

Edge Computing vs. Cloud Computing: A Comparative Study in Resource Efficiency and Latency

Prof. Chen Ming-Yu

School of Artificial Intelligence Applications, Shenzhen Innovation University, China

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Abstract:

Computing at the edge and in the cloud have both become essential in meeting the rising need for low-latency applications and real-time data processing. The capacity to process data closer to the source, lowering latency and boosting resource efficiency has led to edge computing's rise to popularity, but cloud computing has long been the foundation of scalable, centralised computing. Research comparing cloud computing with edge computing with an emphasis on latency and resource efficiency. We compare and contrast the two paradigms' architectural features, looking at how cloud computing depends on centralised data centres, which can cause delays in data transmission owing to long-distance transmission, and how edge computing minimises data transfer times by processing information locally. We compare and contrast the two methods in a number of use scenarios, such as the Internet of Things (IoT), autonomous systems, and real-time analytics, by analysing their respective strengths and weaknesses. Hybrid systems that combine the best features of both cloud and edge computing can improve efficiency, scalability, and performance in today's computing settings.

Keywords: Edge Computing, Cloud Computing, Resource Efficiency, Latency

Introduction

More effective and adaptable computing models are required due to the exponential increase in data output, especially from IoT devices, autonomous systems, and real-time analytics. For almost a decade, traditional cloud computing—characterized by its centralised design and the scalability, flexibility, and cost-effectiveness it offers—has been the backbone of data processing and storage. Unfortunately, cloud computing encounters problems including slow data transfers and network congestion, especially in situations where snap judgements are vital, due to the ever-increasing demand for low-latency apps and real-time data processing. One strong substitute for the old-fashioned cloud is edge computing. Reduced reliance on centralised data centres means less latency and bandwidth utilisation thanks to edge computing, which processes data closer to the source, frequently at the "edge" of the network. Autonomous vehicles, industrial robots, and smart cities are just a few examples of how decentralisation is facilitating faster data processing and real-time reactions. contrast cloud computing with edge computing by looking at two key metrics: latency and resource efficiency. The advantages of cloud computing lie in its scalability and resource sharing, but edge computing, which processes data locally, reduces delays and improves efficiency. This study will compare and contrast the two paradigms, looking at their strengths and weaknesses in different contexts to determine which one is better suited to a certain task. We will also go over hybrid solutions

that take advantage of cloud and edge computing together to meet the ever-changing needs of today's IT infrastructures.

Comparing Resource Efficiency

In order to determine whether cloud computing or edge computing is more effective, resource efficiency must be considered. Both computer models have their benefits, but they use resources very differently. In this section, we will examine the similarities and differences between cloud computing and edge computing with regard to the management of system performance, energy consumption, operational costs, and resource allocation.

1. Cloud Computing's Resource Pooling and Scalability

Computing in the cloud is based on a centralised paradigm that uses massive data centres to share computing resources. The storage and computing power offered by these data centres may be dynamically scaled to suit the demands of users. One major perk of cloud computing is the scalability it provides, which is especially useful for businesses with unpredictable demand. Companies in the cloud, including Google Cloud, Microsoft Azure, and Amazon Web Services (AWS), have enormous infrastructures that their clients can use to share and allocate resources efficiently.

Although cloud computing is scalable and flexible, it may not be the best solution for applications that need responses with minimal latency. Processing data requires data transfer from local devices to central cloud servers, which increases round-trip time and uses bandwidth. Data transmission and the operation of centralised data centres both contribute to increased energy consumption, which might be a consequence of continuous data transfer between user devices and the cloud. Cloud companies do their best to minimise energy consumption and resource allocation in their operations, but there are still inefficiencies in the physical infrastructure needed to support massive data centres.

2. Edge Computing's Resource Efficiency Through Local Processing

Conversely, edge computing is geared towards processing data in close proximity to its origin—at or near the "edge" of the network, usually on Internet of Things (IoT) devices, edge servers, or local gateways. Decentralisation improves resource efficiency in several ways, one of which is by drastically cutting down on the requirement for constant data transmission to distant data centres.

