EDGE COMPUTING AND ITS IMPACT ON IOT

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ABSTRACT: The number of smart devices connected to the internet is increasing manifold on a daily basis, which in turn generates Big Data. This data requires a robust and reliable cloud storage to save the data and protect it from unauthorized access. Further this data requires huge processing power to drive to any tangible and useful information from it. Many business processes are eyeing technologies to improve efficiency, performance and reduce cost of operation of the IoT devices. The leading ways now days is by using Edge Computing, i.e. processing data out of the main cloud or at its edge. The new technology has the potential to deal and wipe off the concerns of response time, bandwidth cost saving, duration of battery life and most significantly safety and privacy of vital data of the organisation.

Keywords: Bandwidth, Big Data, Cloud Computing, Edge Computing, IoT, Latency.

I. INTRODUCTION

Cloud computing is one of a very few technologies which altered the way we survive, learn and study to a gigantic extent [1]. Services such as Facebook, Twitter and Google which uses Software as a Service (SaaS), are being extensively used in our daily life. Internet of Things (IoT) was first tested in management industry for supply chain [2]. But sooner than later it was adapted in other fields as well, such as, healthcare, smart cities, smart parking, smart water system, transportation and many others [3][4]. IoT is most simple terms is "making a computer/chip/smart device sense information from its surroundings without any involvement of humans." With the introduction of Edge computing, Cloud processes has decreased to a greater extent. In 2019, more than 45% of the data generated by IoT smart devices was processed and analysed at the edge of the network [5].

In this research paper, we have tried to inculcate the definition and meaning of edge computing, which will be followed by its working and its paradigm. We have discussed some of the benefits of the technology. A few currently deployed use cases have been studied. In the last section, we put up several challenges and opportunities in the field of edge computing.

II. EDGE COMPUTING

Edge computing is the technology that enables computation to be performed right at the place where the data is produced, i.e. "at the edge" of the network. This helps computations to be performed near to the source where the data has been generated. It includes two streams, ie. Upstream and the downstream [6]. Upstream means that the data is travelling from the data source (IoT device) to the Cloud. This stream works on the behalf of the IoT services. Downstream means that the data is travelling from the cloud to the IoT devices. This stream works on behalf of the cloud services. Both these streams are equally important for the working of the Edge as well as cloud paradigm. "Edge" can be defined as any network resource with computing power in the path between the IoT device and the cloud [7]. Data is stored locally instead of the cloud.

For instance, user's smartphone acts as an edge between smart wearable devices like smart watches, fitness trackers and the cloud. A router/gateway installed in a smart home environment is the edge between the various devices like smart AC, smart lights and the cloud. A cloudlet [8] denotes an edge between a cell phone apparatus and the cloud. The basic difference between Edge Computing and Fog Computing is that, Fog Computing looks after the infrastructure of the network while Edge computing concentrates on the "Things". It is better to infer that in the coming future, Edge Computing can have a strong impact on the sustainable society as of Cloud Computing [9].

