Fog Computing: An Extension of Cloud Computing

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Abstract
Recently, cloud computing has become one of the broadest wide-spread computing paradigms, which consists of offering virtualized computing resources over the Internet on demand. There are many benefits, which include a lowered cost of operations, greater flexibility, and independence from location. On the contrary, cloud computing does have some challenges especially in terms of providing non-deterministic network latencies, security issues, and the inappropriateness of location-agnostic computation for IoT and sensor network applications. Because of these problems, fog computing arose, which is a balancing model that brings the cloud closer to the please furthermore the sources of data into the network's edge.
The approach of fog computing centers around the deployment of active and large scale fog architectures that assist in diverse applications with time-sensitive and resource-restricted options. Fog computing is a perfect middle ground between IoT and cloud computing providing applications and services that require low latency with context awareness. With the paradigm shift between the two methods of computing, fog computing with its features and performance is going to be the core of the future computing generation.

Keywords: Cloud Computing, Fog Computing, IoT and sensor network applications, security issues.

INTRODUCTION

Modern economies are progressively influenced by new technologies like cloud computing that carries the capability to alter the manner organizations process, store and retrieve large quantities of information. Users of cloud computing services are able to utilize numerous IT resources on an as-needed basis which is benefiting the customers in terms of cost, time and scope. It is a revolution that is enabling multi-national corporations as well as medium and small sized enterprises to have a better grasp of their capital and operating expenditures. Of note however is the fact that larger corporations have embraced cloud computing and its associated benefits but there are certain drawbacks like latency and security and scalability as well as poor support of time-sensitive IoT devices. These gaps have created opportunities for others solutions which was fog computing. Fog computing is able to mitigate the distance problem as it brings cloud computing resources closer to the edge or network source. Fog computing addresses location and real-time processing that clouds are unable to provide and act as a link between IoT devices and the cloud. This article discusses fog computing, the latest technology, and its role in improving people's demands for the cloud regarding timing and other parameters.

I. DISTRIBUTED TECHNOLOGIES: BACKBONE OF FOG COMPUTING

Fog computing is not the solo technology but an extended version of various existing technologies, Fog on its own can't be everlasting, for its smooth functioning, collaboration and convergence with existing computing paradigms are important. Here we define the participating computing technologies which lead to the emergence of Fog [3], [4].

- **Distributed Computing:** The collection and collaboration of much autonomous computing clustering define the distributed, each having its own private memory and other resources necessary for communicating through inter-networks. Here the solution to the particular task is being done in a distributive manner, where the different parts of a particular problem are being conducted by different individuals in a collaborative manner [1], [4].
- **Cloud Computing:** Cloud computing is a distributed platform and primarily based on already existing computing paradigms i.e. Centralized, Parallel, Grid and Distributed Cloud computing. It inherits characteristics from the pre-existing computing models. The services and applications are accessible to the different clients using proper internet protocol suite and networking standards. Its key characters, different service and deployment models makes it quite unique and offer various features like cloud agility, improved costs, scalable infrastructure with flexibility and resources and services are being
- **Web of Internet of Things:** Web of the Internet of Things where every entity is connected with smart gadgets, communication is taking place in a sophisticated manner. RFID plays the crucial role in it, the tagged entities generate the data in Fog environment, the Fog nodes, and various network routers direct the workloads to the particular node in the edge network. The connected devices can communicate in three ways, the human-to-human, machine-to-machine and machine-to-human, from smart households, cities, healthcare systems, traffic, different sensors and actuators are embedded in or attached to the objects, by this whole forms a web of the internet of things. In Ubiquitous IoT environment things get connected within fraction nanoseconds, the proliferation of human as well as machine interventions increases rapidly. The number objects participate in IoT, the more is data generation and need more storage space to store it. In order to meet the required demands, the integration of Internet of things along with cloud computing form a platform
- **Edge Computing:** It optimizes the cloud computing by bring the applications, data and various cloud services away from cloud's core network to the extreme of edge network which where all the physical gadgets like handheld devices, sensors, actuators, routers, switches are in contact with the live network, the data generated by these devices, the data analytics is performed on it over the edge network itself rather sending to core cloud network. Edge computing brings intelligence and processing directly to devices like programmable controllers, enabling faster, real-time responses by reducing reliance on distant data centers. (PACs) [6],[7]

