Edge, Fog and Cloud Computing: Offering Strong Computing

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***Abstract*— Advances in the Internet of Things (IoT) and 5G technology require new strategies and technologies to process any data from these areas. With edge, fog and could computing technologies, it will be possible to collect data from devices that use a wide variety of protocols and produce data in many different formats, and process these data in real time. This article, by examining the difficulties in the advancement of computing types and their application areas, the requirements and solutions are presented to provide strong computing.**

***Keywords*—Edge computing, Fog computing, Cloud computing, Data analysis**

I. INTRODUCTION

Cloud computing has become popular since 2005 [1]. It has been an important platform for storing, processing and managing large amounts of data. Data from applications and industries we use in daily life is stored in the cloud instead of local machines. Could computing provides users with remote access to their files, eliminating the difficulty of purchasing expensive hardware for computing and storage [2].

Cloud computing offers services for long-term storage, big data analysis, historical data analysis and less time sensitive data. However, with the development of technologies such as IoT and 5G, traditional cloud computing becomes insufficient in solving problems such as bandwidth limitation, resource allocation and high latency [3]. At this point, extreme computing concepts come into play to improve cloud computing.

Edge and fog computing are similar technologies, but the most important difference is where information is processed. Data from IoT devices and smart sensors are downloaded from the network architecture to the LAN level in fog computing, transferring the data to a fog node or IoT gateway and processing it on the LAN hardware. Edge computing, on the other hand, operates without the need to be transmitted anywhere on physically close communication equipment or physically close communication devices such as programmable sensors. Thus, data processing is done independently from the cloud computing platform and much faster.

New business models need technologies that can maximize real-time data analytics and security. Edge computing technologies should be used in critical situations measured by seconds and seconds such as rapid identification, stock market transactions, worker security, autonomous vehicles, city security, cyber security, rail security, where instant data processing and decision making are very important.

The article, firstly information was given about the architecture and operation of edge, fog and cloud computing technologies, then the requirements were determined to offer strong computing and solutions were proposed for these requirements.

II. EDGE, FOG AND CLOUD COMPUTING

With cloud computing, big data can be stored on the internet and accessibility of this data has become possible. In order to improve the resource in the cloud computing system, the encrypted data was first processed close to the third source of the network information technology edge computing, then IoT to design the on-device computing fog information technologies that take place in the layer between end devices and the cloud. In this section, information about edge, fog and cloud computing architectures will be given and comparisons of these technologies will be made.

A. *Cloud Computing*

The National Institute of Standards and Technology has defined a model that foresees convenient and comprehensive network access anywhere in a common pool of configurable computing resources with cloud computing, minimal management effort or service provider interaction [4].
Its main features are Wide Network Access, resource allocation and flexibility. Wide Network Access allows the user to dynamically access data from remote locations through devices. Cloud computing architecture: It consists of hardware, infrastructure, platform and application layers as shown in Fig. 1 [5].

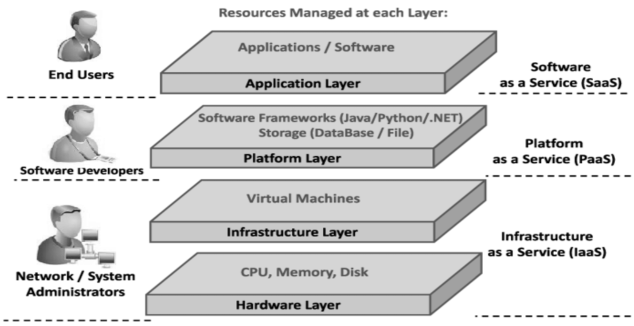

Fig. 1. Cloud computing architecture [6]

IaaS, uses its own operating systems and applications to Cloud Service Provider users and provides physical or virtual infrastructure for processing, networking and storage

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in their running applications [7]. PaaS, users can implement, run, test and also manage their own applications. In addition, the basic operating system and some development software are provided with the application development infrastructure. SaaS**,** the entire infrastructure, operating system applications on the layer are provided by cloud providers. Users can use the software on the web [8].

