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Whither Edge Computing? – A Futuristic Review

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ABSTRACT

It is a well-known fact that the current day Internet is increasingly becoming laden with content that is bandwidth demanding due to ever-increasing number of things getting attached on a day-in and day-out basis. Hand-in-hand, mobile networks and data networks are converging into cloud computing bandwagon. Edge computing as a promising feature has already made inroads to face future requirements and to address exponential demands from cloud. This feature is all about inserting computing power and storage in the vicinity of the network edge. It is asserted that this scheme of operation brings down the data transport time, quick response times and increased availability. Edge computing brings bandwidth-intensive content and latency-sensitive applications closer to the user or data source. In this paper, we explain the drivers of edge computing and have delved on various types of edge computing currently available and going to throng in near future. This paper is intended to draw a comprehensive picture of what is happening in edge currently and what would happen in the near foreseeable future.

Keywords: Edge computing, Edge analytics, Cloud, Fog, Mobile edge, IoT, Smart city

1. INTRODUCTION

Edge computing is nascent relative to Internet of Things (IoT) as well as cloud computing. Simply said, it is about taking the frontier of computing applications, data and services towards the edge or the logical extremes of a network from the centralised store houses. So said, edge computing facilitates the enablement of analytics knowledge generation and services to occur in a location which is in the immediate vicinity of sources of data. Eventually, this scheme demands the leveraging of resources such as laptops, smart phones, tablets and sensors that may not be continuously connected to a network. Edge Computing encompasses a wide range of technologies in its ambit[1]. The list is in order

- Wireless sensor networks
- Mobile data acquisition
- Mobile signature analysis
- Cooperative distributed peer-to-peer ad hoc networking
- Local cloud or fog computing
- Grid/mesh computing
- Distributed data storage and retrieval
- Autonomic self-healing networks

- Virtual cloudlets
- Remote cloud services
- Augmented reality.

In comparison with cloud computing, the edge computing has distinguishing features such as heterogeneous hardware, unreliable low bandwidth communication network, limited on-board energy budget, limited processing power applications and services. Moreover, edge computing-related processes and algorithms will not rely on any central coordinator and are fault-tolerant as incidences of node/link failures are common. A conceptual presentation of edge computing in relation to cloud computing is made in Figure 1.