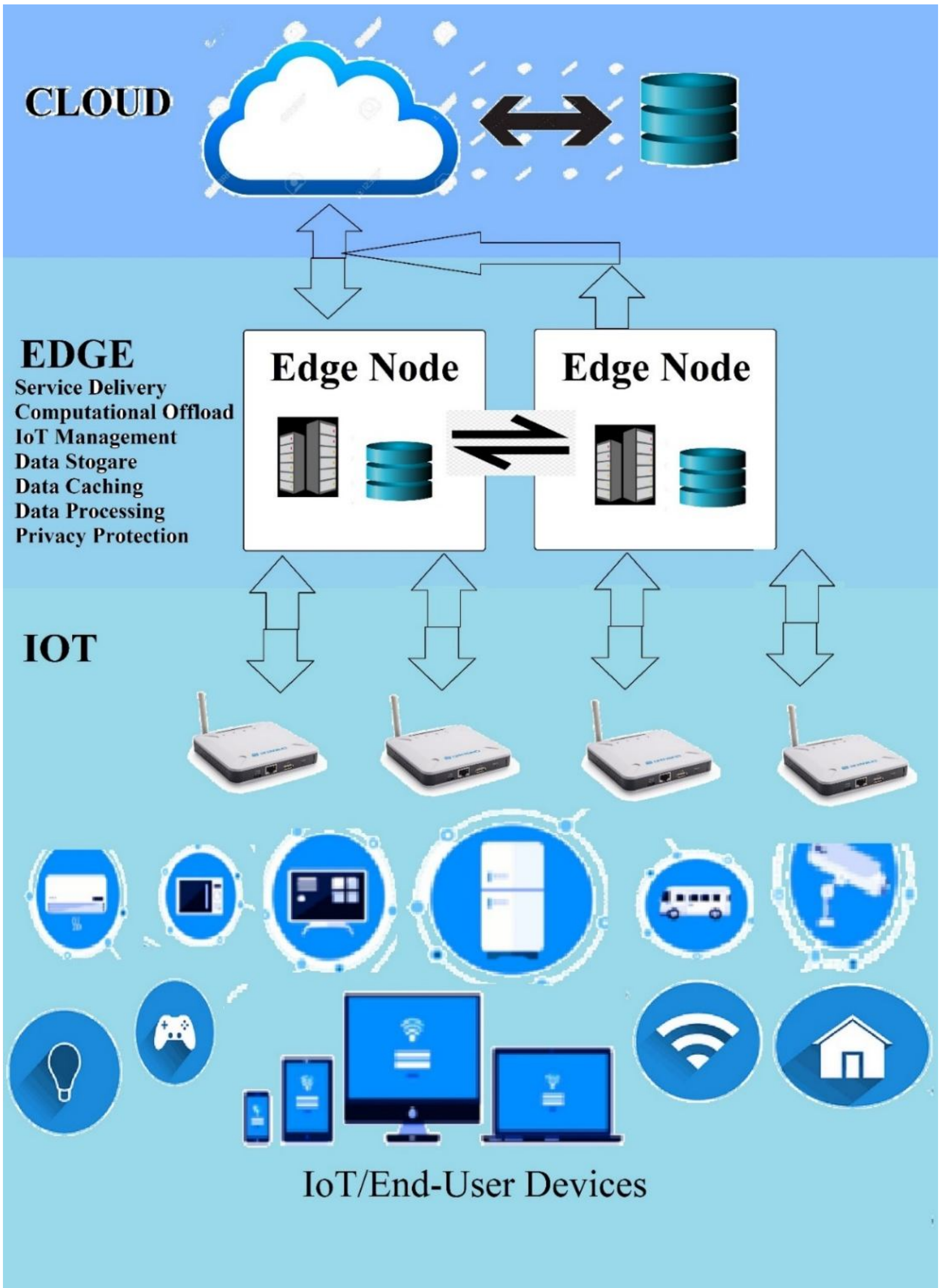

Figure 1: Edge computing paradigm

Figure 1 illustrates the Edge computing paradigm. The IoT/end user devices are the data producers as well as the data consumers. These include all the smart devices available like, smart phone, smart watches, smart cars, smart parking systems, smart lightings, smart speakers, smart homes, Smart TVs. Smart cameras and computer systems etc. The things, such as, gateways, routers, mini servers, micro data centres can act as the edge. They can request service and data from the cloud and at the same time perform the computing tasks. Edge performs service delivery, Computational Offload, IoT management, Data Storage, Data Caching, Data Processing. The Edge needs to be designed in such a way to meet the requirements in an efficient manner, with reliability, security and privacy protection in mind. The cloud is the all the databases, servers and the super computers which store the big data and perform the major computational tasks.

III. WORKING OF EDGE COMPUTING

Keeping the above explained paradigm in mind, now we will explain the how edge computing works in real life scenarios. Every IoT sensor produces big data on a daily basis. In cloud computing, the data generated by the IoT devices is transferred to the unified and centrally placed database present in the cloud in matter of seconds, where it is stored and processed. In case an action is required on the basis of the received data, the central server responds back to the device accordingly [10]. The process of send the data and receiving the response typically takes less than a second to finish, but there may be scenarios where the response from the cloud gets interrupted or delayed due to a some abnormalities or glitch in the network, slow internet connection or due to the reason that the data centre is located very far away from the device. Figure 2 explains the concept.