B. Fog Computing

Fog computing is the architecture between cloud and data source. The computation is performed on the fog nodes that collect data from their devices in the network. Preferably the most advanced fog nodes are selected, these nodes selected have interoperability. Its key features are extreme location awareness, less latency, mobility support, real-time interaction, heterogeneity, and interoperability [9].

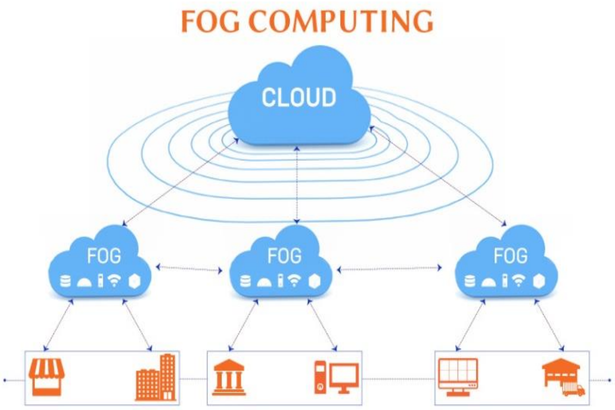

Fig. 2. Fog computing architecture

It has a three-tier architecture as shown in Fig. 2. The lower stage consists of edge devices such as sensors or actuators. In the middle tier are fog nodes that collect data from end devices. Fog nodes collect data from network devices such as Bluetooth or WiFi and from edge devices. It provides a bi-directional gateway between edge devices and the cloud and handles requests from edge devices in real time. Fog nodes are mostly created from routers or base stations. At the upper level is the cloud data center, which receives data from the fog nodes.

C. Edge Coputing

Edge Computing is a distributed information technology architecture where data generated by smart devices and sensors can be processed and stored in real time without being sent to the cloud by smart devices. With this feature, it optimizes the cloud system, data is sent to the cloud for historical and big data analysis, less time sensitive operations and long-term storage.

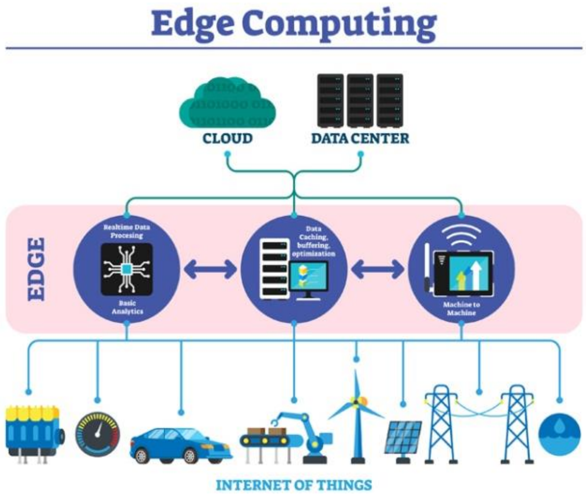

Fig. 3. Edge computing architecture

In the system whose architecture is given in Fig. 3, edge analytics software is embedded or embedded in an IoT gateway on a remote unit and processes the sensor data from this single unit. This data is transmitted via IoT protocols to any end gateway on or in the device itself, via any transfer layer protocol [10]. Gateways process the accumulated data before transmitting it to the cloud. In this way, they provide security against unauthorized access from both users and other devices on the network. Data on the network can be monitored or stolen by users who do not have good intentions [11].

D. Comparison of Edge, Fog and Cloud Computing

Edge, Fog and Could computing are compared in Fig. 4 and Fig. 5 based on traditional features, key technologies, communication features, positive and negative aspects.

