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RESEARCH ARTICLE

AN EXAMINATION OF FOG COMPUTING AND ITS APPLICATIONS IN MODERN TECHNOLOGIES

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ABSTRACT

Network components between devices and the cloud carry out application-specific functionality in a fog computing architectural style. Healthcare is currently undergoing some of its most fundamental transformations. Wireless sensor technology is one of the forces behind these changes. In addition to providing access to a greater variety of biometric characteristics, sensors are growing smaller so they may be worn without interfering with daily activities. Fog computing's topology, or the geographically dispersed nodes that carry out computation and provide storage and network services, is its defining feature. Access points, routers, and network gateways can incorporate fog computing resources in addition to the standard network features. Instead of transferring IoT data to the cloud, the fog processes and stores it locally at IoT devices. The fog offersservices that are more responsive and of higher quality than the cloud. Fog computing may thus be the greatest option for enabling the IoT to offer effective and secure services to a large number of IoT users. By emphasizing the advantages and implementation difficulties, this article demonstrates the state-of-the-art of fog computing and its integration with the IoT. Right now, healthcare is undergoing some of the most significant transformations ever. Wireless sensor technologies are one of the main reasons for these changes. Many of the objects we use on a daily basis may soon be able to connect to the Internet and communicate with one another without the need for human intervention, thanks to the Internet of Things. This review paper examines fog computing and its applications in Healthcare, Cloud Computing and Internet of Things.

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INTRODUCTION

The phrase "fog computing" was first used by the industry as a metaphor for the basic architectural concept underlying it: fog is a region that lies between the ground, where the users' devices are situated, and the cloud (data centers). Edge computing, which contrasts with the cloud and describes jobs that are located at the edge of the network, is a word that is frequently used synonymously. Keep in mind that the term "edge" can be used to describe many architectural layers. In an industrial environment, the term "edge" frequently refers to nodes in a manufacturing facility that are located on site with the user, such as as a network gateway or a machine controller. The edge, as defined by ETSI nomenclature, is the outermost point of an operator's network, such as an LTE base station, as seen from the perspective of internet service providers. Fog computing's topology, or the geographically dispersed nodes that carry out computation and provide storage and network services, is its defining feature. Access points, routers, and network gateways can incorporate fog computing resources in addition to the standard network features. Dedicated fog computing nodes may also exist, similar to the mobile edge computing (MEC) servers found in LTE base stations and access points as described by ETSI. Other gadgets, such as home automation hubs, can be used as dedicated gateways installed at home. Fog computing may accomplish a variety of functions, depending on the application and domain. Filtering, aggregating, analyzing, and momentarily storing data are typically included in jobs. A single fog computing node or a group of nodes working together can do fog computing. When more processing power is required, this can increase scalability, offer redundancy, and give flexibility by adding more fog nodes. Since programmes may be run using techniques like virtualization and sandboxing, fog computing shares many concepts with cloud computing. The idea of compute offloading, which has been studied in research, for example, by cloudlets, and may also be found in what is referred to as mobile cloud, is central to fog computing. Similar to this, crowd computing emphasizes the use of the dispersed processing power offered by, for example, mobile devices. Fog computing minimizes the amount of data transferred to the cloud, which lowers bandwidth use and associated expenses. Because the initial data processing takes place close to the data, there is less latency and the system is more responsive as a whole. The intention is to offer millisecond-level responsiveness, allowing for the processing of data in close to real time. The network might be seen as a component of the fog computing architecture even though it often provides computational resources at the LAN level as opposed to the device level, as is the case with edge computing. However, fog computing is network agnostic in that it can function with wired, wireless, or even 5G networks. Fog computing negates some of the "anytime/anywhere" advantages of cloud computingsince it is anchored to a specific area. Fog computing may be vulnerable to security problems like man-in-the-middle (MitM) attacks or spoofing of Internet Protocol (IP) addresses under the correct conditions. Fog computing is a system that makes use of both edge and cloud resources, therefore there are hardware expenditures involved. Even though fog computing has been around for a while, there is still considerable confusion surrounding its definition due to the fact that different manufacturers define it differently.

Internet of Things: One of the inventions receiving attention and with the potential to provide our society countless advantages is the Internet of Things (IoT). The Internet of Things is about to reach a point where many of the things we interact with on a daily basis will be able to connect to the Internet and communicate with one another without the need for human interaction. The initial goal of the Internet of Things (IoT) was to automate the storage and processing of data by using different types of sensors to gather data from the environment and decrease the need for human data entry. The IoT has various problems, including performance, security, privacy, and dependability because it has limited calculations in terms of processing power and storage. The Cloud of Things (CoT), which combines IoT with cloud technology, is the ideal solution for solving the majority of these problems. The CoT offers rapid, affordable installation and integration for sophisticated data processing and deployment, and it streamlines the flow of IoT data collection and processing.