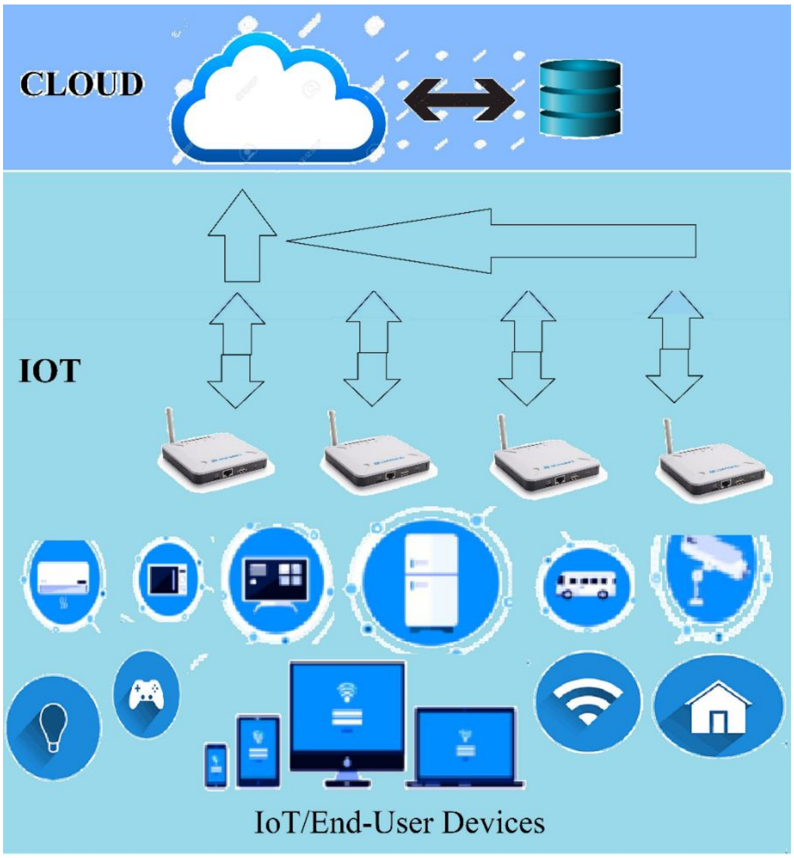

Figure 2: Cloud Computing Paradigm

But in Edge Computing, the data generated by the IoT devices and sensors does not require to travel to the cloud. In some cases, the device itself, and in most cases, the next node (router, mini server) on the network is capable of processing the data and giving out proper responses and/or completing actions. This results into shortening of the data travel path, and cutting down the time to response to a greater extent. The IoT device is no longer dependent on the services of the cloud or in some cases, internet connectivity. It can function as an isolated, standalone network node. A current example for this would be an Alexa device with built in smart home hub. It can control ZigBee devices (on/off) through voice commands even if the internet connection is down or not working [11].

IV. WHY EDGE COMPUTING

i. Low Bandwidth requirements:

Giving all the computational work to the cloud proved to be very efficient since the cloud had tremendous computing power. But with the increase in the number of devices seeking the services of the cloud, the bandwidth requirement also increases, which is basically on a stand still. As the devices increase, bandwidth is becoming the bottleneck in the network. The big data is not able to reach the cloud in the desired time frame. For example, an aeroplane is estimated to generate 5 to 8 TB of data per flight [12]. But the bandwidth between the aeroplane and the base station is not capable of transmission of such big data. Most talked, autonomous vehicle system, is estimated to generate 1 TB of data every second [13]. This data needs to be processed instantaneously for the vehicles to make correct decisions. Taking the scenario, there will be hundreds of cars in an area, the bandwidth requirements increases exponentially.

ii. Low Energy requirements

In the coming future, all the electronic gadgets will be a component of the IoT system. The number of things at the edge is soon going to touch a billion mark. The big data which is produced by these devices will not be handled by the conventional cloud computing paradigm discussed earlier. This will result into the big data produced to be never transferred to the cloud, but will be consumed by the edge [14]. Cloud computing structure is not very efficient for IoT. Most if not all IoT devices work on batteries with very low energy requirements. These devices may not be capable to transmit such huge data to the cloud, therefore Edge will make IoT more efficient and sustainable.

iii. Better Privacy

The data generated by the IoT sensors can be sensitive and private. If the data produced by these IoT sensors is transmitted to the shared cloud, there are chances of the data being compromised or captured wrongly. If the data is processed near to the device generating it, and near to the user, the data will be safer and less prone to compromise. For example, wearable health devices collect numerous physical data of the user which is private to that user, processing the data at the edge would safeguard user privacy [15].

iv. Transition of smart devices from data consumers to data producers

Smart devices, earlier, were considered to be data consumers. For instance, watching a video from YouTube on a smart phone. Now a days, smart phones are also producing data in the form of photos, videos, logs etc. Almost all the users click photos and make videos and upload them instantly on social networks. Moreover, in a minute, online streaming giant YouTube sees more than 72 hours of new video content uploaded to it; Facebook users share 25,00,000 images/videos; Twitter sees around 3,00,000 new tweets and Instagram users post nearly 2,20,000 new photos [16]. This data can be of large size, and a lot of bandwidth would be utilized to upload them. In this case the images and videos need to be rendered to a suitable size and resolution at the edge itself, reducing the size of data to be uploaded it to the cloud which would requires more functions at the edge.

