TECH REPORT:
EDGE COMPUTING

IDB

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EXECUTIVE SUMMARY

Edge computing represents a significant advance in data processing, offering agile and efficient solutions across a variety of industries and applications.

This technology enables data to be processed closer to where it is generated, effectively addressing challenges such as latency, privacy, security, and transmission efficiency.

Edge computing excels in scenarios that require real-time decision-making, limited or unstable connectivity, and contexts where privacy and security are paramount. Consequently, it has become a strategic choice for sectors such as industrial manufacturing, connected healthcare, intelligent transportation, and precision agriculture. In these sectors, technology enables everything from predictive maintenance and real-time optimization to patient monitoring and urban traffic management, providing tailored and efficient solutions.

The adoption of edge computing in Latin America and the Caribbean (LAC) underscores its ability to address the region's unique challenges, including limited connectivity and the need to process data in remote locations. Innovative projects in smart public lighting, urban security, and sustainable resource management highlight the transformative impact of edge computing in improving quality of life and operational efficiency.

Looking ahead, edge computing stands at the forefront of technological innovation. Deeper integration with artificial intelligence and the rise of 5G will unlock fresh opportunities for Internet of Things (IoT) applications. Moreover, the evolution of Edge-as-a-Service promises flexibility and efficiency for businesses of all scales. Data security will continue to be a focal point, with novel solutions aimed at safeguarding information in this decentralized setting.

To capitalize on the possibilities offered by edge computing, organizations must adopt a strategic stance. This entails carefully evaluating their requirements, educating personnel on relevant technologies, and implementing appropriate security protocols. Staying on top of emerging trends and working with specialized technology partners will be essential to successfully navigating the dynamic landscape of edge computing.

DEFINITION

The concept of edge computing may seem like a recent development, but its origins can be traced back to the early stages of computing. Initially, before the advent of modern computer networks, computing tasks were performed locally on individual devices. A classic example is a pocket calculator, which handles all computations internally without relying on external resources.

The late 1990s and early 2000s saw the rise of cloud computing, revolutionizing data storage and processing. Instead of relying on the local computing power of a single device, cloud computing allows users and enterprises to access computing resources via the Internet, hosted in remote data centers. This technology offers numerous advantages, including scalability (the ability to adjust computing resources as needed), cost savings in infrastructure, and the flexibility to access applications and data remotely.

As technology progressed and the proliferation of internet-connected devices, particularly within the Internet of Things (IoT) ecosystem, accelerated, the imperative to process data closer to its source has become evident. Thus, in the mid to late 2010s, the term of "edge computing" emerged, focusing on processing data directly on or near the device generating it. Edge computing gained momentum due to the need to reduce latency (response time) in critical applications, enhance data privacy and security, and efficiently manage the vast amounts of data generated by IoT devices. It also addresses bandwidth limitations by offering more efficient data processing solutions for the IoT and real-time applications' era. This approach optimizes resource utilization and enables a more rapid and tailored response to the specific needs of each context, marking a significant advancement in how data is managed and processed in the current digital environment.

EVOLUTION

The evolution of edge computing has been fueled by several key factors that have contributed to its rapid growth and adoption in recent years:

- **Proliferation of IoT devices.** The widespread adoption of Internet of Things (IoT) devices has been instrumental in driving the development of edge computing. These devices generate huge amounts of data that require fast and efficient processing. The need to process this data locally, without relying on a constant connection to the cloud, laid the foundation for the adoption of edge computing.

- **Addressing latency challenges.** The expansion of IoT has highlighted the limitations of centralized cloud processing, particularly in terms of latency. Edge computing emerged as a solution to this challenge, enabling data processing closer to its source. By minimizing latency, edge computing increases the speed and efficiency of data processing, improving overall performance.

- **Technological advancements.** Continuous innovation and advancement in edge computing devices have played a pivotal role in their widespread adoption. Hardware improvements have led to the development of more compact, powerful, and energy-efficient devices, facilitating their deployment across various environments.

- **Integration with 5G technology.** While edge computing can function independently, the introduction of 5G technology has fostered the creation of hybrid systems that combine edge and cloud computing. The high speeds and low latencies of 5G enable seamless data transfer between IoT devices and the cloud in hybrid setups. This integration improves the efficiency and flexibility of data processing and analysis.

