The influence of edge computing on the development of smart cities

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Abstract
When it comes to understanding the process of integrating technology into our daily lives, we need to know that processing data in a fast and secure way is one of the key factors to build up a smart city. Objectives of the study: to put into perspective how edge computing works and how it can be used in a smart city, reviewing information from publications that discuss how Internet of Things (IoT) can make the digitalization process easier. The paper is important because it summarizes how IoT can be the base of a smart city, putting the emphasis on how important is the process of transmitting and receiving data in a fast and secure way. Prior work: there are a numerous choices of articles that talk about how edge computing can be considered the center of the networking system in a smart city, proving that information theory in the context of passing data is crucial for the future society. Approach: systematic review of literature. Multiple scientific papers will be reviewed to get a proper understanding of the topic, focusing on answering a set of questions defined at the beginning of the study. Implications and value: this review can be a starting point for future research because the questions answered offer a different, more cohesive approach to the influence of the information theory domain on our society. It can also be viewed as a good introduction for engineers and developers on how data transmission is crucial to digitalization of a physical environment.

Keywords: IoT, digitalization, cybersecurity, network.

1. Introduction

Today's society is full of surprises and technological advancements, and we could certainly say that we expected this type of evolution looking back at how things changed throughout the years.Therefore, we might want to shift the perspective of how we look at the improvement processes of our infrastructure and we can start by going backwards, looking at the current situation, keeping in mind where everything started.

Internet of Things (IoT) is a very popular concept that has its origins in the 20th century. Everything started with a vending machine in an American university campus. The vending machine had an internet connection and was able to display the count of the remaining sodas and their temperatures. After that, people understood that devices connected to the Internet are the future and the concept has grown over the years into what we know today. [1]

In a society that places Internet of Everything (IoE) on a higher position when it comes to research and investments IoT has its own place, a place that is really important, but also dependent on other architectures such as cloud architectures or edge computing ones. These approaches may seem similar when approached in a general way, but when one starts to analyze and compare them one will see that they are indeed different, but also dependent on each other.

With the rapid evolution of IoE we have to understand that we live in a time where access to the internet is the main tool when it comes to everything: marketing, data processing, agriculture, politics. Keeping that in mind we will see that these things were possible

because of the evolution of the Web. Migrating at a steady pace to Web 3.0 we are now seeing a multitude of expansions from Web 2.0, facilitating access to huge chunks of data that can be linked together, putting emphasis on the whole picture that we can get from big data [2].

Now, how can a smart city be defined? Technology and its usage play a big role in how one can point out the fact that a city is a smart city, which means that any city that uses technology for its own benefit, in a way that is eco and cost friendly can be categorized as a smart city [3].

Cloud computing is something that we knew would come in handy and overtime this concept was proposed in one way or another, but today we can properly understand the benefits of storing and retrieving data from the cloud. Edge computing on the other hand may seem a bit odd at first, but when we break it down to the fact that it means moving processing units as close as possible to where the data is collected, the concept does not seem as odd anymore.

1.1. Scope and research questions

Edge computing and its influence on the development of smart cities is an extremely vast topic, which means that it can be broken down into many parts. Therefore, this review paper will showcase a brief understanding of some parts of this topic by providing answers to the following research questions:

- What is the difference between edge computing and cloud computing?
- Should everything be edge computed? Why not?
- How can edge computing have a positive impact on the development of a smart city?
- Can artificial intelligence be a part of a good edge computing network?

1.2. Methodology

The answer to the questions above was an approach that revolves around the systematic literature review methodology, meaning that multiple data sources were reviewed and summarized for the sake of giving answers that can be seen from multiple perspectives.

The sources cited are part of different academic databases such as: SCRD Journal, IEEE Xplore, Fair East Publishers (FEPBL), Scientific Research and Science Direct.

1.3. Acceptance criteria

Needless is to say that when using a systematic literature review methodology it is important to have a well-defined acceptance criteria for the papers used in the study and for this paper the studies selected needed to comply to the following requirements: the articles had to be quite recent (above 2018) and they needed to be as diverse as possible (the more diverse the approach the better), but still relevant to the given topic.

2. About smart cities and how can edge computing be defined?

2.1. What is a smart city?

Smart city is a generic syntax used today whenever a topic focuses on economic, environmental and social stability, but because it became such a widely used term it seems

that it became quite generic. A smart city achieves prosperity and stability in the areas named before by the usage of technology and advanced software to enhance urban infrastructure and to improve the quality of life [4]. This means that Information Technology (IT) plays a crucial role in the development of our society, especially in this context, which means that multiple problems occurred:

- How can data be transferred more effectively in the city area?
- Is the method of transferring data secure?
- Is the latency of the transfer process low enough? Why not?

If we dive a little deeper into the subject, we will see that we cannot always draw the line if a smart city is more sustainable and almost every time the focus will be put on some of the problems, not all of them [5].

The facilities offered by a smart city may include: the digitalization of the public government system, smart parking, better infrastructure for energy usage, better public transport.

