# Edge Computing

**Shruti J Pote**

*Kolhapur Institute of Technology , College of Engineering Kolhapur.*

Department-Computer Science and Engineering

## ABTRACT

With Digital Transformation and emerging technologies that will enable "smart" everything – cities, agriculture, cars, health, etc in the future require the massive deployment of Internet of Things (IoT) sensors while edge computing will drive the implementations. The proliferation of Internet of Things (IoT) and the success of rich cloud services have pushed the horizon of a new computing paradigm, edge computing, which calls for processing the data at the edge of the network. Edge computing has the potential to address the concerns of response time requirement, battery life constraint, bandwidth cost saving, as well as data safety and privacy. In this paper, I introduce the definition of edge computing, followed by several case studies, ranging from cloud offloading to smart home and city, as well as collaborative edge to materialize the concept of edge computing. Finally, I present several challenges and opportunities in the field of edge computing, and hope this paper will gain attention from the community and inspire more research in this direction.

## 1. INTRODUCTION

CLOUD computing has tremendously changed the way we live, work, and study since its inception around 2005. For example, software as a service (SaaS) instances, such as Google Apps, Twitter, Facebook, and Flickr, have been widely used in our daily life. Moreover, scalable infrastructures as well as processing engines developed to support cloud service are also significantly influencing the way of running business, for instance, Google File System, Map Reduce, Apache Hadoop, Apache Spark, and so on.

Internet of Things (IoT) was first introduced to the community in 1999 for supply chain management, and then the concept of "making a computer sense information without the aid of human intervention" was widely adapted to other fields such as healthcare, home, environment, and transports. Now with IoT, we will arrive in the post-cloud era, where there will be a large quality of data generated by things that are immersed in our daily life, and a lot of applications will also be deployed at the edge to consume these data. By 2019, data produced by people, machines, and things will reach 500 zettabytes, as estimated by Cisco Global Cloud Index, however, the global data center IP traffic will only reach 10.4 zettabytes by that time. By 2019, 45% of IoT-created data will be stored, processed, analyzed, and acted upon close to, or at the edge of, the network. Some IoT applications might require very short response time, some might involve private data, and some might produce a large quantity of data which could be a heavy load for networks. Cloud computing is not efficient enough to support these applications. With the push from cloud services and pull from IoT, we envision that the edge of the network is changing from data consumer to data producer as well as data consumer. In this paper, we attempt to contribute the concept of edge computing.

## 2. LITERATURE SURVEY

**1."Mobile Edge Computing: A Survey"**

- Authors: Shi, W., Cao, J., Zhang, Q., et al.
- Published in: IEEE Access, 2016.
- Summary: This paper provides a comprehensive survey of mobile edge computing (MEC), which extends edge computing capabilities to mobile networks. It discusses architecture, challenges, and potential applications of MEC.

**2. Edge Computing: Vision and Challenges"**

- Authors: Shi, W., Dustdar, S.
- Published in: IEEE Internet Computing, 2016.
- Summary: This paper outlines the vision and challenges of edge computing. It discusses various application scenarios, including IoT and augmented reality, and highlights the need for resource management and security in edge environments.

**3. MEC in 5G Networks: An Overview"**

- Authors: Mekki, K., Bennis, M., Shihada, B., et al.
- Published in: IEEE Communications Magazine, 2017.
- Summary: This paper discusses the integration of mobile edge computing with 5G networks, highlighting how MEC can enhance the performance of 5G services by bringing computation closer to the radio access network.

**4. Security and Privacy for Edge Computing: A Review"**

- Authors: He, W., Yan, G., Da Xu, L., et al.
- Published in: IEEE Access, 2017.
- Summary: This review paper focuses on the security and privacy challenges in edge computing. It discusses threat models, security mechanisms, and privacy-preserving techniques for edge environments.

## 3. METHODOLOGY

### 1. What is Edge Computing?

Edge computing is a “mesh network of micro data centers that process or store critical data locally and push all received data to a central data center or cloud storage repository, in a footprint of less than 100 square feet,” according to research firm IDC. Edge computing is a method of optimizing cloud computing systems by performing data processing at the edge of the network, near the source of the data. This reduces the communications bandwidth needed between sensors and the central data center by performing analytics and knowledge generation at or near the source of the data. This approach requires leveraging resources that may not be continuously connected to a network such as laptops, smartphones, tablets and sensors.