- **Economic impact across industries.** Edge Computing has evolved beyond merely enhancing user experience to having a significant economic impact across diverse industries. It is used in sectors such as manufacturing, healthcare, agriculture, and transportation to provide efficient solutions for real-time data analysis, automated decision-making, and operations management.

WHEN TO USE EDGE COMPUTING

Edge computing has become a preferred option in various scenarios and applications, especially when compared to cloud computing. Here are the reasons why edge computing stands out as the right choice, particularly in the context of Latin America and the Caribbean:

Real-time decision-making. Edge computing is crucial in applications that require immediate response, such as emergency response systems or critical infrastructure monitoring. By processing data directly at the source, latency is virtually eliminated, enabling fast and accurate decisions that are critical to the operation and security of these systems.

Limited or unreliable connectivity. In regions with nonexistent, slow, or unstable internet connections, which are common in many emerging markets in LAC, edge computing becomes essential. Processing data locally eliminates dependence on constant internet connectivity, ensuring operational continuity and efficiency.

High privacy and security. Edge computing is preferred for applications that require high levels of data privacy and security. By processing and storing data locally, the risk of exposure during data transmission over the Internet is significantly minimized. This is critical in sectors like healthcare, where telemedicine requires meticulous handling of personal data, and in business environments dealing with sensitive information.

Reduction of data transmission costs. Local data processing at the edge reduces the need to transmit large data volumes to the cloud, significantly decreasing bandwidth and transmission costs. This aspect holds particular relevance in LAC, where connectivity costs can be a limiting factor.

Efficient scalability. Edge computing enables more efficient scalability by distributing data processing across multiple nodes. This improves the ability to handle large volumes of data generated by multiple devices, an important consideration in environments with an increasing number of IoT devices.

Regulatory compliance. Edge computing facilitates compliance with regulations that restrict data transfer across international borders. By processing data within the appropriate jurisdiction, companies can more easily adhere to these regulations.

Personalization and local responsiveness. For applications that require either adaptation to the local context or specific responses to local events, edge computing offers an effective solution. This enables faster and more effective adaptation to local conditions, which is especially useful in geographically and culturally diverse regions such as Latin America and the Caribbean.

Improved energy efficiency. Data processing at the edge promotes a number of sustainability strategies, such as using renewable energy directly at the source of device charging and optimizing software and hardware to maximize energy efficiency. It also provides more efficient cooling solutions tailored to small infrastructures. In addition, proximity to points of use reduces the need for long-distance connectivity, further reducing energy consumption.

EDGE COMPUTING AND CLOUD COMPUTING

Today, edge computing and cloud computing coexist and complement each other based on the specific needs of applications. The decision to use edge or cloud computing depends on factors such as the need for real-time processing, geographic location, data volume, and security concerns. For example, applications that require immediate response, such as driver assistance systems in cars, benefit from edge computing, while those requiring large-scale data analysis, such as processing extensive datasets, favor cloud computing.

Here's a comparative table summarizing the key differences between edge computing and cloud computing technologies, emphasizing the areas where each approach holds advantages, depending on specific application needs:

CRITERIA	EDGE COMPUTING	CLOUD COMPUTING
Connectivity	Preferred in limited or unstable connectivity	Relies on stable and fast internet connection
Transmission and Maintenance Costs	Lower transmission costs	May incur higher bandwidth costs
Scalability	Distributes processing, scalable to multiple nodes	Centralizes resources; scalable but depends on the cloud
Regulatory Compliance	Facilitates compliance with local regulations	May face challenges in cross-border regulations
Personalization and Local Response	Rapidly adapts to local conditions and events	Less customization to specific local conditions
Energy Efficiency	Potentially more energy-efficient	Dependent on centralized data centers
Analysis and Storage Capacity	Limited capacity for massive analysis and storage	Ideal for analysis and storage of large volumes of data
Centralized Management and Maintenance	Requires distributed management and local maintenance	Facilitates centralized management and maintenance
Global Access and Collaboration	Less suitable for global access and collaboration	Enables global access and collaboration
Data Backup and Recovery	May present challenges in backup and recovery	Robust solutions for data backup and recovery

The decision between edge computing and cloud computing requires a thorough assessment of specific business requirements, considering critical aspects such as data sensitivity, latency requirements, scalability, cost, and deployment complexity. Following this assessment, the most appropriate solution, or a hybrid blend of the two, can be identified to best meet business objectives.