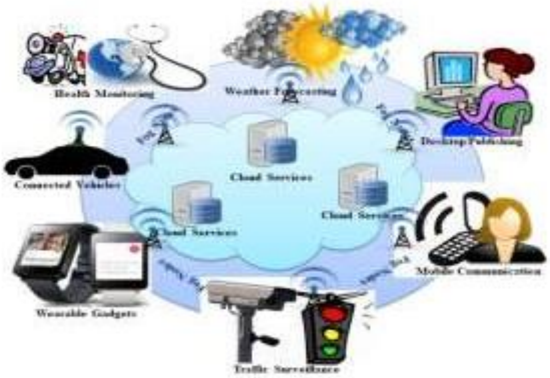

Figure 1 Cloud of Things [7].

Figure 2 Big Data

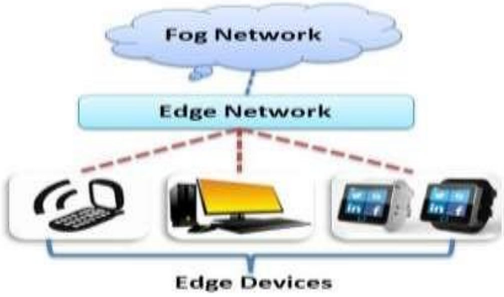

Figure 3 Edge Devices [6-7]

- **Big Data:** Big data (4V's) are the large data sets, being stored in cloud data centres, data analysis leads to results of information, the data generation of various organizations like money transactions, social media, digital marketing, giant e-commerce sites continuously generate data both in the form structured or unstructured. While it is becoming a heck of a problem for companies to handle the vital data in traditional processing techniques like RDBMS and other data analytical tools, big data analysis carried out its data operations by using high-quality software concurrently running on servers in a cloud platform [4],[22].

FOG COMPUTING

Fog computing offers the functionalities that of cloud, like data storage space, networks, compute processing power but with greater extent and proximity as Fog nodes reside near to the edge devices of the end users and leverage the resources and decrease the latency. It extends the cloud capabilities, processing computational power to the edge of the network of an edge device [4], [6], [9].

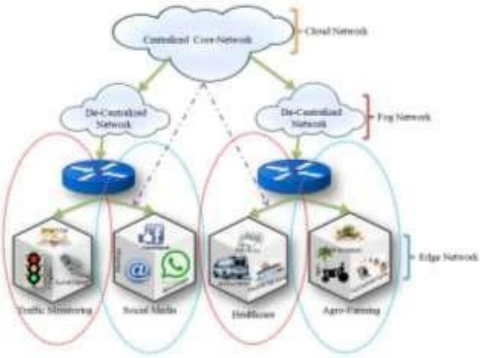

Figure 4 Fog Computing Layered Architecture[4]

Fog Computing Characteristics

Fog computing is offering the various services like computational power, data storage, networking among the edge devices and cloud-centric entities participating in collaborative fashion. Although Fog is not a solo technology, has to depend on the cloud for full functionalities and smoothly running of the services and applications in IoT environment. The services are taken from core cloud computing to the edge network for better execution. Some of the characteristics of the Fog computing That define its feature to be the next biggest evolution in Information technology [8], [9], [11], [20].

- Geographical Distribution, compared to the cloud, a centralized platform, for offers the services geographically wide dispersed for distributed deployment models. Fog is playing a vital role in delivering the highly enhanced high quality to the Fog connected Vehicles through Fog nodes and smart gateways. The sensors/actuators monitoring the distributed computing systems and various data storage resources like microdata centres, cloudlets [12].
- Large Fog nodes, spatially network, make it possible for edge devices to communicate in coordination.

