Edge Computing

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***Abstract*—This research is a useful summary about Edge Computing and its concepts, and how this technology is currently helping different data transmission infrastructures to be more efficient, secure and faster, while also implementing an ease way to work with IoT and 4.0 Industry. In addition, this article also talks about the current situation of Edge Computing in Costa Rica. In this way, providing useful results on how this technology is currently applied and the benefits it brings when applied to a technological system compatible with it.**

***Index Terms*—Data transmission; IoT; 4.0 Industry**

I. Introduction

With the rise of IoT and 4.0 industry, the increase in the number of connected devices around the world and the large amount of data that these devices produce becomes a big problem for data centralization and management, Edge Computing comes to solve this problem with an interesting solution.

It is introduced what Edge Computing is and how this technology solves a major problem of how data is manipulated in the tech industry for greater efficiency. Also, about the situation in Costa Rica regarding Edge Computing and how this technology is used in this country.

This research contributes to the understanding of Edge Computing technology, and how this technology is capable of solving many problems with intelligent, safe and efficient solutions, providing the user, company or country with an infrastructure capable of taking advantage of the technologies applied to their systems.

II. Definition

According to [1] the term Edge Computing refers to:

> Edge computing is a distributed computing framework that brings enterprise applications closer to data sources such as IoT devices or local edge servers. This proximity to data at its source can deliver strong business benefits, including faster insights, improved response times and better bandwidth availability."

In this way, it is understood that applying edge computing results in superior manageability and response times, being beneficial for structures where scability is a determining point when applying different technologies, thus allowing to reduce resource consumption.

On the other hand, the rise of the Internet of Things and the 4.0 industry are key determinants that edge computing is continuing to grow steadily, while the exponential growth of connected devices around the world is a problem for today's infrastructures. Since, managing this large number of linked devices and their data is a complex and heavy task, this is where Edge Computing offers a solution to support the efficiency of these systems that are responsible for centralizing and processing data. As show in fig. 1, with Edge Computing, data is processed and analyzed closer to where it was created, because that means data doesn't have to travel to the cloud or a data center to be processed. Another benefit is the fact that the latency when working with these systems is significantly reduced [1].

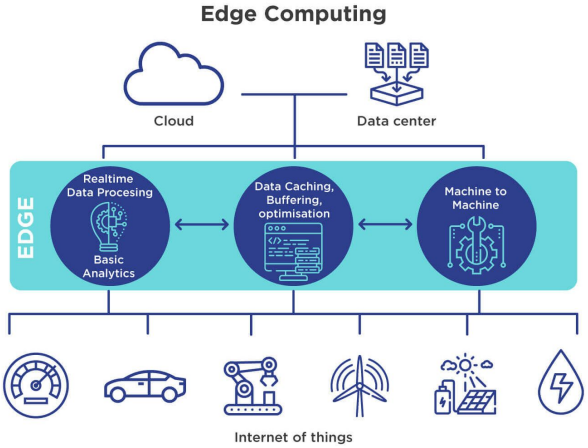

Figure 1: Edge Computing architecture [2]

III. History

The beginnings of what is now known as Edge Computing can be traced back to the concept of CDN, or Content Delivery Network. This term is defined by [3] as "a network of servers hosted by a service/content provider in multiple locations of the world that is shared by multiple end users". This indicates that the content provided would be always served from the nearest server to the user requesting for said information. The term was put forward by the Akamai Company in 1998, where they would establish that it consists on an Internet-based cache network, where the emphasis would be data backup and cache [4]. This would evolve into Edge Computing later by emphasizing on function cache instead, which is data processing.

Following the CDN, in August 2006, a new business model was brought to the public's attention by the CEO of Google Eric Schmidt. He exposed what the concept of "Cloud Computing" meant; a collection of networks in

which the users could utilize its modalities from any device, via the Internet. The primordial services provided by this technology are Software, Platform and Infrastructure, all of them as different services that, just as water or electricity, could be provided or distributed around the world [5].

The rising of Cloud Computing meant that there would be a centralization of data inside the cloud of each enterprise that worked with loads of information. Nevertheless, the amount of users that transmitted information grew exponentially, therefore demanding a solution for the analysis of that much information. Cisco, in 2011, then proposed a new term that would seek out to solvent this problem: Fog Computing. The concept is defined by [6] as follows:

> "Fog Computing is a geographically distributed computing architecture with a resource pool which consists of one or more ubiquitously connected heterogeneous devices (including edge devices) at the edge of network and not exclusively seamlessly backed by Cloud services, to collaboratively provide elastic computation, storage and communication (and many other new services and tasks) in isolated environments to a large scale of clients in proximity."

Because the devices were heterogeneous, the technology functioned as an intermediary between the cloud and all the processing, storage, and networking services the end device would require. This meant that the fog nodes (the previously mentioned heterogeneous devices) could be deployed anywhere with a network connection, relieving the enormous data flow that a certain company could receive [6]. Hence the name, Fog Computing; fog is closer to the individual that the cloud.