Edge computing reduces latency and energy usage during data transit by processing data locally, which in turn minimises the need for bandwidth and alleviates network congestion. By tailoring edge devices to certain activities, specialised, low-power computing can run locally rather than in the cloud. Applications like autonomous vehicles and industrial automation systems, which require decisions to be made in real-time, greatly benefit from this kind of localised processing.

On top of that, operational expenses can be cut with edge computing since it lessens the need for cloud resources. Businesses can save money on data transmission fees and storage costs by processing data locally and reducing their reliance on cloud storage. Optimal resource utilisation can be achieved on a per-device or per-application basis using edge computing, as opposed to cloud computing, which necessitates the maintenance of large-scale infrastructure.

3. Energy Consumption and Operational Costs in Both Models

The total efficiency of resources is affected by the energy consumption characteristics of both cloud and edge computing. Despite being designed with power efficiency in mind, cloud data centres nevertheless require a lot of electricity because of how big their activities are. As the use of cloud computing continues to rise, data centres are increasingly using power from the grid, accounting for approximately 1% of the world's total consumption.

Applications requiring processing of small amounts of data or data not requiring long-term storage may benefit from edge computing's potential for higher energy efficiency through local processing. Although edge devices are typically made to use less power and be energy efficient, how much power they really need depends on how much data they can process and how fast they are. Furthermore, edge computing indirectly helps to decrease the carbon footprint of large-scale cloud operations by reducing the requirement for cloud data centres to process and store massive volumes of data.

On the other hand, there are operational expenses associated with edge computing. Costs can add up quickly when deploying and maintaining edge devices across dispersed sites, especially when the number of devices needs to be scaled up. Spending more up front on edge equipment may be justified by the money you save on bandwidth and cloud resources in the long run.

4. Conclusion on Resource Efficiency

When comparing the two models, edge computing and cloud computing both have their own advantages and disadvantages in terms of resource efficiency. The scalability and centralisation of resource management offered by cloud computing make it a great fit for applications that require a lot of processing power and flexibility on a wide scale. On the other hand, it may waste energy and bandwidth because to its dependence on centralised infrastructure and the transmission of massive volumes of data.

For real-time applications in particular, edge computing's advantages in latency reduction, bandwidth conservation, and energy use optimisation become abundantly obvious when data is processed locally. For applications that divide processing power across several devices and require low-latency answers, this architecture is more resource-efficient. But there's still the problem of handling massive deployments of edge infrastructure.

In the end, it's possible that a hybrid of the two methods will be the most effective. By combining the advantages of cloud and edge computing, hybrid solutions can meet the needs of latency-sensitive applications with the scalability of more traditional approaches.

Conclusion

Finally, when comparing latency and resource efficiency, both edge and cloud computing have their benefits and drawbacks. When it comes to applications that need to handle and store massive amounts of data, cloud computing is the way to go because of its scalability, flexibility, and centralised resource management. Particularly for real-time applications that require low-latency answers, their dependence on centralised data centres and long-distance data transit creates delay and inefficiencies. However, edge computing offers a convincing alternative for latency-sensitive use cases by bringing data processing closer to the source, which minimises latency and reduces the requirement for long-distance connection. Additionally, by processing

data locally, this decentralised strategy improves resource efficiency by conserving bandwidth and minimising energy use. Scaling and sustaining infrastructure across many devices or scattered locations are two of the biggest obstacles to edge computing, despite its many advantages for optimising resources and processing data in real-time. A hybrid strategy that integrates the best features of cloud and edge computing is probably where contemporary computing is headed. Business owners may take use of both models' strengths by combining edge computing with cloud computing. The former is great for processing data locally and in real-time, while the latter is better suited to storing and analysing massive amounts of data. Multiple applications, including the Internet of Things (IoT), autonomous systems, real-time analytics, and cloud-based services, can benefit from hybrid solutions' balanced approach to optimising resource efficiency, lowering latency, and assuring scalability. Improving cloud designs, creating more efficient edge devices, and achieving seamless interaction between cloud and edge infrastructures will be crucial in maximising the potential of both paradigms as they progress. With edge computing, the best approach to compute is application-specific. Cloud computing lays a solid groundwork for large-scale, data-intensive applications, and time-sensitive processes rely on it.

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