The Emergence of Edge Computing Technology over Cloud Computing

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Abstract
We live in an increasingly connected world and the use of technologies such as the Internet of Things and artificial intelligence will drive companies to produce massive amounts of data and to find more agile ways of collecting and analyzing that data. The concept of edge computing has been around for some time, but it is only now that it is really starting to take hold. The reason: devices are getting smarter. They can process data because they themselves possess a memory, processing power and a network connection. Therefore, they have become miniature data centers. This is always an advantage if reaction times must be in the millisecond range because the speed of signal propagation is bound by physical laws. Also, these days, remotely deployed sensors and devices require real-time processing. However, a cloud system is generally too slow in such circumstances, and particularly when an analysis must be completed instantaneously. So, edge computing is particularly useful for IoT devices in locations or regions with poor connectivity.

Keywords*:* *Edge Computing, Internet of Things (IoT), Cloud Computing*.

INTRODUCTION

Edge computing is an increasingly important component of the Internet of Things (IoT) infrastructure, especially in cases where it is necessary to obtain a timely and autonomous response from devices based on the input received. This is particularly true in sectors such as the automotive sector, where IoT devices play a decisive role in the safety of people, or in the manufacturing industry, where the ability of machines to act independently based on circumstances is one of the main aspects of Industry 4.0 (GE Digital, 2018). However, in almost every domain in which large amounts of data are collected through sensors connected to a network it is necessary to utilize solutions that allow performance to be sufficiently high.

The term "edge computing" refers to the technologies that enable computing for cloud services and upstream data for IoT services on the edge of the network. We define an "edge" as any computing and network resource along the path between data sources and data centers in the cloud. A smartphone, for example, is the edge between a human body and a cloud, a smart home gateway is the edge between a home and a cloud, and a micro data center is the edge between a mobile device and a cloud. The reason for the development of this type of advanced computing is that computing should ideally occur in close proximity to the data source. From our point of view, the term edge computing is interchangeable with fog computing, but edge computing focuses more on the things side, whereas fog computing is concentrated more on the infrastructure side. We envision that edge computing could have as big an impact on our society as cloud computing (Shi et al. 2016).

The remainder of this paper is organized as follows. In Section 2, background information on edge computing is provided together with a brief review of the relevant literature. Next, in Section 3, the concept of edge computing infrastructure is described. Then, in Section 4, the way in which edge computing can support superior industrial automation is discussed. This is followed by Section 5, in which the method for is proposed. After that, in Section 6, the need for edge computing as opposed to cloud computing in the IoT is discussed. Finally, in Section 7, some final conclusions are presented.

EDGE COMPUTING: BACKGROUND INFORMATION AND LITERATURE REVIEW

The rapid development of IoT projects in a variety of use cases in the business, consumer and government sectors is driving the creation of decentralized IT architectures that are capable of processing data directly at the points where they are produced or at least as close to them as is practicably possible (Axellio, 2018). Currently, around 10% of the data generated by businesses is created and processed outside a traditional data center or cloud (GE Digital, 2018). The utilization of edge computing means that part of the data processing function can be carried out closer to the source of the data; rather than first sending it over the internet to a datacenter for processing in the cloud.

Edge computing saves cost, consumes less bandwidth, improves security and lowers latency. Through this technology, data are initially stored and processed locally, as close as possible to the source of the data (Satyanarayanan, 2017). This can be on the IoT device itself, if it has enough computing power and storage capacity, or in a “mini datacenter” that collects and analyzes the information from several nearby IoT devices (Janakiram, 2018). Edge computing expands IoT services and brings them closer to the user, thus bringing the payback of the cloud closer to the place where data are created and acted upon. In addition, edge computing is needed in IoT to improve efficacy and shrink the volume of information that needs to be transmitted to a central server for processing. This is frequently done to bring about efficiency, but it can also be used for compliance and security. Edge computing can be applied in the smart grid, smart city, smart buildings and vehicle networks.

The edge computing approach can generate several benefits for an organization. First, it can maximize big data analysis by keeping some tasks out of the main cloud’s data storage queue, allowing them to complete faster. It is simply not necessary for each analytical action to pass from the device to the cloud and vice versa. In the case of a solution with video cameras for example for retail, security applications or consumer behavior, it is possible to create business rules that only send reports to the data center about certain events because edge computing devices can sort tasks according to priority, thereby keeping critical actions inside the node. For instance, in the retail case, it is possible to make video surveillance cameras start to transmit data to the cloud only when a defined type of event occurs; for instance, when an intruder or shoplifter has been identified, transmission is initiated (Gyarmathy, 2018).