After culminating with the expansion of Fog Computing, a need to consolidate the connection between the information provided and its analysis rose. This was where Edge Computing saw a golden period of development (2015 to 2017). The composed system that resulted after uniting all previously mentioned technologies left a great form of treating data as close to the user as possible. This meant faster data analysis, lower latency, and better interactions between devices [4].

IV. Concept

Edge Computing technology is based on the collection and processing of data locally, in order to reduce return traffic to the central cloud, using technologies such as: wireless sensor networks or networks and ad-hoc processing and making use of the IoT where the edge devices, which are the ones in charge of collecting large amounts of data and then sending them to the Data Centers or to the cloud for processing.

A. Edge Gateway

The edge gateway is a crucial part of edge computing. To bring together various communication technologies, it extends cloud capabilities to your local edge devices. It's like having your own mini-cloud, with efficiency, security, low latency and local autonomy. It can be a device or software, which is used as a bridge to connect the cloud and controllers, sensors and smart devices.

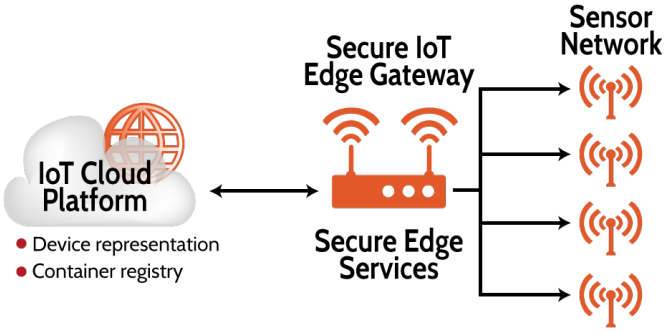

Figure 2: Edge Gateway [7]

B. Edge Devices

Refers to any device that generates or collects data, for example: Sensors, industrial machines, and more devices related to the use of the Internet. It is responsible for processing and storing part of the data they emit on the devices themselves, without sending them directly to the cloud. An edge device is any piece of hardware that controls data flow at the boundary between two networks. Edge devices fulfill a variety of roles, depending on what type of device they are, but they essentially serve as network entry or exit points. Some common functions of edge devices are the transmission, routing, processing, monitoring, filtering, translation and storage of data passing between networks. Edge devices are used by enterprises and service providers [8].

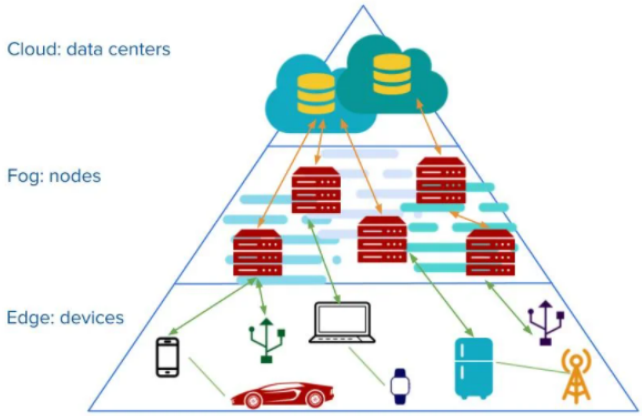

Figure 3: Edge Devices relationship [9]

C. Data Security and Privacy

Through the Edge Computing nodes travel data that involves the privacy of the client that uses this infrastructure,

providing the necessary security to this data is something that this technology must meet to be applicable in a real environment.

On the other hand, conventional data protection methods are not fully functional in Edge Computing, since it is an infrastructure that works so close to the data source that it is difficult to provide security to this system due to the increase in vulnerabilities.

However, there are processes through which solutions to these problems can be found, one of these is to make the user the one who encrypts the data and then sends it through the internet, thus granting privacy and security to their data. Other concepts, such as the migration of data security solutions from other computing paradigms to Edge Computing, parallelize the distributed computing architecture, limited terminal resources, edge big data processing, highly dynamic environment and other characteristics have helped make security more reliable and lightweight on this infrastructure [10].

D. Speed and Efficiency

Cloud Computing over time and the increase in the amount of data handled by the internet has had a deterioration in its speed, to the point that by 2022 there are many systems that use Cloud Computing that have relatively high response times, being something very dangerous if this were to happen in a real-time system that needs an almost immediate response.

According to [10] Edge Computiong offers a solution for the speed and efficiency:

> It emphasizes proximity to users and provides users with better intelligent services, thus improving data transmission performance, ensuring real-time processing and reducing delay time. Edge computing provides users with a variety of fast response services, especially in the field of automatic driving intelligent manufacturing, video monitoring and other location awareness, rapid feedback is especially important.

In summary, Edge Computing offers the user a much more efficient and faster experience when communicating with different services through the web and other interconnection systems such as real-time technologies that keep people's lives safe, like an automated car as show in fig. 4.