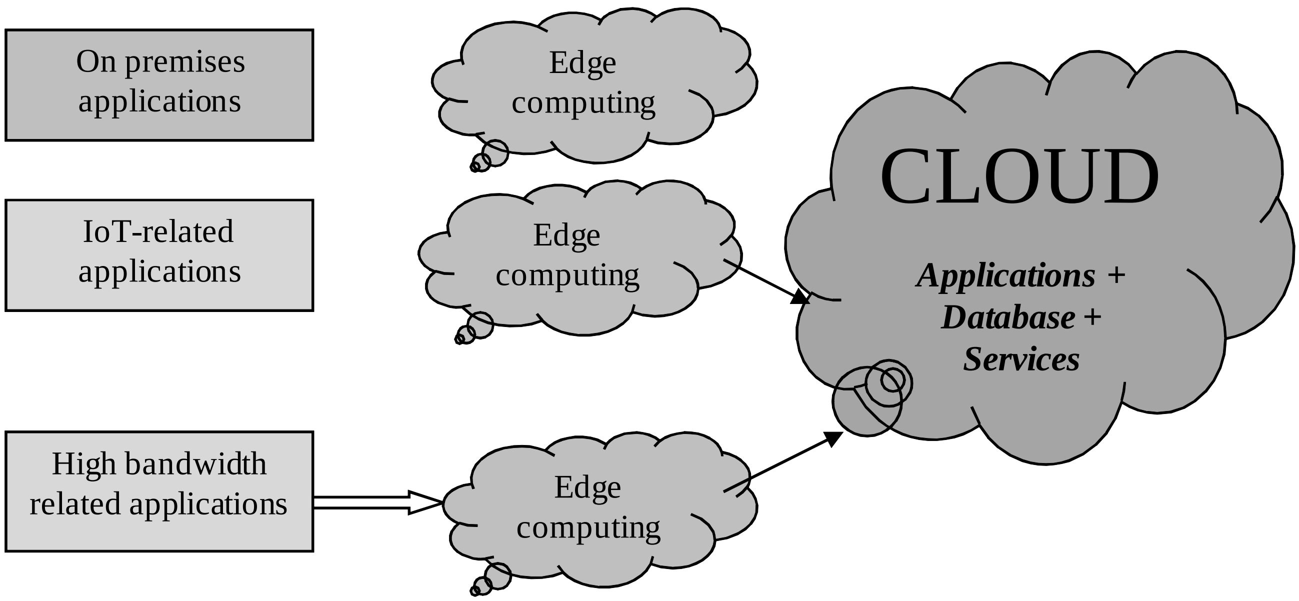

Figure 1: Conceptual presentation of edge computing in relation to cloud computing

Rest of the paper is organised as follows, Sections 2 and 3, respectively, deals elaborately on the two predominant endeavours of edge computing, namely the edge analytics and mobile edge computing (MEC). In Section 4 a sneak into future edge computing patterns is made; in Section 5, a general discussion about the pros of edge computing is made, and finally the paper concludes in Section 6.

2. EDGE ANALYTICS

Edge analytics is one of the major endeavours that happen in the edge. This approach paves the way to efficient contextual data collection and analysis. The efficiency comes from the fact that the computational work is performed on sensing devices such as sensors, actuators, network switches or other devices. This strategy avoids the transmission of the whole data to a centralised computing environment, which is none other than the cloud. The increased attention to edge analytics is the contribution of the IoT paradigm to a great extent. IoT has become more prevalent as a network of connected things (sensors, actuators, controllers, concentrators). The actions are prevalent at the edge of the IoT [2]. IoT environments are in fact the confluence of high data rate sensors such as video camera, environmental sensors and smart metres to name a few. These sensors are known for generation of high data volumes that are stored close to the point of capture. Only a small portion of data is ported to the cloud. It is expected that in the near future, porting of the generated data from billions of IoT devices to the cloud can cause insufficiency of the existing cloud infrastructure. As a solace to this, the concept of edge computing is beginning to emerge. With this concept, the contextual data processing, networking and analytics are augmented in the proximity of so-called IoT devices and applications[3,4].

The essence of edge computing is the localisation of certain kind of analysis after pulling them from the cloud. This kind of analysis includes aggregation operators over data streams as well as local decision-making[5]. The advantages gained with this kind of a pull are quicker response times, reduced traffic in the net and no impediments from network latency. A big plus point about edge analytics is its scalability. The drudgery of processing enterprise data is alleviated by pressing analytics algorithms to service on IoT devices, despite of huge data being collected by the connected devices deployed by organisations[6]. By 2020, its projected there will be anywhere from 25 to 50 billion *things* connected to the IoT, that is up to seven connected things for every person on Earth. These billions of connected things are anticipated to generate data volume far in excess of what can easily be processed and analysed in the cloud. Because with cloud, the constraints of energy (network lifetime), bandwidth and network latency are to be dealt with[7].

As massive streams of data arrive from connected devices, they also bring drudgery of managing that data and difficulties in drawing meaningful insights. Currently, the available approaches for managing such huge data are solely based on objectives set forth for the business and the technical challenges. Customarily centralised cloud and data centres are pressed into service to cope up with IoT. Such centralisation approach is dire need for analysing data streams, which are not sensitive to time and speed. But in majority of the situations, quick transmission or availability data analysis outcomes is required to ensure efficient execution and implementation of changes. If this doesn't happen, realising the full potential of IoT data becomes a mirage. To mitigate this, organisations are beginning to articulate analytics at the edges of their environments. This immediately calls for enabling the endpoints such as sensors, controllers, equipment and machines and in nearby aggregation locations such as basements, control rooms, data closets and ceilings with analytic capabilities[8]. With this, collection and analysis of the data happens locally in real or near real time. As a sequel, the knowledge or information garnered out of the localised analysis may be ported to the data centre or cloud for storage, earmarking for advanced statistical analysis.