Chakraborty and Datta (2017) discussed harmonized and interoperable home automation solutions that try to take advantage of the concepts of edge computing, virtual IoT devices (VIDs) and the IoT, while edge computing for the aggregation and data processing of sensor networks and individual physical devices were described inZhang et al. (2017) who defined edge computing applications in the IoT Power (PIoT) such as the smart home, transmission line monitoring, the smart substation. On the other hand, Endler et al. (2017) analyzed the unique features of the IoT in relation to security issues and presented a security architecture that focused on using edge and Smart Things networks.

More recently, Pan and Mcelhannon (2018) explored the key rationale behind edge computing, as well as the state-of-the-art efforts, key technologies and research topics in this area, in addition to the typical IoT applications that would benefit from the presence of an advanced cloud. In a more specific direction, indicated how a managed IoT edge computing platform could support the dynamic deployment of virtualized containers running distributed analytics. On the other hand, the aim of Alrowaily and Lu (2018) was to briefly review the concepts, features, security, IoT-enabled edge computing applications and their security aspects in today’s data-driven world. In the same year, in another review-based work, Yu et al. (2018) conducted a comprehensive survey to analyze how edge computing could be used to improve IoT network performance. In a similar vein, Premsankar et al. (2018)supported the idea of using edge computing for emerging IoT applications as a way to increase of interactive applications using sensor streams. Finally, the last work worthy of mention in in this brief review of the relevant literature is that of He et al. (2018) who scrutinized IoT security issues.

EDGE COMPUTING INFRASTRUCTURE

Figure 1 below depicts a typical IoT infrastructure in order to facilitate an understanding of the role of the edge in that infrastructure.

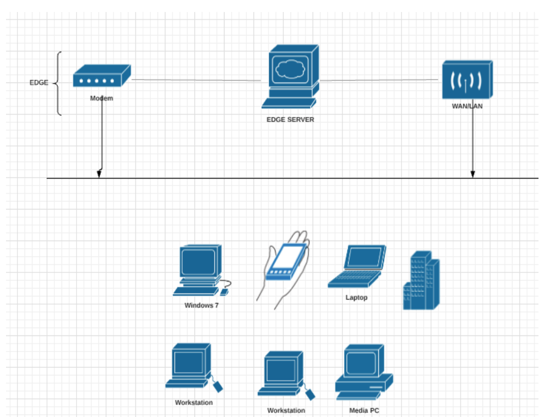


Figure 1: Edge computing infrastructure

It can be seen from the figure that at the margins of the infrastructure (bottom) lie all the elements that are in direct contact with the phenomena that IoT devices are designed to detect, namely sensors, actuators and devices. The sensors are like the sense organs of the human body and the IoT has the role of collecting the data and information for which the infrastructure was created (Miller, 2018). These data can be obtained from the external environment, from an internal environment or from within a complex system such as machines destined for production (Wood, 2018). Examples of sensors include GPS receivers; temperature sensors, light sensors, files, humidity sensors, specific product data and vehicle diagnostics systems (Miller, 2018).

Edge Computing to Support Superior Industrial Automation

It is well known that the cloud has a capacity and bandwidth problem, but this is not just a matter of concern for the future. It is an issue that has had serious consequences already. For example, an important Amazon Web Services datacenter failed, shutting down many services in the United States and some even worldwide for hours (Alba, 2017). If the cloud is disconnected for a period as in this case, if there were local capacity it could have at least cushioned the failure (Alba, 2017).

Initially, the concept of fog computing was proposed a means to provide for a greater proportion of computing intelligence and storage capacity at the edge of an organization's own network. It was envisaged that this would relieve the burden on central data storage and communication and make it possible to better manage the huge amounts of data of the "Internet of Everything" in the first place (Alba, 2017).

Moreover, even the sometimes already high latencies that occur with large cloud providers could be mitigated using edge computing technology.

Cisco, IBM and Microsoft further developed this concept into what is now generally referred to as edge computing, meaning computing at the edge of the network that is directly linked with data-producing devices (Parakh, 2018). The Linux Foundation has also tackled the issue and, together with more than 50 companies, launched an initiative aimed at providing open and consistent frameworks for edge computing in the IoT (Bihari, 2018).

Edge computing is now one of the top ten technology trends in the infrastructure and operations space, with a focus on real-time applications that require very fast response times. Edge computing shortens communication time to just a few milliseconds (Bihari, 2018). To put this in context, in traditional cloud computing, the average response time is hundreds of milliseconds. Edge computing leaves some of the compute-intensive operations on edge servers, making data processing less dependent on the capabilities of each device (Carlini, 2018). There are also advantages in terms of IT security.

IoT Needs Edge Computing More Than It Needs the Cloud.