E. Scalability

To have good scalability with an edge computing architecture, you may need a model that satisfies some concepts, for example, connectivity between edge devices, nodes, servers, etc. There are actually two dominant models, the hierarchical model and the software-defined model [12].
1) Hierarchical Model: The hierarchical model focuses on defining the different parts of the Edge Computing architecture in such a way that a hereditary type relationship

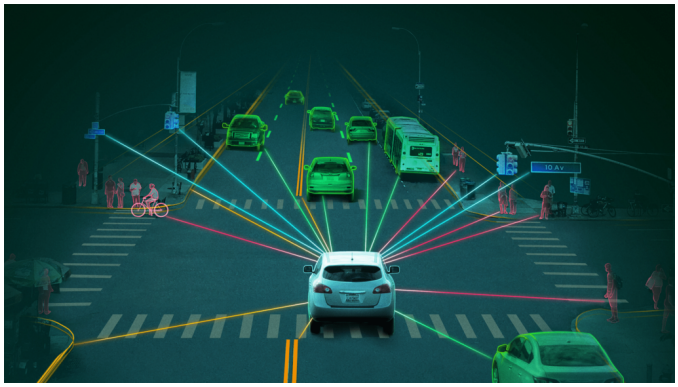

Figure 4: Car as an Edge Device [11]

can be created where each node has its function and at the same time is related to another within the structure, in this way each node fulfills its due function and the system is maintained [12].
2) Software-Defined Model: On the other hand, the Software Defined Model system focuses on implementing concepts that help manage Edge Computing and its various complexities, for example, using Software Defined Networking, which is a viable solution in terms of infrastructure management. There are even other models that help reduce implementation, administration and management costs [12].

V. Applications

Applications of the recently introduced Edge Computing have been developing over the last few years, increasing with the expansion of communication technologies and Internet of Things (IoT). The focus of these innovations applying Edge Architecture revolve around the concept of smart devices, smart cities, massive Cloud computing and mobile Edge Computing. The utilization of these modern technologies, as stated before, helps information to be analyzed faster, with less latency and with greater efficiency, enhancing direct cause-and-effect interactions.

A fitting example of the cause-and-effect situations which control is attributed to Edge Computing is the set of appliances inside what is known as a "smart home". Complex actions such as controlling lighting around the house, security systems, controlling energy and water consumption, and turning on and off devices, can be realized remotely by the application of this technology; the obtaining of signals from an electronic device are instantly passed through these systems, allowing the process to be done in a matter of seconds, or even less [13].

The whole operation in which instructions are received and sent is located as near as possible to the remotes that produce said commands. As stated by [12], "these device-to-device networks allow devices to exchange information in hybrid communication protocols", which allow the process to achieve the Quality of Service (QoS) requirements.

To continue with an example of a larger scale, one of the most used applications of the technology of interest is located inside industrial processes. Numerous businesses developed a new perspective regarding the storage and analysis of information. As stated in the definition of Edge Computing, the information would be analyzed by nodes on the edge of its retrieval. This would allow servers to process less amount of data, enhancing the latency and a faster response to the instructions provided, and cleanses the information, so that only the necessary data is transmitted to the headquarters of the business [14].

Finally, the greatest level of application of Edge Computing consists of the widely known term "Smart Cities". [13] define a smart city as "one that uses various types of IoT devices to collect data and uses these data to manage events and deliver insights". With this statement, it is possible to asume that the computing on edge proliferates in such cities.

Some of the examples of the technology of interest is the control of water consumption, energy management, lighting and control on the roads; this last one rises upon the others due to its rapid advancements, where the objective focuses on enhancing the safety of drivers and traffic management [14].

VI. Edge computing in Costa Rica.

Applications such as Uber, Didi, Waze or also the new technologies of electric vehicles with automatic driving or artificial intelligence systems, work as edge devices that are responsible for obtaining data to process them through technologies such as edge computing, and then use the information obtained. to make decisions or improve the operation of some systems. all these technologies are in operation in Costa Rica.

Wind River, a company that arrived in Costa Rica in 2018 that is responsible for the production of software for the intelligent edge, launched Wind River Studio, which is a cloud-native platform for the development, implementation, operations and maintaining critically important smart systems at the edges where safety, security and reliability are required. This platform enables productivity gains, improves agility and improves time to market with seamless technology integration including extreme edge cloud computing, data analytics and more. Studio's cloud-native infrastructure software and analytics capabilities address the complex needs of service providers surrounding the deployment and management of an ultra-low latency, physically partitioned cloud-native infrastructure [15].

VII. Conclusion

The Edge Computing Architecture functions efficiently regarding the analysis of information and regulation of the data flow, which, currently, comes as massive loads of it. However, because it works so closely to the source of information (it being the user and its device), it becomes extremely challenging to apply the correct measurements of security over the data, which locates the information in a vulnerable spot. Analyzing data in the edge enhances the speed, but decreases confidentiality.

Even though there is still some issues to resolve, it is safe to conclude that the Edge Computing is an amazing alternative for faster data transmission and comunication with other devices, proving to be even more efficient than the Cloud Computing and Fog Computing Architectures. It is specially effective when applied to systems in which real-time interactions and calculations are needed.

Regarding the future of this architecture, studies affirm that, in this moment, "around 10% of enterprise-generated data is created and processed outside a traditional centralized data center or cloud". By 2025, [16] predicts this figure will reach an oustanding 75%. Edge Computing will then become essential for the process for analyzing data flow; it will make it a lighter and more efficient interaction.

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