Mobility support, it is one of advanced feature of Fog that differentiates it from cloud computing, it is important for many Fog applications to communicate directly with an edge in real-time scenarios. It provides the location awareness as well, to locate the communicated edge, with mobility, it provides essence to the entities to follow proper pursuit to accomplish the various tasks in IoT environment.

Real-time interactions, the processing mechanism in Fog domain is not like to that of batch processing rather it is real-time interaction, the process of communication between the edge and Fog node is taking place in real-time as it bypasses avoids cloud interference in communication.

- Supports heterogeneity, Interoperability, since in IoT environment, different sensors, network routers of different manufacturer company did not have to face the interoperability heterogenic issues, the edge devices and Fog nodes interact with one another without hardware compliance issues as well.
- Fog proximity plays a significant part in the data processing as it is close to the source Lightweight applications that required low and predictable latencies and response time in the IoT environment.

Energy efficiency, being dispersed geographically, various Fog nodes on concentration generate less heat as compared to cloud data centers, cloud servers, and will be an important tool for optimal energy management policies

II. FOG COMPUTING: A PLATFORM FOR IOT

ENABLED PARADIGM

Some Fog scenarios where it is crystal clear that its involvement enriches the user experience to adopt them. Fog plays a vital role in their smooth functioning. Some of the scenarios here to mention are important like Connected Vehicle, Smart Grid, and Wireless Sensor and Actuator Networks [18]. various networking i.e. Wi-Fi Hotspots, 4G, RSUs, traffic light system, the connectivity is being maintained throughout the interactions. With Fog provides the Space Construction Vehicle (SCV) an ideal platform for entertainment, safety and traffic management system and data analytics on the go. Mobility support and location awareness, with enhanced reduced latencies, is what need for the real- time interactions in IoT. The nodes connect in smart traffic lights communicate locally, it will be continuously updating traffic situations by sending the signal to the nearest network towers. The smart connected systems, will are excellent to detect any unfavourable situation like accidents and may act in advance and will avoid, it will provide safety to both pedestrians and drivers. Since the smarts devices connected with smart vehicles can’t store the data for long and has to send to the core cloud network for long-term data analysis [6], [7], [12], [13].

Figure 5 Connected Vehicles [12]

- **Smart Cities**: a rapid proliferation in population, changes in lifestyle standards, and shift from rural to urban leads to urbanization. Most of the population of every nation is making continuously moves to cities, as these are equipped with the availability of modern technology in sectors like education, health, commerce than the rural areas. Urban population is using various electronic gadgets embedded with RFID sensors, actuators, and are being used efficiently to manage the various available resources. Each and every intellectual are connected with each other through the network, continuously generate and manage the data traffic (power, transportation, water, recycle management) [7], [8], [13].
- **Connected Vehicle (CV):**The connected vehicles like fully loaded GPS enabled cars with interactive cabin system, where interaction among the various participants in IoT platform make it a rich experience among the RFID tagged entities like a driver, a car and network connection. The data generated by these entities is huge and need real-time operations. The
- **Smart Grid:** the smart grid is another use-case and making way for the green computing and removing the ageing effect of the old infrastructure when electricity was limited to customer utility. As more machines interact continuously, smart grids will help the electricity demands which would work in cooperation with the cloud, it will be going to benefit the society unprecedently and will provide the various opportunities and offer them the reliable and efficient means of energy, and its availability will benefit both the commerce as well as health systems. Some of its advantages here is important to mention

- Efficient data transmission, better energy utilization
- Flawless data services between the utility and clients.
- Fewer energy disturbances and better restoration methods.
- Improved cost operations, clients will be offered utility services at feasible and affordable prices
- On-demand as per requirement will lower the energy costs
- Scalable integration of renewable energy resources.
- Secured and improved security protocols.