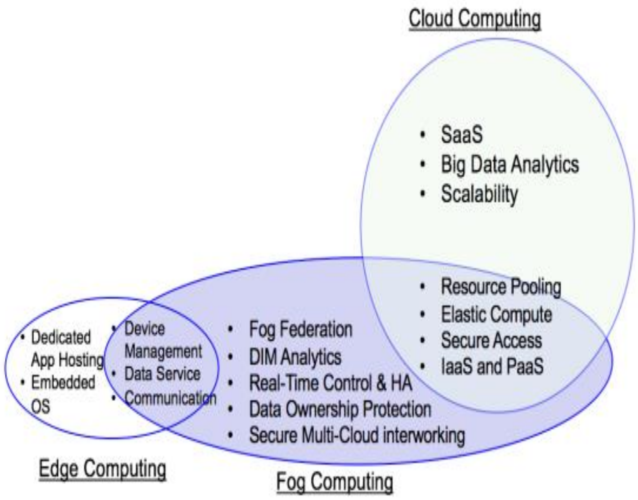

Fig. 4. Comparison of edge, fog and cloud computing

	Cloud Computing	Fog Computing	Edge Computing
Pros	Easy to scale	Real time data analysis	Itsimplifies internal communication by means of physically wiring physical assets to intelligent PAC to collect, analysis and process data.
	Low cost storage	Take quickactions	PACs then use edge computing capabilities to determine what data should be stored locally or sent to the upper layer for further analysis
	Based on internet driven global network on robust TCP/IP protocol	Sensitive data remains inside the network	
		Cost saving on storage and network	
		More scalable than edge computing	
Cons	Latency/Response time	Fog computing relies on many links to move data from physical asset chain to digital layer and this is a potential point of failure.	Less scalable
	Bandwidth cost		Interconnected through proprietary networks with custom security
	Power consumption		Cannotdo resource pooling
	Privacy, security, and legal issues		

Fig. 5. Pros and cons features of cloud, edge and fog calculation

III. REQUIREMENTS

Strong computing for the constructive solution in IoT applications where end devices are geographically dispersed, there are difficulties in connectivity to cloud-based systems, but latency tolerance is also low, so it is not very reasonable to send data back to the cloud and return it to the cloud. needs to be presented. In the reviews, the requirements for presenting strong computing were determined as follows:

Speed and Latency, The time to send the data obtained from the devices to the cloud for analysis and processing is much longer than the required milliseconds in today's applications. Time-sensitive applications, like industrial IoT, require immediate processing of device data to make timely corrections. Latency sensitive applications such as augmented reality games require end-to-end latency (including network and transaction latency) under 10-20 ms [12], [13]. However, the latency between an end user and the closest available cloud data center is 20–40 ms and extends up to 150 ms [14].

Service Management, An increasing number of devices, such as IoT sensors and actuators, may require powerful computing machines to operate and manage such devices.Service distribution, error management, hardware installation and device on / off etc. [15]. Edge computing only acts as an intermediate layer to provide computing power. While providing control of devices, on the other hand, it enables services to be customized according to the environment [16].

Security, Sending sensitive operational data from the field to the cloud actually risks both data and your end devices. To ensure that data is transferred securely to cloud storage systems, it is necessary to deploy different levels of security mechanisms in an IoT system. Many applications dealing with personal data generate large amounts of personal data that are too risky to be distributed in the cloud system, so these applications are often preferred to be placed in a secure cloud owned by an individual and trusted third party. Similarly, many industry applications prefer to use a secure cloud for security reasons.

Data Integrity, It transfers the processing and storage of data obtained from cloud computing network devices to external sources. Sensitive data obtained from important applications is usually stored in a cloud of unknown physical size, so data integrity is an important component to be considered.

Data Transfer and Bandwidth Costs, Resources are paid for rented resources in the cloud system, and the pay-as-you-go model applies. However, in critical and large applications, the total investment cost to be made is preferred instead of leasing. In some applications, transmission from edge devices to the cloud is expensive enough to prevent this process due to the size of data. Moreover, the daily cost of transferring this data means communication costs that are unsustainable in the long run.

Energy efficiency, the energy consumption of large IoT devices remains an important issue [17]. Edge computing enables these devices to intelligently make decisions such as on / off / hibernate that reduce overall energy consumption [18].

Legal requirements, In sectors and regions where legal requirements are very important (such as Europe, where the General Data Protection Regulation (GDPR) applies), the need for localized data centers increases, as the method of processing this information is tightly controlled, including where personal information is stored and how it is transmitted.