In this context, hybrid systems that blend edge computing and cloud computing are emerging as a valuable strategy. Important or sensitive data is processed locally at the edge in these systems, which reduces latency and improves security. The processed results, such as identifiable information or metadata, are then sent to the cloud for comprehensive analysis and storage. This hybrid model effectively handles large volumes of data by leveraging the speed of the edge for initial processing and the capacity of the cloud for long-term storage and analysis. The result is a comprehensive solution that effectively integrates speed, security, and scalability.

USE CASES

Edge computing is being used in a wide range of industries to provide innovative solutions to specific challenges. Below, we delve into some of the more notable use cases, with an emphasis on scenarios where connectivity is limited, real-time data processing is imperative, or where efficiency and speed are critical.

- **Industrial manufacturing.** Edge computing plays a vital role in predictive maintenance and real-time optimization in industrial settings. By processing sensor data directly within production plants, edge reduces latency and enables immediate responses for machinery adjustments and fault prevention. This immediate responsiveness is critical in industrial environments where every second counts.

- **Connected healthcare.** In healthcare, edge computing is crucial for real-time patient monitoring, especially in critical situations. Since transferring sensitive health data to the cloud can cause delays, local processing of data on medical devices enables faster and more secure response, which is essential for medical emergencies or continuous monitoring of chronic conditions.

- **Intelligent transportation.** Edge computing's ability to process data locally is vital for real-time traffic management. Latency in data transmission to the cloud can affect the effectiveness of decisions in critical situations, such as rapidly changing traffic conditions. Edge computing enables immediate response to changing situations, improving safety and efficiency in cities.

Retail and customer experience. In retail, edge computing improves the customer experience by processing data locally at the point of sale. This enables personalized recommendations and efficient inventory management in real time, which would be slower and less effective if relying on cloud processing.

Environmental monitoring. Edge computing is instrumental in processing data in remote environmental monitoring locations with limited internet connectivity. Environmental sensors are often installed in remote areas where transmitting large amounts of data to the cloud would be impractical. By analyzing data locally, edge provides valuable insights into environmental conditions without the need for constant internet access, essential for monitoring and managing ecosystems effectively.

Smart agriculture. Similar to environmental monitoring, edge computing supports smart agriculture by locally processing data from remotely located agricultural sensors. This enables farmers to make informed, real-time decisions without continuous Internet connectivity by locally processing soil and weather data, which is critical in rural areas with limited connectivity.

Security and surveillance. Edge computing is essential for processing images and video locally, eliminating the need to send large amounts of data to the cloud. This is particularly useful in facial recognition and video analytics, where edge can identify people or events of interest and transmit only the essential information, such as the name of an identified person, instead of the entire video.

Entertainment and media. In the entertainment industry, edge computing addresses high traffic and real-time data demands, particularly in streaming and live events. By processing and storing content close to the end user, edge reduces latency and improves delivery quality, ensuring a smooth and uninterrupted user experience, even in high-demand situations.

KEY CHALLENGES OF **EDGE COMPUTING**

Edge Computing has indeed become a prominent and indispensable part of the technological landscape, with numerous providers offering solutions, tools, and services to facilitate its adoption. These solutions can be easily integrated into existing systems, enabling companies to deploy and scale their edge applications with ease, without the need to build infrastructure from scratch.

However, in addition to the specific challenges faced by the IDB, the following are some of the most common ones that can arise in any edge computing initiative:

Selecting the right infrastructure. It is important to choose an appropriate infrastructure for each edge computing project. This includes hardware, software, networking, and storage. Infrastructure selection should take into account project requirements, budget, scalability, and data processing capacity.

Integration with existing systems. To ensure that the project works properly, it is necessary to integrate its hardware and software with those of existing systems. This can be challenging, especially if they are not compatible.