V. BENEFITS OF EDGE COMPUTING

Putting the computation power near the proximity of the data source presents a number of advantages when compared to the traditional cloud-based computing.

i. Reduced response time/ latency

Running Facial Recognition at the edge rather than the cloud has helped researchers to complete the recognition of any face with reduced response time by 169 to 900ms, that is, the system was able to recognise the face in time ranging from 169 to 900ms less than that of cloud system [17].

ii. Reduced energy requirements

Researchers used cloudlets to transfer the computing tasks for wearable devices. In this case the response time was reduced by 80 to 220ms. The energy consumption was also recorded to be reduced by 30-40% when using edge [18].

iii. Increased data security

As the data in edge computing is distributed to the devices only or at the nearest node, it is difficult to attack each device to steal the data [19].

iv. Better app performance

Since the data is being processed at the edge, apps like Facebook, Instagram, photos app give better performance to the users. It reduces the lag time, and the users get seem less app navigation when still the images/videos are still getting uploaded [20].

v. Reduced operational cost

Edge helps in reducing the data traffic cost as well as the cloud data storage requirements. Which helps in reducing costs. At the same time, connection issues will not be that problematic since the devices can work autonomously [20].

vi. Unrestricted scalability

Unlike cloud, in edge computing the user has the option to increase their IoT network as and when required, referencing to the storage available to the user is not essential [21].

VI. REALTIME USE CASES

i. Autonomous vehicles

Self-driving vehicles is the most used example of edge computing. A moving vehicle cannot wait for a response from the cloud when there is a pedestrian crossing the road. The stop decision has to be made on the spot immediately. All the related data needs to be processed at that very time and action has to be taken. Vehicles can also communicate with each other directly without any involvement of the cloud, and exchange information about traffic, weather, accidents etc [22].

ii. Healthcare devices

Next use case lies in the health care domain. Wearable and health monitor devices can prove to be real life savers in many scenarios. A heart rate monitor which is made standalone and capable of analysing data related to wearers health, can immediately give necessary response to raise an alarm to the caregiving personnel when the patient requires assistance [23].

Surgery assisted by robots also uses edge computing. It is beneficial when every nano second counts. They need to be capable to analyse the data by themselves and provide assistance in the surgery [24].

iii. Security solutions

Smart security systems should be capable of responding to security threats within seconds or ms. Therefore, edge computing would be its best bet. With a smart security camera, motion can be detected in the area, if trespassers are detected, users would be intimated instantaneously instead of transferring the whole feed to the cloud for processing and getting inferences [25].

iv. Content filtering/aggregation

As the data generated by the IoT devices is huge, content filtering would help in reducing the volume of data being transferred to the cloud, which in turn will help in saving the bandwidth. Similar data should also be aggregated together for fated and better performance [26].

v. Smart Home

Edge computing will help smart home a lot. The data generated by these devices should be processed and consumed within the home environment due to privacy concerns. This needs a technology like edge computing. The things can be connected and managed with ease with the help of an edge gateway installed within the home. This would even help in using the smart devices when the internet connection is down.

vi. Smart Cities

Edge computing paradigm can easily be scaled from a personal/home environment to a community to a city. Smart cities would generate 180PB of data per day [27]. Making cloud handle such data would require tremendous bandwidth and processing power to get instantaneous inferences. It most cases it might even be unrealistic. Smart roads, smart water system, smart drainage system etc will all benefit from edge computing in one or the other way. Geographical based systems like utility management, inventory management, supply chain would all benefit from edge computing.

vii. Industry 4.0

The fourth industrial revolution is the ongoing transition of traditional manufacturing system and legacy industrial practises combined with the current smart technology. It focuses on large scale M2M and IoT deployment to increase automation, better communication and self-monitored smart machines which would analyse and eliminate problems without the intervention of humans [28].