Following four elements form the analytic systems in the ambit of IoT:

- ***Sources of data:*** They form verity of endpoints, where data is gathered and transmitted. They are no other than discrete gadgets such as sensors, machines, energy producers, medical devices or even security cameras. In addition, the data sources can be entities that aggregate many endpoints, for example a building, a factory or a vehicle. The data coming from these endpoints is often transmitted in a variety of protocols including DNP3, LAN, ZigBee and SCADA.
- ***Edge aggregation and analytics:*** Depending on the use case, the data sources may be set up to feed data directly into an edge aggregation and analytics device or directly to the cloud. So far as an intelligent gateway is concerned, portion of the data can be processed right away using local analytic software and to generate data-driven actions and insights. Some of the gateways have a single endpoint feeding its data, whereas one of the gateways has several endpoints streaming data to it in a variety of protocols. An appropriate example could be that of an intelligent gateway mounted on a rooftop HVAC unit which is capable enough to collect hundreds of data objects per second.

- ***Storage and analytics:*** Sensor data sent to the data centre or cloud can be stored and further analysed for benchmarking, predictive analytics and other long-term planning. Data scientists can run advanced analytic algorithms against the data to gain new insights and fine-tune the analytics performed on the edge device.
- ***Insights from data:*** The culminating point in an IoT system is the facilitation of customers and employees to garner insights from the data. To gain deeper contextual insight, IoT data can be blended with internal and third-party data sources. To quote an example, integration of IoT data with CRM(Customer Relationship and Management) or ERP (Enterprise Resource Planning) system data, social media as well as weather data. In addition, organisations can provide rich analytic-based applications for customers to view and interact with their data. The benefit of towing analytics to the edge is basically to offset many of the cost and performance issues associated with running entire analytics in a centralised place. The gateways also provide a flexible platform for the development of analytics solutions that eases big data management, increases efficiency, maintains operations in a meticulous way and improves scalability.

3. MOBILE EDGE COMPUTING (MEC)

It is European Telecommunications Standards Institute and Industry Specification Group that have fixed the nomenclature of MEC. European 5GPPP has considered MEC as a prime technology for 5G networks[9]. MEC is all about providing data transfer between the nearest cloud service enabled edge network and the end-user, that is a mobile in specific. Such a connection enhances computation and avoids many problems including system failure[10,11].

Some of the salient features of MEC are [12]

- MEC platforms can function aloof from the rest of the network, simultaneously having access to local resources. This is very important for machine-to-machine scenarios. The MEC property of segregation from other networks also makes it less vulnerable.
- It is always advantageous to analyse and materialise big data with MEC as they are deployed in the nearest vicinity.
- MEC services are deployed at the nearest location to user devices, isolating network data movement from the core network leading to high quality with low latency and high bandwidth.
- MEC receives information from edge devices within the local access network to discover the location of devices.
- Applications providing network information and services of real-time network data can benefit businesses and events by implementing MEC in their business model. These applications are capable of estimating the congestion of the radio cell and network bandwidth.

3.1 Current and Foreseeable Applications of MEC

Two predominant applications of MEC are augmented reality and content delivery. Augmented reality applications have recently adopted mobile technology, some notable ones are Layar, Junaio, Google Goggles and Wikitude[13]. AR (Augmented Reality) enables real environment user experience by combining real and virtual objects existing simultaneously[14]. Recent AR applications have become adaptive in sound and visual components, such as news, TV programmes, sports, object recognition, games and others[15]. However, AR systems usually demand high computing power for task offloading, low latency for better QoE (Quality of Experience) and high bandwidth that is conducive to sustaining interminable IT services. As far as content delivery is concerned, the mobile user makes HTTP (Hyper Text Transfer Protocol) requests that pass through the edge server. This server handles user requests by performing number of tasks to load web pages on the user–device interface. These requests and responses are time efficient as the edge server is deployed close to the edge devices. The edge computing infrastructure is time-efficient as compared with the traditional Internet infrastructures where user requests are handled by the servers that are distantly placed at the service provider side. In addition, edge computing also analyses network performance during on and off peak hours. The future trend of MEC applications are detailed in Reference[16]. Several research papers have heralded the wide-ranging applications that includes smart grids, automobiles, wireless sensor networks, ocean monitoring, software defined network, smart building control and health care[16–22].