Maintenance and management. The management and maintenance of edge computing devices can be a difficult task. Devices can pose significant challenges, especially when they are distributed across multiple locations. Trained personnel and appropriate management tools are necessary to keep the system running efficiently. Solutions that enable over-the-air activation, maintenance, and updates are recommended.

Connectivity. Connectivity is a critical aspect of edge computing, particularly in hybrid systems that rely on both edge and cloud computing capabilities. Industrial environments and remote areas may face difficulties with limited or unstable connectivity, so appropriate solutions must be implemented to ensure the success of the project.

THE FUTURE OF **EDGE COMPUTING**

The future of edge computing appears highly promising, poised for continued growth and evolution in the years ahead. Drawing from current trends and forecasts, here are some key highlights regarding the trajectory of edge computing for 2024 and beyond:

- **Integration of artificial intelligence.** AI is expected to play a key role in edge computing, enabling real-time data analysis and processing, autonomous decision-making, and intelligent anomaly detection.
- **Wider adoption of 5G technology:** 5G will significantly enhance edge computing capabilities by providing high-speed, low-latency connectivity, enabling new use cases and greater efficiency in data processing.
- **IoT applications.** Edge computing will continue to strengthen its role in the IoT, facilitating efficient connectivity and data exchange between multiple devices.
- **Edge-as-a-Service (EaaS).** The evolution of Edge-as-a-Service will enable organizations to deploy edge computing and services with greater flexibility and speed, without the need for substantial infrastructure investment.
- **Focus on data security.** There will be a greater emphasis on improving security measures within edge devices to safeguard the integrity and confidentiality of data, both during storage and during transmission.

- **Deployment of edge containers.** The use of edge containers can be expected to increase to help decentralize computing resources and improve the digital experience for users.
- **Edge data analytics.** Edge data analytics will provide organizations with contextual information to support decision-making and identify anomalies, patterns, and optimization opportunities.
- **Blockchain and edge computing solutions.** More digital solutions will emerge that integrate blockchain technology and edge computing, enhancing data security and integrity in distributed environments.
- **Growth of edge computing data centers.** Data centers will continue to adapt to the evolving demands of edge computing by developing agile, scalable and robust solutions.

In summary, edge computing is positioning itself as a key technology for the future, with continued growth and the emergence of new applications and services that take advantage of its speed, efficiency, and security.

REQUIREMENTS **AND OBSERVATIONS**

Businesses aiming to adapt to the evolving landscape of edge computing should consider a set of strategic approaches and recommendations. These strategies will not only enable them to harness the benefits of this technology but also navigate the challenges associated with its implementation and future development:

ASSESSMENT AND STRATEGIC PLANNING

- Conduct a comprehensive analysis of the organization's specific needs and how edge computing can address them. This includes assessing data sensitivity, latency requirements, scalability, costs, and deployment complexity.
- Develop a strategic plan for the required infrastructure, aligning it with the nature of applications and the volume of data to be processed.

TRAINING AND SKILLS DEVELOPMENT

- Invest in training programs for staff to enhance their expertise in edge computing, AI, and IoT technologies, ensuring a proficient team capable of effectively managing and maintaining systems.
- Explore partnerships with technology vendors and specialized providers to access additional expertise and support.

INNOVATION IN DATA SECURITY

- Prioritize data security by implementing the latest solutions in cryptography, authentication, and perimeter security tailored for edge computing environments.

- Establish robust security protocols and backup procedures to safeguard data both during storage and transmission.

CONNECTIVITY OPTIMIZATION

- Assess and deploy robust and stable connectivity solutions, particularly in remote or industrial settings, to ensure the reliability of edge computing systems.
- Prepare for the integration of 5G networks and plan how this technology can improve edge computing operations and performance.

ADOPTION OF FLEXIBLE ARCHITECTURES

- Implement flexible and modular architectures that facilitate seamless integration of new devices and scalability of systems as business needs evolve.
- Consider using containers and orchestration solutions to simplify the deployment and management of applications in edge environments.

EXPLORATION OF EDGE-AS-A-SERVICE

- Research and consider adopting Edge-as-a-Service models to mitigate initial investment costs and complexity associated with managing edge computing infrastructure.
- Evaluate EaaS providers offering solutions tailored to the specific requirements of the business.