In the IoT era, the evaluation of information in real time is becoming the standard requirement for many companies. Those companies that rely on the IoT cannot avoid the cloud because it allows the control and maintenance of machines and robots from a distance (Michalowski, 2017). By way of example, self-driving cars must coordinate with the cloud in order brake automatically to avoid an accident. However, in the cloud, the presence of more applications leads to higher latencies, so delay times increase in order to minimize response times. The solution seems to be to bring the computing units that are responsible for processing the data and making the decisions closer to the respective cars or other types of machine. Then the data does not have to be transmitted over a long distance to the cloud; rather, it can be processed locally, for example in a smart base station located on a mobile phone mast or in networked objects and machines such as the cars, robots or surveillance cameras themselves. Edge computing can help in such situations because edge architecture, which requires additional hardware and software components, supports high-performance real-time operations because network latency or batch processing does not slow it down (Parakh, 2018). Hence, edge computing can speed up processes and could be of more value to the IoT than cloud computing.

Proposed Method

In light of the foregoing, the main aim of our research is to suggest a suitable edge computing environment and a range of services for e-Government by considering the requirements (cost, security, functionality and performance). To achieve this aim, we set the following sub-goals:

- Sub-goal 1: Suggest appropriate cloud computing environments (public, private, hybrid, community cloud).

- Sub-goal 2: Suggest appropriate cloud computing services (Internet as a service, platform as a service, software as a service).

- Sub-goal 3: Propose a cloud computing model, after determining the appropriate cloud computing services and environments.

As the first step in our research, we conducted a review of the relevant and related literature on edge computing environments and services.

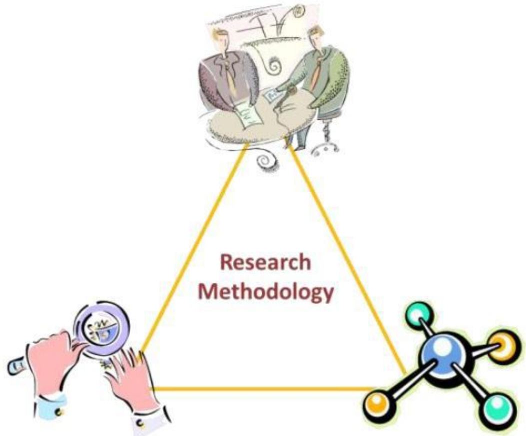
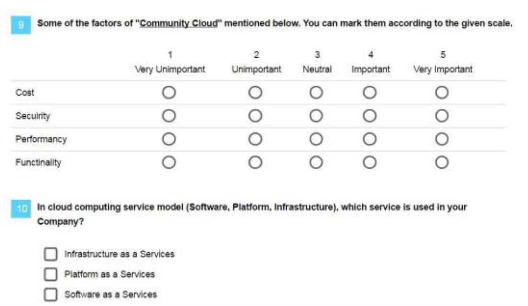


Figure 2: Edge-computing technique



9 Some of the factors of "Community Cloud" mentioned below. You can mark them according to the given scale.

	1 Very Unimportant	2 Unimportant	3 Neutral	4 Important	5 Very Important
Cost	○	○	○	○	○
Security	○	○	○	○	○
Performancy	○	○	○	○	○
Functinality	○	○	○	○	○

10 In cloud computing service model (Software, Platform, Infrastructure), which service is used in your Company?

- ☐ Infrastructure as a Services
- ☐ Platform as a Services
- ☐ Software as a Services

Figure 3: Edge computing technique – Survey Result

Three different cloud environments can be used in e-Government. In a public cloud environment, data and services can be used by the general public and a range of other types of user, and the data are stored in an external system. Therefore, the use of the public cloud in government is not completely appropriate because confidentiality and security are a matter of concern.Therefore, we decided to deploy the edge computing cloud, the ECC, for the public option. Specifically, we used a general business incubator that was set up between the government and the business sector (G2B) and that supports IT projects in order to deliver a secure data connection and isolate the portal in order to enable the sharing of application and IT resources between the enterprise sector and a public cloud.

In the case of the private cloud, the applications and data can be stored and accessed securely only by the authorized users of a company/organization. Thus, the private cloud can be used for delivering a high level of privacy and security for internal e-Government data that can only be accessed by e-Government employees.

On the other hand, the community cloud was used in our model to ensure effective collaboration between government entities. In our model, more than 70 government entities can share the infrastructure and services such as storage, servers, networking services, and information, as well as access applications that are protected by a high level of security by the presence of a secure government network between them.