3.2 The Issues

MEC is not exempted from issues, but as expected, it is the security issues that are seemingly bothersome. They are

- Hosting of several applications at the edge for the purpose of extending services to mobile users, pose confidentiality-related risks. It is possible to sniff the line between MEC and cloud-connecting channels[23].
- MEC is vulnerable to non-integrity threats as the multiple stakeholders such as end-users, service providers and infrastructure lenders are involved[24].
- There are fair chances of denial of service attacks, particularly over MEC systems at multiple locations[12]. The reason being attributed is the non-isolated nature of MEC systems.

4. FUTURISTIC VIEW

As the edge computing progresses with new embellishments, it is rather befitting to foresee the possibilities that have started to showcase and in impending states. In the near future, video analytics, mobile big data, smart grid, smart-building control, software-defined networks, wireless sensor and actuator networks, and ocean mentoring are slowly paving their way, the application area is expanded to smart-building control and software-defined network, and ocean monitoring[25–29]. In this section, we highlight some of the upcoming domains of edge computing.

4.1 Collaborative Edge

Due to exorbitant cost of data transportation from cloud to the stakeholders and also due to privacy concerns, data is rarely shared between edge and cloud. This hints at missing collaboration between the two. A new structure named collaborative edge is emerging to solve this problem. Collaborative edge connects edges of geographically distributed multiple stake holders. Such a collaborative edge is believed to provide opportunity for stakeholders to share and cooperate with each other [30]. Healthcare industry is going to be hugely benefitted. Health care industry demands data sharing and collaboration among enterprises[31]. Another foreseeable area is mobile edge cashing which is aimed at reducing end-to-end delay. Cooperative caching can be leveraged to exploit caching diversity by allowing users served by multiple base stations under the emerging user-centric network architecture[32].

4.2 Interactive Edge

The real time applications that are time sensitive cannot suffer from latency issues with traditional cloud offloading. With edge computing, the quality of interactive services could be increased by bounds.

Some of the applications which get benefitted include the following:

- Online shopping services are currently done in the cloud. The process sometimes consumes long-time owing to lowered network speed and decreased load on servers. With online shopping process slowly augmenting mobile day by day, it is important to improve the user experience, especially reducing reduced response delay. This can be done by offloading shopping cart updates from cloud servers to edges.
- Searching and navigation services involving a small geographical area can be just done by edge nodes. What nodes have to store in them is the map pertaining to the area.
- Data, content filtering and aggregation of the data could be done at the edge nodes, thus reducing the volume of data that needs to be transferred otherwise.
- Fast-response demanding applications such as internet games, augmented reality and location-based services can make use of edge nodes. This surely reduces latency besides providing improved user experience.

4.3 Smart Home and Smart City through Edge

Currently, the gadgets such as smart light, smart TV, smart sensors, robot vacuum and others are connected to the cloud to run smart home environment. Needless to say that these gadgets would generate copious amount of data. Interestingly, this data should be consumed for monitoring smart environment in the home. This is prudent enough to say that the use of cloud computing becomes uncalled for. This calls for an edge gateway which performs on edge operating system. This alteration provides for the local processing of data and reducing the demand for high bandwidth.

Edge computing may further be extended from smart home to smart city. The days are not far away in implementing edge computing to effectively implement services oriented towards making of smart cities. Some of them which are already on anvil are smart transportation, smart health and well being, smart waste management, smart water management, smart green house gasses control, smart power grid, smart and retail store automation to mention a few[33].