FOCUS ON DATA ANALYTICS AND AI

- Integrate advanced data analytics and artificial intelligence solutions to enable real-time information processing and analysis, enabling faster, data-driven processes for decision-making.
- Stay abreast of advancements in AI and machine learning to continuously enhance data analysis capabilities and operational efficiency.

FUTURE READINESS

- Maintain a proactive stance on emerging technology trends, such as blockchain and new data center solutions, to leverage these technologies as they mature and become more accessible.
- Foster a culture of innovation within the organization, encouraging exploration and adoption of new technologies and practices to stay ahead of the curve.

ADDITIONAL **REFERENCES**

The 5G Edge Computing value opportunity
Posted by KPMG, 06/2020
https://assets.kpmg.com/content/dam/kpmg/co/sac/pdf/2020/07/5g-edge-computing-value-opportunity.pdf

Data growth will precipitate growth for edge data centers in Caribbean, IDC says
Posted on EdgeIR.com, 07/14/2022
https://www.edgeir.com/data-growth-will-precipitate-growth-for-edge-data-centers-in-caribbean-idc-says-20220714

AWS to open Edge Computing zones in six LatAm cities by 2023
Posted in BNamericas, 02/17/2022
https://www.bnamericas.com/en/news/aws-to-open-edge-computing-zones-in-six-latam-cities-by-2023

Brazil's Edge Computing investments set to soar with 5G, analytics and cloud
Posted in BNamericas, 02/11/2022
https://www.bnamericas.com/en/features/brazils-edge-computing-investments-set-to-soar-with-5g-analytics-and-cloud

Latin America, on the edge of Edge Computing?
Posted in Tegnologicos.com, 09/09/2022
https://www.bnamericas.com/en/features/latin-america-on-the-edge-of-edge-computing

Top Edge Computing Companies for 2022
Posted in CIO Insight
https://www.cioinsight.com/infrastructure/edge-computing-companies/

Top 10 Edge Computing Companies of 2022
Posted in eWEEK, 12/02/2021
https://www.eweek.com/networking/edge-computing-companies/

100 Edge Computing companies to watch in 2023
Posted in STL Partners
https://stlpartners.com/articles/edge-computing/edge-computing-companies-2023/

36 Edge Computing companies to watch in 2023
Posted in TechTarget, 12/13/2022
https://www.techtarget.com/searchcio/tip/5-edge-computing-vendors-for-CIOs-to-watch

Top 5 Edge Computing use cases and examples
Posted in TechRepublic, 09/13/2022
https://www.techrepublic.com/article/edge-computing-use-cases/

10 Edge Computing use case examples
Posted in STL Partners
https://stlpartners.com/articles/edge-computing/10-edge-computing-use-case-examples/

Examples Of Edge Computing (11 Examples)
Posted in Prize, 03/15/2021
https://premioinc.com/blogs/blog/examples-of-edge-computing

Top 10 Edge Computing Trends Shaping the Digital Landscape in 2024
Posted in Tech Research Online, 10/30/2023
https://techresearchonline.com/blog/top-10-edge-computing-trends-in-2024/

The Rise of Edge Computing: IT's Next Frontier in 2024
Posted in IT Executives Council, 11/20/2023
https://itexecutivescouncil.org/the-rise-of-edge-computing-its-next-frontier-in-2024/

Explore the Top 10 Edge Computing Trends in 2024
Posted in StartUs Insights
https://www.startus-insights.com/innovators-guide/edge-computing-trends/

¿Cómo deben prepararse los CIO de América Latina para aprovechar Edge Computing en diversas industrias?
Article in Spanish posted in Intelligent CIO, 01/27/2023
https://www.intelligentcio.com/latam-es/2023/01/27/como-deben-prepararse-los-cio-de-america-latina-para-aprovechar-edge-computing-en-diversas-industrias/

8 Edge Computing trends to watch in 2024 and beyond
Publicado en TechTarget, 18/01/2024Posted in TechTarget, 01/18/2024
https://www.techtarget.com/searchcio/tip/Top-edge-computing-trends-to-watch-in-2020