Numerous benefits for various IoT applications are brought about by the convergence of IoT with cloud computing. However, because there are so many IoT devices with diverse platforms, it might be challenging to create new IoT applications. This is because IoT apps employ sensors and other IoT devices to create enormous volumes of data. After that, this enormous data is analyzed to make choices regarding different activities. All ofthis data demands a lot of network capacity to send to the cloud. Fog computing is used to address these problems. IoT users may use services like data processing and storage through fog computing. Fog computing is centered on giving fog devices access to data processing and storage on-site rather than transferring it to the cloud. Fog and the cloud both offer networking, computation, and storage resources. Fog computing is used in the Internet of Things (IoT) to increase performance, efficiency, and to transport less data to the cloud for processing, analysis, and storage. In order to reduce network traffic and delay, the data gathered by sensors will instead be routed to network edge devices for processing and temporary storage.Fog as a service (FaaS), where a service provider deploys an array of fog nodes throughout its geographic footprint and serves as a landlord to many tenants from different vertical industries, is a new possibility for services created by the merging of fog computing with the IoT. Local networking, compute, and storage resources are available on each fog node. FaaS will make it possible for new business models to provide services to clients. Contrary to clouds, which are typically run by large businesses with the financial resources to construct and maintain sizable data centers, FaaS will allow both large and small businesses to deploy and run private or public computing, storage, and control services at various scales to satisfy the needs of a variety of customers. This is because IoT apps employ sensors and other IoT devices to create enormous volumes of data. After that, this enormous data is analyzed to make choices regarding different activities. All of this data demands a lot of network capacity to send to the cloud. Fog computing is used to address these problems.

There are several advantages of cloud-to-things (CoT) integration. For instance, it facilitates the management of IoT resources and offers IoT services that are more economical and effective. Additionally, it delivers rapid, affordable installation and integration for sophisticated data processing and deployment while also streamlining the flow of IoT data and processing. The CoT paradigm is not simple; it also poses new difficulties for the IoT system that cannot be solved by the conventional centralized cloud computing architecture, including latency, capacity limitations, resource-constrained devices, network failure with sporadic connectivity, and improved security. For IoT applications, the conventional centralized cloud computing architecture faces significant difficulties. For instance, it is unable to handle Internet of Things time-sensitive applications like gaming, augmented reality, and video streaming. Additionally, because it is a centralized paradigm, it lacks location awareness. These problems can be solved using fog computing. IoT gadgets and expansive cloud computing and storage services are connected via fog computing. A component of the cloud computing paradigm called fog computing brings the cloud closer to the network's edge. Between end devices and traditional cloud servers, it offers a highly virtualized model of processing, storage, and networking resources. Most of the data generated by these IoT items and devices must be processed and analyzed in real-time in order to boost the efficiency of IoT applications. Fog computing will bring cloud networking, computation, and storage capabilities to the network's edge, addressing the issue of IoT devices operating in real-time and enabling efficient and secure IoT applications. Fog computing offers a variety of applications and services with widely dispersed installations. Through the proxy and access points positioned in accordance with lengthy highways and tracks, the fog has the capacity to deliver effective real-time communication between various IoT applications, such as linked automobiles. For applications that need minimal latency, including streaming video, gaming, augmented reality, etc., fog computing is seen to be the ideal option. Numerous IoT applications will benefit greatly from the use of fog computing. In particular for time-sensitive IoT applications, the fog facilitates real-time interactions between IoT devices to minimize latency. Fog computing also has the capacity to handle large-scale sensor networks, which is a major issue with the IoT's exponentially increasing number of devices, which will eventually number in the billions.