4.4 Video Streaming and Analytics

It is not exaggeration if we say that it is more than 30 billion images a second and 100 trillion images an hour that will get captured by 2020 by surveillance cameras across the globe. It could be anybody's guess that in the near future, there may be one billion cameras, almost twice today's number, mounted at traffic intersections, transit stations and other public areas, helping to make our cities safer and smarter. This is huge enough of to churn out images. In a Smart City or AI City, they are also mounted in retail stores, service centres, warehouses, for ensuring safety and security, gathering information to boost sales, track inventory and improve service. To make sense of this huge gallery of images, conventional methods of video processing, either using human monitoring or handcrafted computer vision algorithms, will not be able to meet the speed and accuracy demands[34]. Sending every bit of video data from thousands of cameras at edge back to a traditional data centre or cloud for processing is unwieldy because

- It imposes high latency for response.
- It is expenditure intensive due to the high bandwidth requirement for video streams.
- It is susceptible to snooping when relayed over public network.

The issues mentioned above can be easily resolved by using compact converged edge systems capable of processing all camera feeds directly at the edge.

4.5 Blending of 5G and Edge Computing

It is a known fact that the basis for developing 5G technologies was to address the exponential rise in the number of mobile devices seeking the internet connection. However, nowadays, the spurt in 5G coincides with the boom of connected devices and systems associated with IoT. Wearables, automobiles and smart gadgets such as heating units bring with them large amount of data. Besides increased processing power, 5G comes with a speed 10 times faster than that of 4G. This increased speed eliminates the daunting costly downtime. As an example, a sensor detecting some efficiency changes in the machine in a manufacturing unit can report the same instantly to the concerned control unit instantly within no time. Processing these high volumes of data at a faster rate will in turn demand new devices, new applications and new issues. This will surely drive the need for edge computing.

4.6 Natural Calamities and Edge Computing

One important thing that has missed the attention of people is the beneficial side of edge computing during natural disasters and calamities. If a data centre goes berserk during a natural fury, then edge computers can swing in to action if they are programmed a priory. With this, the management of the disaster can be made effective and efficient. This calls for creation of a network of computationally powerful mobile phones, routers and other necessary hardware so that the managers doing redressal services share and act on information gathered from people distressed by avalanches, floods, hurricanes, earth tremors, tornados and other natural disasters.

5. DISCUSSION

In the light of above elaborations, it can be said that the edge computing may be seen as some kind of a network of miniature data centres that locally process the data and store critical data component and push the rest to the cloud repository. The increased sway towards edge computing will definitely result in following impacts:

- The IoT solution costs may eventually scale down as there is going to be less traffic to and from data centres. It will also facilitate easier business management.
- As most of the processes gets executed at the source or in the immediate vicinity of the source, the devices can operate normally even with intermittent connectivity. This also takes out the need to establish an all-time connection of devices with Internet.
- We have seen in literature that a complete adaptation of cloud by businesses has not happened because of security concerns. With edge computing in place, personal information can be processed locally with the strict compliance of security demands as sought by business rather than pushing off this information to the cloud.
- As latency will wane away, edge computing will surely bring in the much needed speed and quicker response times for those devices connected to Internet.
- It is envisaged at this point that edge and cloud computing are not far-reaching entities. Instead they are juxtaposed for the better management and analysis of huge data to magnificently increase the value of IoT.

6. CONCLUSION

In this paper, we have presented edge computing as an emerging technology. Edge computing is blessed with distinct characters that it is indistinguishable from the kind of devices; it is controlled mostly by the users, it is coordinated by trusted edges, leverages the resources at the place where data is generated and it has proximity. This paper also highlighted two faces of edge computing, that is edge analytics and MEC in a deep detail. We have also foreseen the trend of edge computing in future years to come in terms of its expansion to the realm of collaborative edge, interactive edge, smart home and smart city through edge and video analytics at the edge.

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