Need for Independent Operation in Remote Locations, System downtime in remote locations decreases, and when the central system is inaccessible, it ensures that operation can continue independently in these locations. In case of any interruption in the network system with the cloud, data analysis and processing should continue by using edge information structures and when the network connection is established, the processed data should be transferred to the cloud for long-term storage.

IV. SOLUTION SUGGESTIONS

It can be used for edge computing PLC solution. PLC (Programmable Logical Controller): They are automation programs used in production systems and control of machines. When choosing PLC in a control system, features such as cost, program backup feature, real time clock, command processing speed, technical support, communication possibilities, number of timers and counters, password protection, interrupt operation capability should be taken into consideration.

It can be used for PAC solution for edge computing. PAC (Programmable Automation Controller): It is an automation program used for multifunctional, open and integrated control systems. PAC's key features include multi-language support, a modular design, integrated with many databases such as SQL, easily programmable with a USB port, multitasking applications and more I / O capabilities.

Can be used for Remote I / O solution for end computing. Remote I / O modules: provides adaptive planning, fast setup, safe start-up, minimized downtime for better performance and efficiency. It also provides easy connectivity and simple installation, visual convenience, reliable process continuity.

The hardware option required for the solution for fog computing is more limited than the edge computing. However, various smart devices with IoT gateways are available on the market for filtering and normalizing data before it is transferred to the cloud.

As a software solution for fog computing, the IIoT gateway, which is the industrial network product of Moxa, has Linux version support and incorporates data collection and device control functions.

As another software solution for fog computing, the software called ThingsPro Suite responds to Modbus data collection and wireless management requirements, but also offers the flexibility to program user applications, taking it to a much better point where they can be done in the IIoT gateway.

As a software solution for edge computing, MEG5000 is a powerful gateway developed by Robustel over the Linux-based RobustOS operating system. MEG5000 is a modular edge gateway for IoT. It is configurable and manageable, allowing real-time data analysis and processing on end devices for high performance IoT deployments.It also offers a user-friendly interface. There is also the option to develop software via C, Python or Java. It has a rich App range for more specific IoT application needs.

If the devices performing data collection and processing in end computing applications do not support the required protocols, a protocol conversion is required. This need can be met with protocol gateways that support many different protocols such as Moxa, Modbus, Profibus, Profinet, EtherNet / IP.

In addition, in the end computing applications, the OPC UA supported software package offered by Moxa, or the ioLogik 2000 series smart I / O modules with data collection, storage and transfer to the cloud on demand can be used as solutions.

Content caching or content delivery network in edge computing is a way to reduce the data transfer process on the network and optimize response time by caching popular content locally [19]. This practice has been well studied, mature and has benefited many applications [20,21]. Therefore, cloud computing has been used to distribute the content delivery network [22]. With sis computing, content caching depends on the user's location and the importance of the content [23].

Another proposed solution is LPWAN (Low Power Wide Area Network), providing resources for trained devices and networks at long range. xamples of LPWAN based applications: SigFox and LoRa. Covering a large area, this network provides low power usage.

Another solution proposition is cellular networks for long distance communication in IoT applications. For example, B-IoT and LTE-M applications use cellular networks that can be defined as LPWAN technology in low-power and low-cost IoT communication.

Another solution proposal is the IEEE 802.15.4 standard. The MAC layer structure is not suitable for IoT low power and multi-hub communication. Therefore, the IEEE 802.15.4 standard can be used for low-power, low-speed wireless embedded radio communication at the media access layer.

Finally, another solution proposal is the IEEE 802.11 standard, representing the protocols established over WLAN in the local network. Its high power usage and data transfer rate is an important alternative for delay sensitive fog applications.

V. CONCLUSIONS

This article, the requirements of cloud-based edge computing and fog computing paradigms are determined, and hardware and software solutions are proposed to combine data obtained from different sources into meaningful and valuable information, to process this information, to provide powerful computing for augmented virtual reality applications and IoT applications. Speed and Delays, Security, Data Integrity, and Energy efficiency have become prominent requirements in all three computing. It also proposes to use a mixed model where cloud and fog computing resources are used together for applications that are dispersed in the field, processing large volumes of data and requiring fast response.

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