Health Care: Some of the most fundamental changes in the history of healthcare are presently taking place. One of the driving causes behind these shifts is wireless sensor technologies. Sensors are getting smaller so they may be worn without interfering with daily activities and are giving access to a wider range of biometric traits. Sensors must be wireless and wearable in order to monitor patients at this level. This limits their size and has an impact on the amount of energy, memory, and computing power they can provide. Additionally, data must be combined from several sensors and is only useful in context. In order to analyze, aggregate, and store the data, sensors communicate it to other, more advanced computing equipment. The only way sensory input is valuable is if we can learn something from it. Other healthcare-related factors like big data and machine learning, whose accuracy may eventually surpass that of people, offer these insights. Big data analysis may be used to research the efficacy of medicines, identify patients at risk for chronic diseases, ensure that patients comply with treatment programmes, optimize procedures, and personalize care in addition to automatically or manually analyzing medical pictures. Border routers, which connect wireless nodes with limited resource availability to current network infrastructures, enable connectivity. As a result, a device-to-cloud architecture is made possible in which the infrastructure separating the device from the cloud is just utilized as a communication pathway. The sensors are liberated from battery-draining computational activities thanks to cloud computing, which also offers almost limitless resources. The cloud is one potential location where data from many sensors may be combined, providing the large-scale data sets necessary for the aforementioned analytical activities. Such a basic sensor-to-cloud architecture, however, is not workable for many applications in health informatics. Regulations may not always permit the storage of patient data outside of the hospital. Patient safety concerns in the event of network and data center outages make it undesirable for some applications to completely rely on remote data centers. Fog computing is one potential approach to bridging the sensors and analytics gap in health informatics. This is a type of distributed system architecture where the application-specific logic is spread throughout the infrastructure between the devices nearest to the customers or the data centers (the cloud). The likes of gateways, routers, and access points are examples of such infrastructure elements. This increased computing flexibility creates new opportunities for resolving healthcare-related problems.

Due to an aging population and a growth in chronic illnesses, healthcare systems in the majority of nations confront significant problems that will only become worse. There is an increasing scarcity of nursing professionals in several nations. At the same time, there is a need to save expenses without compromising patient care quality. As a result, the healthcare sector advocates for a healthcare delivery strategy that emphasizes information. A component of this delivery paradigm permits remote patient monitoring, which improves patient accessibility, quality, efficiency, and continuity of treatment while also lowering healthcare costs. Today, hospitals waste a lot of time manually collecting biometric data and moving it across systems, frequently using a pen and paper. Caretakers' time will be freed up through remote monitoring. Automated monitoring, which can take the place of manual supervision, is another development. The enhancement of healthcare procedures is another aspect. Many operations are manually scheduled, which results in their being completed in a sequential manner rather than making better use of resources. Additionally, sensors will make it easier to obtain accurate information about the location and current state of the equipment, carers, and patients. Sensors will also give a more accurate image of the patient since they can continually record data and give an understanding of a wider range of biometric markers. This will transform medical diagnosis and therapy. An effective way to connect sensors is to use WPAN technology. Although they often have a smaller range than Wi-Fi or cellular connections, they also use less energy. WPANtechnologies can have certain drawbacks, though. They don't provide the requisite bitrates for biological signals like EEG or ECG for various applications, especially if patients are wearing many sensors. Furthermore, the body can impede electromagnetic signal emissions in particular positions. As a result, the link's quality either declines or it becomes impossible to communicate with in-body gadgets. A unique standard for wireless body area networks (WBAN) was created with IEEE to address the issues with WPANs. One hub serves as the single gateway to other networks using a one- or two-hop star architecture. Additionally, IEEE offers three distinct physical layers that may be used for various purposes. Compared to certain WPAN technologies, the narrow band physical layer offers a somewhat greater communication range at significantly lower data speeds. The 402-405 MHz medical device radio communications band (MICS) and the 2.4-2.45 GHz industrial, scientific, and medical band (ISM) are two existing frequency bands that are used by the narrow band. Higher data speeds and lower transmission power are provided by the ultra wide band physical layer than by narrow band. It is also possible to construct this layer to use less energy per bit than the narrow band.

Galvanic coupling on the surface of the human body is used by the human body communication layer to transmit data. Antenna issues and issues with signal propagation are eliminated. It is also regarded as the physical layer with the most energy efficiency for high-data-rate needs. In the situation of mobile deployment, cellular networks on mobile devices serve as WPAN gateways that link directly to the WAN. As intermediary nodes, WBAN gateways such as smart watches can be employed. The WPAN level connects off-path nodes, such as equipment used for environmental sensing.The nodes are positioned at the LAN level, similar to fall detection equipment. In the deployment situation for hospitals, nearby data centers are frequently accessible. Other off-path computation nodes, such as localization devices and stationary equipment in labs or operating rooms, exist on both the LAN and PAN levels. Patients use specialized gateways linking WBAN or WPAN to the LAN through proprietary gadgets they wear. We frequently find tiny local servers in non-hospital deployment scenarios, such as doctor's offices or nursing homes. As off-path compute nodes, lab equipment or environmental sensing devices are used. The same non-intrusive sensing equipment that was mentioned in the home scenario is worn by patients. Similar proprietary sensing equipment is worn by a patient in the hospital scenario as well as the transport deployment scenario. This links to a WPAN network gateway that serves as a bridge to the car's WLAN router. While traveling, theWLAN router uses a cellular network to connect to the WAN. On a LAN level, medical equipment and wired monitoring devices are connected. Many methods assign the calculation work to a single node at the PAN or LAN level. Data is processed at this level before being sent to the cloud and higher tiers. There are several different duties. A common use case is the gathering and analysis of time-sensitive data for the purpose of critical monitoring, such as fall detection. Another illustration is, which shows a sensing platform where a worker node in the fog is receiving compute instructions from a global task scheduler in the cloud. This tells the worker node to only gather and filter the most crucial and pertinent information.