Mihai Adrian Lungu compared smart parking solutions focusing on how rapid urbanization changed and exerted pressure on cities infrastructure and how smart parking can be a solution for this problem. In his study he explored different models that vary from solutions that lease underutilized lands to models that propose sensors as a solution to improve parking space by guiding the driver to a piece of land that is free to use [6].

2.2. Defining edge computing

Edge computing is a computing paradigm, which changes how data is handled and processed, moving the computing as close to the edge as possible, hence the name. The main purpose of edge computing as Keyan Cao et al say "is to make computing closer to the source of the data" [7].

This approach appeared because of the portability of the devices that increased throughout the years. With this evolution, the data that we started to consume grew up to a point where we encountered some problems regarding cost and time efficiency while using our devices.

Even though this problem may not happen very often to the average user, what happens with companies? This is an important question because the evolution of devices did not only impact individuals, but changed the core of how businesses work, shaping the future of IoT and IoE. Nowadays everything is online, accessible every hour of the day, which means that companies will experience early on their journey that they need to find a solution that is cost and time efficient and secure as well.

With business growing exponentially, cities grew as well, making possible the expansion of the smart city phenomenon. That is why the need to process big chunks of data became too costly to transfer and compute at once in the cloud, making edge computing the perfect solution for smart cities.

2.3. Edge computing versus cloud computing

One of the biggest confusions is that edge computing and cloud computing are not different.

While they might have some similarities in common, this assumption cannot be further from the truth.

Cloud computing came in handy when on premises solutions seemed too costly. Why should a company invest a lot of money into storing and processing data when an external provider can do that for less and even provide more security? With that in mind, cloud computing can be defined as the usage of resources, hosted by some external providers, facilitated by the usage of the internet. Cloud computing impacted the IT industry in a way that shifted the perception of business on how to store and handle data. It can be broken down into three types based on how one can use and access the cloud providers. These categories are public, private and hybrid. Public cloud providers offer their full-service package to their customers meaning that they provide both the infrastructure and computing capabilities. Private cloud can be accessed and used by a single company and hybrid cloud tries to combine the public and the private platform facilitating transfer between the two, making the deployment process for the companies more versatile and fitting to their specific needs [8].

Cloud computing can be fast, but if you want to process a lot of data, you may want to consider where the provider is hosting its servers and how costly they are for the amount of data that you are trying to handle.

Edge computing on the other hand is focused on the edge of the network, bringing computing as close as possible to the device that collects data. By doing that, real-time responsiveness is possible. Also, because we bring the computing closer to the edge we can process big chunks of data simultaneously. One thing to know is that all this information needs to be stored and most of the time, the choice is to store it on the cloud.

The key difference between these two is responsiveness, and the choice one should make should be based on the fact that edge computing is really well suited to process big volumes of data in real-time, while one might want to use cloud computing when the data that they want to process is not time sensitive.

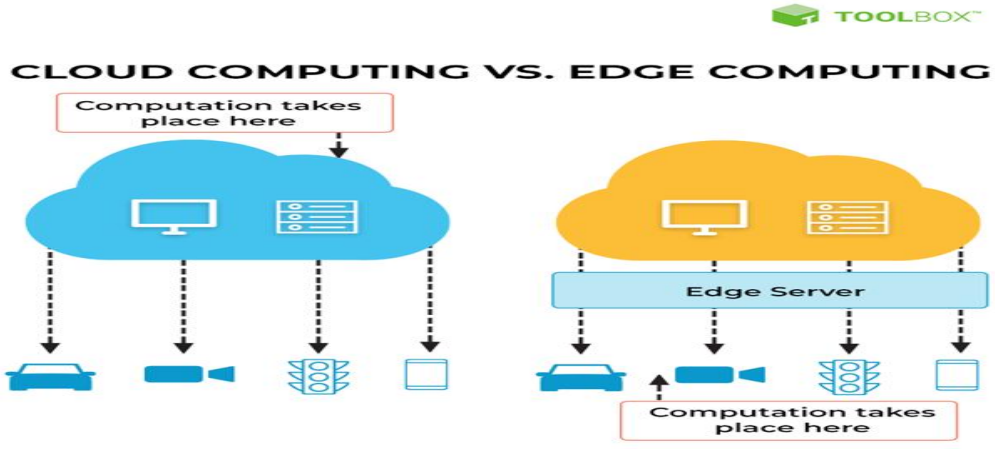

Fig. 1. Edge computing versus Cloud computing
Source: https://www.spiceworks.com/tech/cloud/articles/edge-vs-cloud-computing/.

3. The importance of edge computing in the development process of a smart city

3.1. Security threats in edge computing

Everyone wants to live in a smart city, but because this concept implies that the use of technology is for the benefit of the citizens the public administration should prioritize some aspects regarding the security of the provided digital services.

