. For cars operate independently requires a power to analyze certain data at that point in real-time, such as driving conditions and directions. Other data may need to sent to a manufacturer to help improve vehicle maintenance or track usage. A fog computing environment would provide communications for all of these data sources both at the edge i.e. in the car, and to its end point i.e. the manufacturer.

Real-time analytics: Manufacturing systems that need to react to events as they happen, to financial institutions that need real-time data to influence trading decisions or monitor for fraud, fog computing deployments can help to provide a mechanism to transmit data between where it is made and a number of places where it needs to go.

Smart cities and smart grids: Utility systems, like linked cars, are increasingly relying on real-time data to run more efficiently. Because this data is sometimes created in far away regions, processing it close to where it was created is critical. Other times, data from a huge number of sensors must be gathered. Both of these problems could be solved with fog computing designs.

4.2. Cloudlets

Cloudlets can be thought of as a smaller version of clouds, with the primary difference being that cloudlets are located close to the network's devices, at the network's edge. It's the cloud that's close to your location. Cloudlets, like edge computing, assist in the processing and computing of offloaded processes from network devices. I need to explain what is meant by 'Offloading'.

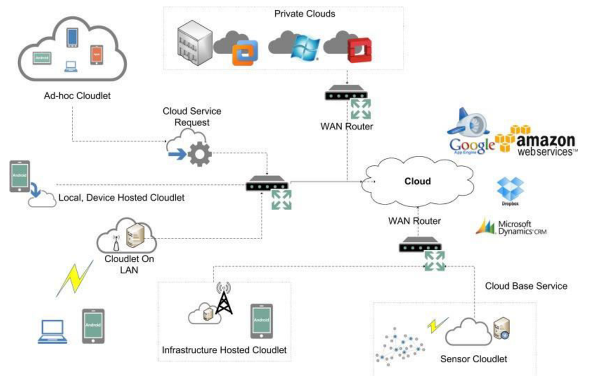

Fig. 2 Cloudlets.

A multitude of advanced functions, such as augmented reality, face recognition, natural language processing, gaming, video processing, and 3D modelling software, are now being built into mobile and other IT devices. These applications are typically resource-intense, necessitating heavy computing and considerable energy consumption. However, in terms of processing power and battery life, mobile devices are limited. So, in order to run these programms, resource-intensive programms are uploaded to the cloud utilizing a mechanism known as offloading, where all of the processing may be done in the cloud using the resources available there, and the results are sent back to the IT devices in our hands. The entire process or a portion of the process is offloaded to the cloud for processing, depending on the type of activities and the required resources.

Latency and bandwidth concerns arise when sending data from data resources to clouds located thousands of miles away. There will be delays, packet loss, and interruptions in the user experience if the internet service provider fails to conserve the connection between the device and the cloud server. As a result, the Cloudlet concept was developed to avoid and mitigate these issues.
Cloudlets are mobility-enhanced small-scale cloud data centers positioned at the Internet's edge, according to a common definition. As a result, resource-intensive operations can be offloaded to cloudlets for processing, which reduces latency, bandwidth, and saves time. The advantages of cloudlets in terms of latency and bandwidth are particularly relevant in the context of autos, where they can supplement vehicle-to-vehicle systems being investigated for real-time control and accident avoidance. A cloudlet can act as a proxy for the cloud and

provide its important services in the event of a breakdown. Actions that were tentatively committed to the cloudlet may need to be propagated to the cloud for reconciliation when the problem is repaired. Another advantage of adopting cloudlets is the preservation of privacy and security. When we use the cloud for processing, our safe data must go to cloud servers located thousands of miles away, putting the data's security at risk. Hence, by using cloudlets, all the private data will be processed at the edge of devices and help in the conservation of the security and privacy of data.

4.2.1 Benefits of Cloudlets

Soft-state: One of the most crucial characteristics. Once installed, the cloudlet is completely self-contained and does not require any expert support.

Powerful and well-connected to Internet: It's a computer or a cluster of computers with a lot of resources that are well connected to the Internet and may be used by adjacent devices. Cloudlets, likewise, have an efficient and dependable Internet connection, which is normally via a wired connection.

Highly responsive cloud services: Low end-to-end latency and high bandwidth are easier to achieve when a cloudlet is physically close to an IT device. This is useful for applications that offload computation to the cloudlet, such as augmented reality and virtual reality.

Privacy-policy enforcement: By acting as the initial point of contact in the infrastructure for IoT sensor data, a cloudlet can enforce its owner's privacy restrictions prior to data being released to the cloud.

Scalability via edge analytics: When raw data is evaluated on cloudlets, the cumulative ingress bandwidth demand into the cloud from a big collection of high-bandwidth IoT sensors, such as video cameras, is significantly reduced. Only the extracted data and metadata must be sent to the cloud (which is much smaller).

Available for use by nearby mobile devices: It's logically close to devices, which implies that any mobile devices on the LAN have a short latency to the cloudlet and a lot of bandwidth to send data.

5. Challenges

Cost: Edge computing devices with processing capabilities are expensive. Increased equipment is required to operate older versions that lack such processing capabilities, resulting in additional expenditures. An edge computing framework's configuration, deployment, and maintenance are all costly endeavors.

Data: Edge computing processes only a subset of data, implying that a significant amount of raw data is discarded. This 'trash' could have contained significant data that could have supplied new insights. As a result, organizations face a difficulty in categorizing data in a way that not only enhances efficiency but also prevents the loss of crucial data.

Power: Businesses will need high-power CPUs to provide cloud-like distant services to their commercial customers for multi-tenancy needs. Businesses will need high-voltage, three-phase energy to achieve this, which might be tough to come by, especially in rural locations.

Security: When it comes to edge computing, security is a hot concern. While proponents of edge computing suggest that it will help to localize security concerns, others claim that increasing the number of data processing locations will increase the attack surface proportionately. Separate data processing equipment and devices also run the danger of becoming attack vectors.

Use cases: Businesses must appropriately identify which functions should be handled at the edge and which should be handled in the cloud. This is crucial since it will eventually explain their return on investment.

6. Conclusion

Edge computing envisions to bring services and utilities of Cloud computing closer to the end user for ensuring fast processing of data-intensive applications. In this paper, we studied the fundamental concepts related to Cloud and Edge computing. We had a overview of the state-of-the-art in Edge computing. We presented characteristics of Edge computing. Furthermore, we identified and discussed several research challenges. This study concludes that the state-of-the-art in Edge computing paradigm suﬀ ers from several limitations due to imperative challenges remaining to be addressed. Those limitations can be compensated by proposing suitable solutions and fulfilling the requirements such as dynamic billing mechanism, real time application support, joint business model for management and deployment, resource management, scalable architecture, redundancy and fail-over capabilities, and security.

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