Cloud Computing: No previous computer paradigm that came before got the attention that cloud computing enjoys from consumers and service providers as the most promising computing paradigm. Through the use of the cloud, computing resources including hardware, platforms for application development, and software are made available as online services. When opposed to the conventional paradigm of buying, owning, and operating your own computing devices, cloud computing offers customers a number of benefits. The economic benefits and the removal of computer system administration activities and related costs are the key advantages of cloud computing over traditional computing paradigms. Users can access cloud services and pay on a utility costing basis for just the services they use. Users of cloud computing have various benefits over those of conventional buy, own, and manage your own computing systems.

The economic benefits and the absence of administration responsibilities for computer systems and related expenses make cloud computing superior to the traditional computing paradigm. Users can access cloud services and pay only for the services they use according to a utility costing model. Customers utilize services like electricity, water, gas, and telephone regardless of the kind and location of service generation, and they only pay for the services they actually use. Similar to this, the cost of cloud computing services is determined by the amount of time consumed rather than how many resources were used. Clients can solely focus on their core business operations because all computing gear and software is housed in a faraway data center run and managed by a service provider. Even clients working in industries connected to computers, such as software development, need not worry about buying their own gear and software, like development platforms or project management tools, or managing them internally. Even while cloud computing provides so many benefits, it also has certain drawbacks. These drawbacks include the need for a client access link with a large capacity (bandwidth), high latency, and security. The burgeoning Internet of Things paradigm, which envisions connecting every device to the internet, and particular computing demands like sensor networks are both severely impacted by these limits. Researchers have developed a new type of cloud computing model to get over the drawbacks of cloud computing and fulfill the needs of new computing models and paradigms. Instead of being far away at an unidentified place in the midst of the Internet cloud, the devices that respond to and process client requests are housed either at the edge of the local network or quite near to it in this new paradigm. The term "Fog Computing" has been used to describe this type of cloud computing approach. Regardless of usage, the hardware resources rented from data centers had a set capacity identical to the gear installed at home. The disadvantage of this type of arrangement is that most of the time the hardware that has been bought or leased sits idle because of underuse, losing valuable financial capital that might be used to fund other resources or the main company functions. Undersized hardware would function poorly at times of heavy demand, leaving unhappy consumers who would eventually have an adverse effect on long-term profitability and business. Therefore, the profitability of corporate operations is impacted by both overcapacity and under capacity. The cost of renting hardware from a cloud service provider, however, is dependent on utilization and does not need an upfront payment. As a result, the consumer almost always sees a 100% return on his money. Cloud computing effectively converts capital expenditures (Cap Ex) into operating expenditures (Op Ex) because there is no initial investment in computer resources and just use fees need to be paid. This frees up the limited financial capital to be invested in core business. A virtualized platform called fog computing is often situated between end user devices and cloud data centers with Internet-hosted servers. As a result, fog computing can offer superior service quality in terms of latency, energy use, reduced data flow over the Internet, etc. The ability of fog computing to enable applications that need low latency, location awareness, and mobility is its key characteristic. The fact that the fog computingdevices are extensively spread and installed near to the end users enables this capability. Thus hosted fog computing nodes must have enough processing speed and storage space to meet resource-intensive user requests. Cloudlets and edge computing are two more comparable ideas where it has been suggested that the computing resources be positioned closer to the customers to get around the limits of cloud computing. Cloudlets are virtualized computers with plenty of resources that are near to mobile consumers so they can react to their requests quickly while still having good Internet access. Cloudlets are particularly made to offer services to mobile users, who can utilize them as thin clients to access cloudlet resources located just one hop away from their location but with restricted local resources. claim that owing to their additional needs, such as smaller size, less weight, and longer battery life, mobile devices would always be resource-poor in comparison to stationary systems such as desktop, laptop, and servers. However, new applications and paradigms like augmented reality, speech recognition, natural language processing, and interactive media demand a lot of resources in order to analyze data quickly. The only option is to place the high capacity resources as near as possible to the end user. Therefore, cloudlet is situated appropriately to meet these kinds of needs and expectations. In reality, all of these highly virtualized, potent computing models—implemented closer to the end users to meet the demands of emerging computing and networking scenarios—have the same or very similar characteristics, despite the fact that different researchers have coined different terms to describe them. As a result, they can all be seen as being the same. Every device connected to the Internet under the Internet of Things is expected to have an IP address. A key component of the envisioned IoT is vehicular networks, a particular kind of future mobile networks. For the aim of conveying crucial information between these items, communication would occur between cars, vehicles and access points, and between access points in vehicular networks.