VII. CHALLENGES

In this section, we will discuss some of the challenges in edge computing paradigm [29].

i. Programmability

In cloud computing, the cloud is the main entity which decides where the computing is to be performed. The devices feed their data to the cloud and all the programming and the codes are in the cloud which is universal to all the devices. But in case of Edge computing each IoT device or node has its own code/program to analyse and generate the data. They might even have heterogeneous programs which might not be compatible to each other. So, a universal standard of programming should be set for IoT devices which should be accepted worldwide.

ii. Naming

The number of IoT devices connected to the edge are going to increase on a daily basis. The naming of these devices is a prime concern, since naming deals with identification, data transfer and communication, addressing etc. So, a standard and efficient naming system needs to be introduced for edge computing. The naming system should be able to handle the to and fro movement of the things, a topology that supports dynamic network, security of data and privacy protection. One more concern to be addressed by the system should be the scalability issue since there is going to be a large number of unreliable things.

iii. Data abstraction

Data abstraction has been dealt with in cloud computing, but it is still a challenging issue in edge computing. With the number of IoT devices/ data generators being huge, abstraction of data becomes important as well as difficult. For example, a smart thermometer would record and report the temperature at almost once every minute, but at most, this data would be consumed only a few times in the day. Secondly, in case of a security camera, it keeps on recording throughout the day, but the data will only be saved in the database for some time with no one actually using it, further it will be removed from the database.

iv. Differentiation

As the number of IoT devices is going to be huge, the edge should be able to differentiate between the devices with highest priority and the ones with the lowest. With high and low priority, we mean that, in a smart home environment, critical services such as healthcare devices (fall detection, heart rate detection) should have the highest priority followed by failure alarm, trespass alarm, fire detection, smoke detection, followed by entertainment services such as smart lights and others.

v. Extensibility

Extensibility generally implies extending the network or adding new smart devices to the current infrastructure. New devices should be able to be added to the network seamlessly and without any problems to the user. A device failure and replacement should be hassle free and easy.

vi. Isolation

There can be several applications that control the same devices or we can say share the same data resource. For instance, to control a smart light the user might have a number of applications installed for the purpose. But if a particular application stops responding or crashes or server does not respond, the user should still be able to control the lights with alternate methods i.e. the complete system should not crash.

vii. Reliability

It is the key challenge for the edge computing paradigm. Every electronic device has to fail. There can a number of reasons for failure but most of the times it is very hard to find. For example, misfunctioning of an AC can be due to compressor failure, power cable defect or bad battery in temperature controller. Edge network can determine that the AC has failed, but knowing the exact cause of failure will be very helpful in diagnosing it. EdgeOS should also be able to maintain a topology of the complete system which will make network management and problem detection easier.

viii. Privacy and security

IoT devices produce big data on daily basis. If these devices are deployed in a home environment or in the field of healthcare, the loss of such data generated can lead to privacy intrusion. For instance, with the readings of electricity and water meter of a home, one can easily guess whether the house is vacant or people are staying there. If this data goes in wrong hands, theft or burglary can be carried out. We take the scenario of home Wi-Fi network security. Out of 43,90,00,000 household Wi-Fi routers 49% of the routers are unsecured and more than 80% still have the routers set at default passwords [30]. Finding and implementing more efficient tools are the need of the hour, which will help protect data privacy and secure the data.

VIII. FUTURE OF IOT IS AT THE EDGE

By 2022, more than 75% of the enterprise data will be processed and stored outside of the cloud, which will result in increasing the size of the edge market to overtake the $13 billion mark [31]. With the current trend and speed of acceptance of the edge computing, businesses and IoT developers should consider implementing their upcoming products with the edge technology. With low latency, low bandwidth requirement and low power usage, Edge computing is on its way to make life more sustainable.

IX. CONCLUSIONS

Edge computing blesses the users with a state of art paradigm of computing which embarks low latency and highly reliable IoT devices that promise to combine the best features of the cloud computing paradigm and the power of local processing. Features such as secure boot, root of trust can be used to secure devices and the data. Integration of AI will help the devices to take actions based on past experiences. Edge computing has a great future ahead but first the handling of sensitive and personal data in a secure way has to be dealt with. In this paper, we tried to explain the edge computing paradigm and compared it with the well-established Cloud computing paradigm, with proper reasoning that processing of the data should happen near the data sources. Further, discussion was done on why Edge computing is needed. We discussed the benefits and some currently used use cases of the technology. Finally, we discussed a few challenges in the acceptance of the technology.

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