Edge computing covers a wide range of technologies including wireless sensor networks, mobile data acquisition, mobile signature analysis, cooperative distributed peer-to-peer ad hoc networking and processing also classifiable as local cloud/fog computing and grid/mesh computing, dew computing, mobile edge computing, cloudlet, distributed data storage and retrieval, autonomic self-healing networks, remote cloud services, augmented reality, and more.

## 2. How Edge Computing works?

Edge computing pushes applications, data and computing power (services) away from centralized points to the logical extremes of a network. Edge computing replicates fragments of information across distributed networks of web servers, which may spread over a vast area. As a technological paradigm, edge computing is also referred to as mesh computing, peer-to-peer computing, autonomic (self-healing) computing, grid computing, and by other names implying non-centralized, nodeless availability.

To ensure acceptable performance of widely dispersed distributed services, large organizations typically implement edge computing by deploying Web server farms with clustering. Previously available only to very large corporate and government organizations, edge computing has utilized technology advances and cost reductions for large-scale implementations have made the technology available to small and medium-sized businesses .The target end-user is any Internet client making use of commercial Internet application services. Edge computing imposes certain limitations on the choices of technology platforms, applications or services, all of which need to be specifically developed or configured for edge computing.

## 3. Why Do We Need Edge Computing?

**1. Push From Cloud Services**: Putting all the computing tasks on the cloud has been proved to be an efficient way for data processing since the computing power on the cloud outclasses the capability of the things at the edge. However, compared to the fast developing data processing speed, the bandwidth of the network has come to a standstill. With the growing quantity of data generated at the edge, speed of data, transportation is becoming the bottleneck for the cloud-based computing paradigm. For example, about 5 Gigabyte data will be generated by a Boeing 787 every second, but the bandwidth between the airplane and either satellite or base station on the ground is not large enough for data transmission. Consider an autonomous vehicle as another example. One Gigabyte data will be generated by the car every second and it requires real-time processing for the vehicle to make correct decisions. If all the data needs to be sent to the cloud for processing, the response time would be too long. Not to mention that current network bandwidth and reliability would be challenged for its capability of supporting a large number of vehicles in one area. In this case, the data needs to be processed at the edge for shorter response time, more efficient processing and smaller network pressure.

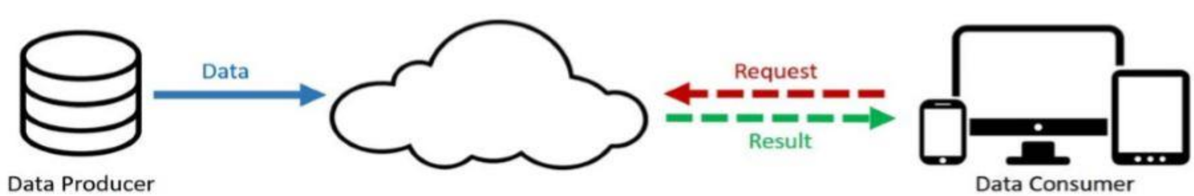


Fig 1: Cloud computing paradigm

**2. Pull from IOT**: Almost all kinds of electrical devices will become part of IoT, and they will play the role of data producers as well as consumers, such as air quality sensors, LED bars, streetlights and even an Internet-connected microwave oven. It is safe to infer that the number of things at the edge of the network will develop to more than billions in a few years. Thus, raw data produced by them will be enormous, making conventional cloud computing not efficient enough to handle all these data. This means most of the data produced by IoT will never be transmitted to the cloud, instead it will be consumed at the edge of the network. Fig. 1 shows the conventional cloud computing structure. Data producers generate raw data and transfer it to cloud, and data consumers send request for consuming data to cloud, as noted by the blue solid line. The red dotted line indicates the request for consuming data being sent from data consumers to cloud, and the result from cloud is represented by the green dotted line. However, this structure is not sufficient for IoT. First, data quantity at the edge is too large, which will lead to huge unnecessary bandwidth and computing resource usage. Second, the privacy protection requirement will pose an obstacle for cloud computing in IoT. Lastly, most of the end nodes in IoT are energy constrained things, and the wireless communication module is usually very energy hungry, so offloading some computing tasks to the edge could be more energy efficient.