Location awareness, wireless connectivity, increased processing demands, reduced latency, real-time interactions, and mobility are some of the crucial characteristics of this communication. In order to fulfill these criteria, there has to be a significant number of processing nodes that are situated close to the clients (vehicles) and are capable of communicating with the clients through wireless networks with little latency. Therefore, compared to cloud computing, where information processing occurs deep within the Internet, fog computing is the most appropriate communication architecture. Large data transmission rates with little latency, delay jitter, and packet loss are required for the new high quality multimedia applications, such as distributed interactive games, video on demand, and streaming. Processing these apps closer to the end users is important to accomplish this. It is challenging to control these elements since cloud data centers are often situated within the Internet. Fog computing is therefore a suitable alternative for these kinds of applications that require high performance. Wireless sensor networks have been widely used in several applications connected to theenvironment. Low power, low bandwidth, and limited processing capability nodes dispersed across large geographic areas are the typical characteristics of these networks. Low latency, location-aware, widely dispersed systems must support these networks in order to analyze and disseminate the data. Instead of cloud computing, these are common traits of fog computing. For many Internet applications, the two most crucial requirements are data security and integrity. Even though the data is encrypted, the longer it remains in transit, the more exposed it is to assaults. Therefore, having minimal hops between clients and servers is always preferable. The smallest distance is feasible while still offering all the other benefits of cloud computing thanks to fog computing. Fog computing outperforms standard cloud computing in such circumstances. Even the accessibility of cloud systems that are connected to the Internet is susceptible toattacks by criminals utilizing different Denial of Service (DoS) attack techniques. It's notnecessary for DoS assaults to target end systems directly; attacks directed at intermediate hardware, such as routers, can be just as deadly. As a result, hackers have several options to exploit cloud computing platforms. On the other hand, because fog computing nodes are widely dispersed close to the user networks' edges, a major assault must be launched against every system in the area of a client in order to target their availability. The attackers' side also needs a lot of resources for this. Given that computer nodes are placed close to end users, there aren't many intermediary devices that an attacker may target. So it is reasonable to say that fog computing systems are less vulnerable to denial-of-service assaults than cloud computing systems. The single nodes cannot have a lot of resources since fog computing needs a huge geographically spread implementation and for budgetary reasons. High-end business computing tasks, including batch processing activities, might call for a lot of resources even when they weren't very delay-sensitive. More so than fog nodes, standard cloud computing platforms are more effective at handling this type of work. Fog computing cannot thus take the role of cloud computing as the only cloud computing model going forward. Therefore, it is safe to assume that cloud and fog would coexist, serving two distinct populations, and would complement one another as needed.

CONCLUSION

It is necessary for sensor devices to offload computational duties since they frequently lack the power to do such computations on their own. On the other hand, due to limitations regarding reliability, privacy issues, or legislation, cloud computing is frequently not a good option for such offloading. Fog computing consequently seems tobe a good idea to address the needs of the healthcare industry given its flexibility to add processing as a part of a network infrastructure. Data can be filtered by fog computing operations to assist protect privacy or lighten the burden on the network. The location of execution can be changed to meet various needs, rules, and the current deployment circumstances. Tasks related to fog computing can serve as interoperability components by modifying particular sensor requirements to standardized and harmonized interfaces. Fog computing jobs contribute a crucial element to make systems more reliable because of their capacityto react quickly to users. However, in order for these advantages to materialize, attention must be shifted away from specific use cases and towards more all-encompassing designs, as was covered above. In the case of Cloud Computing, As can be shown from the study above, fog computingoutperforms cloud computing in meeting the needs of new paradigms. Fog computing, however, cannot completely replace cloud computing since it will continue to be chosen for high-end batch processing tasks that are widely used in the commercial sector. Thus, it can be argued that cloud computing and fog computing will complement one another while having unique benefits and drawbacks of their own. While cloud computing would assist the corporate community by satisfying their high end computing demands while decreasing the cost based on a utility pricing model, fog computing would continue to expand in aiding the evolving network paradigms that require quicker processing with less latency and delay jitter.

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