Digital services require a high level of security because they can be the most vulnerable when it comes to how easy data, especially sensitive data, can be stolen and used in unlawful contexts. As Ryhan Uddin et al stated in one of their studies about vulnerabilities of edge computing, the adoption of this technology "introduced various security vulnerabilities". In their study, they are pointing out that attacks like Denial of Service (DoS) and Distributed Denial of Service (DDoS) can be one of the most used ones because these put a heavy weight on the data traffic. By using repeated requests in an excessive way, DoS and DDoS would make the latency of the edge computed network much slower, putting the local economy at risk by causing possible financial disruptions in the local economic environment. They proposed an interesting approach that can solve this matter by using a combination of federated learning and software networking devices, making the threat detection the focus of this solution [9].

As stated before, edge computing brings the computational process as close to the end user as possible, but it still uses some sort of cloud computing that has other responsibilities rather than being the main computational part of the model. This means that some security threats may come from the usage of cloud architecture. These types of vulnerabilities may not seem direct at first, but when a cloud provider is chosen, everyone should keep in mind that the he should be resilient and fitted for the use case in relation to the geographical area of the smart city and with the providers policies for protecting data [10]. Not every cloud provider may be suited for every use case. As an example, we will analyze a digital service for a city that will let people have access to multiple medical services such as prescriptions and online consultations. If the provider does not state that they are storing data by following data protection protocols suited for medical needs, such as HIPAA, then the provider does not offer the level of security that your use case needs. Another example that takes the geographical aspect in discussion is when the cloud provider does not offer a wide range of computational machines that its services use. This means that when the digital service is used from a part of the world, the cloud provider should have a physical machine that takes the computation as close to the end-user as possible. This is important because if you imagine that a city uses a digital service for public transportation, everyone expects that the information should be displayed in real time. If the cloud provider is not close enough to handle the requests, the data will not be displayed in real time and that will cause delays, making the whole use of edge computing not ideal.

Fig. 2. Server locations of top three Cloud providers
Source: https://www.atomia.com/wp-content/uploads/2016/11/cloud-provider-location-map@2x.png

3.2. The impact of artificial intelligence

Artificial intelligence (AI) has many benefits, making it a good choice that can be used in a complex model such as edge computing. The usage of AI has many benefits for this type of network architecture because it will enhance the process of handling data in the best way possible.

The choice of integrating AI into the edge computing of a smart city can be sustained by two key factors that have a major impact in taking such a decision: AI models and algorithms can help with the task scheduling and managing resources and a good AI cloud based model can allocate the cloud resources better, because it can understand your needs.

Some articles, such as "Edge Computing with Artificial Intelligence: A Machine Learning Perspective" by Haochen Hua et al, state that Edge Computing must benefit from the usage of AI because these models can properly determine the proper bandwidth needed by the network. AI can also determine ways to lower the latency of the network and if we are talking about a smart city that has a big population, such type of intelligence model would be useful when it comes to optimization in context of data processing [11].

Combining these two sounds good, but it has some challenges as well. The choice of AI models can be tedious and difficult, because each choice should be well directed to the best possible outcome for the specific use-case scenario. In addition to that, maintaining these models and their usage is also difficult. A model that was useful now may not be a proper fit for that specific use case in the future, especially in a context such as this one, where smart cities seem to develop at an exponential rate closely related to the development of new technology. Nonetheless, the final factor should be related to how big of a change AI will bring to the table [12].

4. Personal contribution

My personal contribution to the research was prepping and analyzing the concepts presented in the referenced papers. By doing so, I was able to formulate concise and well-informed answers to the questions that I formulated at the beginning of the study. This was important, because it can be a starting point for future research, meaning that the information summarized may prove to offer a different, cohesive and complete approach on how edge computing is crucial in the development of a smart city.

By focusing on presenting concise facts from various sources I was able to reach conclusions that are essential in how things should be handled in a city that is well intertwined with the usage of modern technology.

5. Final thoughts

I consider that the papers analyzed were sufficient and representative for the topic in the current context, making it possible for me to formulate some pertinent answers to the questions formulated at the beginning of the study.

When it comes to the first research question there is no doubt that cloud computing and edge computing are different, each of them being a separate approach and a separate paradigm on how data should be processed, each with their own advantages and disadvantages.

I do not think that everything should be edge computed and the reason being that edge computing is useful in certain scenarios such as public transportation, government announcements, and agriculture. This paradigm is a good approach when we need to handle data fast and in real-time, but if we need to process data and we do not depend on real-time responsiveness, then Cloud Computing might be the better choice.

Edge computing can be beneficial to the development of a smart city because it brings the city closer to the citizens, meaning that people can understand when public transportation is on their way, which parking spots are available or when they should be going to the public administration to pay their taxes and so on. Also, this process should implement at least one model of artificial intelligence because by doing so, we can automate the process in the city in a better way. A good example of this will be to use AI to determine the best moments possible for traffic lights to display the red light based on how busy the streets are, if the traffic is at the rush hour or not etc.

To conclude, I believe that edge computing is a really good choice for the development of smart cities and by using AI in combination with computing devices closer to the edge, many aspects can be optimized, aspects such as transportation and public administration.

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