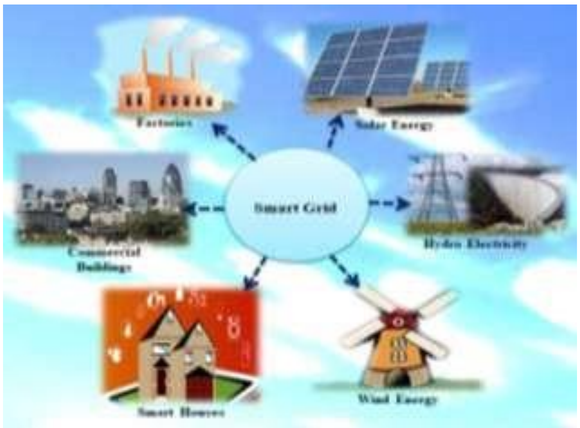

Figure 6 Smart Grid [7].

- **Wireless Sensors and Actuators Networks:** The Motes (WSNs) are delicately designed to be the energy efficiency and extend the battery consumption while in data transmission from edge devices to Fog micro-data centres. These sensors and actuators light weighted and are embedded with low memory, energy, bandwidth, computational power. The Motes are embedded with a de-facto operating system known as TinySO2. These are mostly used to collect the data like weather updates, humidity, Loo, wave intensity, measuring the rainfall, drought and floods warnings[7], [13].

Healthcare Systems: Fog computing plays a vital role in bringing the changes in the healthcare system, it provides the dynamic architecture by reducing the latencies, and offers the mobility support to perform better operations in real time scenario. Since IoT-healthcare devices are producing enormous data at consistently, storage and security becomes matter of concern, cloud computing with Fog technology is proving to be the backbone for the smooth functioning of healthcare systems. Cloud computing, offers high storage and computational processing capabilities. Health wearable gadgets, like smart watches, monitoring sugar level, heartbeat rate and blood pressure level, for these real-time operation, cloud is not feasible because of latency issues, so Fog is the best platform to operate in real-time scenario [14]

III.COMPARISON OF FOG COMPUTING WITH CLOUD COMPUTING

As Fog has its root in cloud computing, so inherits all the features of cloud computing. While cloud computing being centralized distributed paradigm, Fog, in contrast, is a de- centralized paradigm, will offer reduced latencies, quick response time and location awareness of the devices in IoT enabled environment. Both technologies require functioning in coordination as many applications require the attention of both locally as well as globally especially for real-time data analysis. Fog computing is not becoming a universal platform for real-time interactions (machine-2-machine, human-2- human and human-2-machines), the sensors and actuators will act once any interaction is happening, data will be collecting and processed in real-time without further delays or latencies. The sensors at local accessible points of edge network generate the data continuously, the actuators filter the data which can be processed locally and rest of it is sent to the highest core network data storage for further filtration. The core network is the highest level of computing, the geographically wide dispersed large scalable resources. Cloud can be treated as a data repository for Fog where data can be stored for longevity and permanent basis. In below table shows some of the comparisons of the two growing paradigms. With flexibility and elasticity, Fog computing may be delivered as a single node or a large system, it will continue to enhance cloud user experience, bring the services near to end users and seamlessly bring combined Fog-cloud-IoT (Cloud of Things) framework to make the computing accessible from anywhere with better performance. The coordination among various Fog nodes smart gateways provides the platform for the real-time applications to function in Fog-Edge Network [7], [12], [15].

Fog computing is termed to be the future of cloud, but the fact is that Fog is having some serious issues like scheduling and is very difficult and cumbersome tasks than cloud, heterogenetic Fog nodes, owned and maintained by different organizations thus may be prone to the malicious attacks. Fog will be going to benefit the cloud of IoE, will be a much-anticipated platform for low latency applications, edge analysis, will reduce data delay jitter and will be cost efficient, moreover, Fog computing will address the most exciting features and enable to achieve the scalable, flexible, relievable, dynamic and efficient IoE systems.