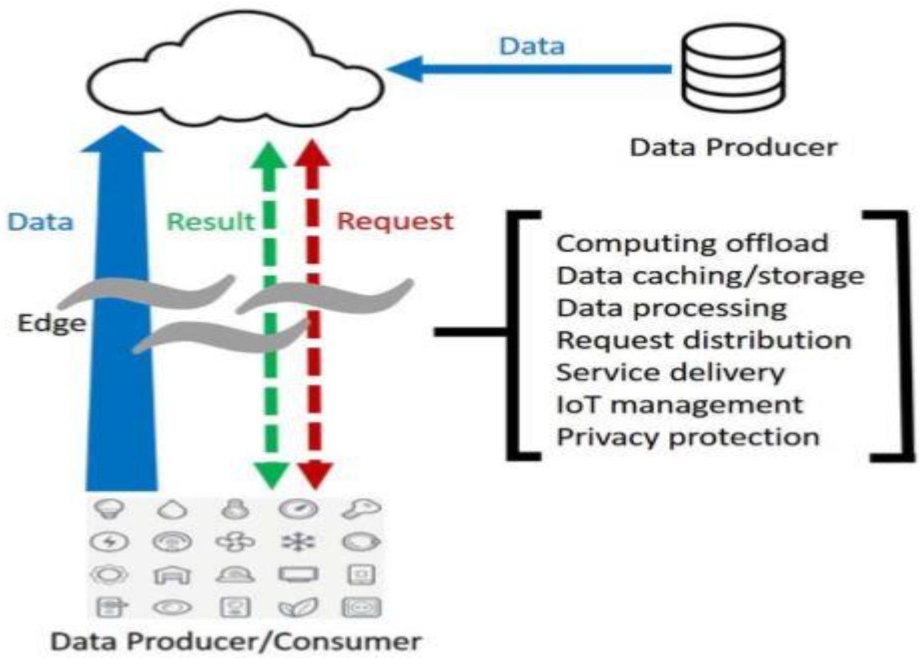


Fig 2: Edge computing paradigm

**3. Change from Data Consumer to Producer**: In the cloud computing paradigm, the end devices at the edge usually play as data consumer, for example, watching a YouTube video on your smart phone. However, people are also producing data nowadays from their mobile devices. The change from data consumer to data producer/consumer requires more function placement at the edge. For example, it is very normal that people today take photos or do video recording then share the data through a cloud service such as YouTube, Facebook, Twitter, or Instagram. Moreover, every single minute, YouTube users upload 72 h of new video content; Facebook users share nearly 2.5 million pieces of content; Twitter users tweet nearly 300000 times; Instagram users post nearly 220000 new photos. However, the image or video clip could be fairly large and it would occupy a lot of bandwidth for uploading. In this case, the video clip should be demised and adjusted to suitable resolution at the edge before uploading to cloud. Another example would be wearable health devices. Since the physical data collected by the things at the edge of the network is usually private, processing the data at the edge could protect user privacy better than uploading raw data to cloud.

| Requirements | Cloud Computing | Edge Computing |
|---|---|---|
| Latency | High | Low |
| Location of Service | Within the Internet | At the Edge |
| Distance of Client and Server | Multiple hops | One hop |
| Geo-distribution | Centralized | Distributed |
| Delay Jitter | High | Very low |

Table 1: Difference between Cloud and Edge Computing

## 4. CONCLUSION

The adoption of cloud computing brought data analytics to a new level. The interconnectivity of the cloud enabled a more thorough approach to capturing and analyzing data. With edge computing, **things have become even more efficient**. As a result, the quality of business operations has become higher. Edge computing is a viable solution for data-driven operations that require lightning-fast results and a high level of flexibility, depending on the current state of things.

## 5. REFERENCES


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