Results

Edge computing is an increasingly important component of the IoT. Edge computing saves cost, consumes less bandwidth, improves security and lowers latency. The goal of edge computing is to improve efficacy and shrink the amount of information sent to the central server for storage. The concept of edge computing provides for a greater proportion of computing intelligence and storage capacity at the edge of an organization's own network. Edge computing is one of the top ten technology trends in the infrastructure and operations space, with a focus on real-time applications that require very fast response times. Therefore, edge computing can offer a solution to the rising security threat witnessed in cloud computing. Our research therefore seeks to leverage edge computing technology.

References

[1] Alba, M. (2017). "*Seven Reasons to Compute at the Edge*". Retrieved from https://www.engineering.com/IOT/ArticleID/15540/Seven-Reasons-to-Compute-at-the-Edge.aspx

[2] Axellio. (2018). "*Edge Computing | Axellio*". Retrieved from https://axellio.com

[3] Alrowaily, M. & Lu, Z. 2018.*" Secure Edge Computing in Iot Systems: Review and Case Studies*". 2018 IEEE/ACM Symposium on Edge Computing (SEC), hlm. 440-444.

[4] Anon. 2018. "*Managed Edge Computing on Internet-of-Things Devices for Smart City Applications - Ieee Conference Publication".*

[5] Bihari, J. (2018). "*Edge Computing: The Definition and Benefits*". Retrieved from https://explore.emtecinc.com/blog/edge-computing-the-definition-and-benefits

[6] Carlini, S. (2018). "*The Drivers and Benefits of Edge Computing*". Retrieved from http://www.apc.com/salestools/VAVR-A4M867/VAVR-A4M867_R0_EN.pdf?sdirect=true

[7] Chakraborty, T. & Datta, S. K. 2017. "*Home Automation Using Edge Computing and Internet of Things*". Consumer Electronics (ISCE), 2017 IEEE International Symposium on, hlm. 47-49.

[8] Endler, M., Silva, A. & Cruz, R. A. 2017. "*An Approach for Secure Edge Computing in the Internet of Things*". Cyber Security in Networking Conference (CSNet), 2017 1st, hlm. 1-8.

[9] GE Digital. (2018). What is Edge Computing? | GE Digital. Retrieved from https://www.ge.com/digital/blog/what-edge-computing

[10] Gyarmathy, K. (2018). "*The 5 Best Benefits of Edge Computing*". Retrieved from

https://www.vxchnge.com/blog/the-5-best-benefits-of-edge-computing

[11] He, D., Chan, S. & Guizani, M. 2018. "*Security in the Internet of Things Supported by Mobile Edge Computing*". IEEE Communications Magazine 56(8): 56-61.

[12] Janakiram. (2018). "*Demystifying Edge Computing -- Device Edge vs. Cloud Edge".* Retrieved from https://www.forbes.com/sites/janakirammsv/2017/09/15/demystifying-edge-computing-device-edge-vs-cloud-edge/

[13] Michalowski, J. (2017). "*How Edge Computing Might Fit into the Enterprise".* Retrieved from https://www.appneta.com/blog/edge-computing-might-benefit-enterprise/

[14] Miller, P. (2018). What is edge computing Retrieved from https://www.theverge.com/circuitbreaker/2018/5/7/17327584/edge-computing-cloud-google-microsoft-apple-amazon

[15] Pan, J. & Mcelhannon, J. 2018. "*Future Edge Cloud and Edge Computing for Internet of Things Applications*". IEEE Internet of Things Journal 5(1): 439-449.

[16] Plakhteyev, A., Perepelitsyn, A. & Frolov, V. 2018. "*Edge Computing for Iot: An Educational Case Study*". 2018 IEEE 9th International Conference on Dependable Systems, Services and Technologies (DESSERT), hlm. 130-133.

[17] Premsankar, G., Di Francesco, M. & Taleb, T. 2018. "*Edge Computing for the Internet of Things: A Case Study*". IEEE Internet of Things Journal 5(2): 1275-1284.

[18] Parakh, M. (2018). "*Fundamentals of Edge Computing and How It Will Benefit the World - DZone Cloud*". Retrieved from https://dzone.com/articles/fundamentals-of-edge-computing-and-how-it-will-ben

[19] Research Guides. (2018). "*Research Guides: How to Conduct a Literature Review: Types of Literature Reviews*". Retrieved from https://guides.lib.ua.edu/c.php?g=39963&p=253698

[20] Satyanarayanan, M. (2017). Edge Computing. Computer, 50(10), 36-38. doi: 10.1109/mc.2017.3641639

[21] Shi, W., Cao, J., Zhang, Q., Li, Y. & Xu, L. 2016. "*Edge Computing: Vision and Challenges*". IEEE Internet of Things Journal 3(5): 637-646.

[22] Wood, C. (2018). " *Is Edge Computing Key to the Internet of Things*". Retrieved from http://www.govtech.com/transportation/Is-Edge-Computing-Key-to-the-Internet-of-Things.html