Table 1: Comparison between Fog & Cloud Computing

Characteristics	Cloud Computing	Fog Computing
Latency	High	Low
Delay Jitter	High	Low
Location of Server Nodes	Within the core network	At Edge of Network
Distance between Client and Server	Multiple Hops	One Hop
Security	Undefined	Can be Defined
Attacks and Vulnerabilities	High Probability	Low Probability
Location Awareness	No	Yes
Geographical Distribution	Distributed Centralized	Distributed Decentralized
Number of Server Nodes	Few	Large
Mobility Support	Limited	Supported
Real-Time Interactions	Supported	Supported
Type of Connectivity	Leased Line/Wireless	Wireless

Intelligence: For better results, computational operations, decision making, Fog is pushing the intelligence closer to the edge device rather than the cloud computing.

IV. SHIFT IN CLOUD PARADIGM TO THE FOG- EDGE NETWORK

Cloud computing is a vast form of distributed computing and is being adopted everyone everywhere. However the proliferation in IoT enabled peripherals leads to some of the problems like network congestions and bottlenecks data accessing. It is a concern for various companies, organizations, institutions to shift from centralized to decentralized domain. Fog computing is not here to replace the cloud computing completely but to enhance and improve its various feature. Fog computing was developed to address applications and services that do not fit the paradigm of the cloud computing leads to the shift in technological domain. Fog is the solution to short comings of cloud computing [15], [16], [17]

- **Bottleneck & Network Congestion**: are the issues in centralized cloud computing that can be addressed properly in decentralized Fog-cloud computing, since processing, and intelligence of decision making needs to be closer to the source of data generation than the core cloud network, Reduction in data movement across the network resulting in reduced congestion.

- **Hops Count:** As the number of hops increase in cloud computing so are the high chances of data tempering. Security violations are so high in it, since the adaptation of Fog computing, security is less compromised than ever before, the data stay near to edge device of the end users leads to the minimal chances of security threats.
- Existing **Data Protection Mechanisms** in Cloud Computing such as encryption failed in securing the data from the attackers, In Fog Computing data is kept right on the queue where the Internet of Everything needs it, maintaining it security within the edge device
- **High Latencies**: in cloud is the biggest challenge for the time-sensitive applications. Fog computing reduces the short comings like latency, high bandwidth, security of cloud computing.

The **Quality of Service** parameter in cloud computing is an cumbersome task and is always neglected during the service level agreements among the various parties in cloud, Quality of Service is one among them, and is always compromised. But with Fog, which is an enabling technology for the real- time latency oriented applications, QoS might find its feet for betterment, with location awareness, mobility edge support, scalability, reliability and security features of Fog computing. Fog will be the suitable platform for mission critical, real-time bounded, live streaming content application to enhance and improve the QoS parameter [8], [14]

V. CONCLUSION

As a step to overcome the shortcomings of traditional cloud computing in working with real time and latency sensitive applications, fog computing has been embraced as a new forward-looking expansion of the cloud computing model, IoT or other modern areas. Fog computing is ideal for time critical applications like smart cities, autonomous vehicles, or healthcare systems, as it allows faster computing by moving processing and storage closer to the edge of the network – where the action is. However, while cloud computing is vital for many business and high throughput applications, the vast bulk of work in the future will be in the real-time processing of a distributed infrastructure – and fog computing provides such capability.

Fog computing is still in its infancy, yet many analysts are predicting that this technology is likely to become an important component of the next generation of distributed computing. Since both cloud and fog computing have different advantages, they are probably going to work together by their areas. It is likely that cloud computing will remain as the primary resource for intensive and cheap services, while fog computing will focus more on enabling new paradigms that need simultaneous fast and location specific interactions. In the future, these two paradigms have too much possibilities to approximately each other integrate the architecture of future networks promoting innovation.

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