It's Time to Think Beyond Cloud Computing
Posted in Wired, 09/23/2017
https://www.wired.com/story/its-time-to-think-beyond-cloud-computing/

Edge Computing: qué es y por qué hay gente que piensa que es el futuro
Article in Spanish posted in Xataka, 01/23/2018
https://retinatendencias.com/negocios/5g-y-computacion-en-el-borde-no-todo-es-nube-en-el-futuro-de-la-tecnologia/

'Edge Computing', o cómo acelerar Internet
Article in Spanish posted in El País, 07/25/2019
https://elpais.com/retina/2019/07/24/innovacion/1563968784_364326.html

Edge Computing: what it is and why it matters
Posted in MIT Technology Review, 06/04/2021
https://www.technologyreview.com/2021/06/04/1025159/edge-computing-explainer/

Edge Computing: Challenges and opportunities
Posted in ZDNet, 08/23/2021
https://www.zdnet.com/article/edge-computing-challenges-and-opportunities/

Edge Computing in healthcare: A new paradigm for patient care
Posted in Healthcare IT News, 23/03/2022
https://www.healthcareitnews.com/news/edge-computing-healthcare-new-paradigm-patient-care

Why Edge Computing Is the Future of Data Processing
Posted in Forbes, 8/04/2022
https://www.forbes.com/sites/forbestechcouncil/2022/04/08/why-edge-computing-is-the-future-of-data-processing/?sh=1d9504d64f24

5G and Edge Computing: It's Not All Cloud in the Future of Technology
Article in Spanish posted in Retina, 07/06/2022
https://retinatendencias.com/negocios/5g-y-computacion-en-el-borde-no-todo-es-nube-en-el-futuro-de-la-tecnologia/

The Future of Edge Computing: 5 Predictions for 2023
Posted in IoT For All, on 02/27/2023
https://www.iotforall.com/the-future-of-edge-computing-5-predictions-for-2023

GLOSSARY OF TERMS

5G Fifth generation of mobile communication technology, providing faster connection speeds, lower latency, and greater network capacity, enabling advanced connectivity and emerging applications such as IoT and autonomous vehicles.

CLOUD ARCHITECTURE An approach to the design and delivery of services and applications that uses remote, scalable computing resources provided over the Internet. It empowers organizations to efficiently utilize computing power without the burden of managing physical servers locally.

BLOCKCHAIN Utilizing cryptographic techniques, blockchain is a digital ledger technology that ensures secure and verifiable transactions across a decentralized network. It provides a transparent and tamper-resistant method for recording digital transactions.

CLOSED-CIRCUIT TELEVISION (CCTV) This video surveillance system employs cameras to transmit signals to designated monitors or a centralized location for real-time monitoring and recording of activities.

DATA CENTER These extensive facilities serve as hubs for large-scale data storage and processing operations utilized by major corporations.

CLOUD COMPUTING Computing model that uses remote computing resources, generally located in data centers, to store and process data. It allows users to access services and applications through the Internet.

COMPUTER VISION A branch of artificial intelligence focused on training machines to interpret and comprehend the visual world, encompassing images and videos, akin to human perception.

CONNECTIVITY The capability to establish links between multiple devices. It is the type of connectivity that determines the speed and capabilities of that connection. For instance, 5G outperforms 4G, while infrared or Bluetooth connections serve distinct purposes from internet-based connections.

EDGE-AS-A-SERVICE (EAAS) This business model provides edge computing services and resources via a cloud-based platform, enabling companies to leverage edge technology without the overhead of managing their own infrastructure.

EDGE COMPUTING Technology that involves data processing at or near the point of generation, rather than transmitting it to centralized data centers or the cloud, facilitating quicker response times and reducing reliance on internet connectivity.

ARTIFICIAL INTELLIGENCE (AI) A collection of technologies and methodologies enabling machines to execute tasks typically requiring human intelligence, such as learning, adaptation, problem-solving, and decision-making.

INTERNET OF THINGS (IOT) An interconnected network of physical objects equipped with sensors, software, and communication technologies, enabling data sharing and connectivity over the internet.

LATENCY The time interval between data generation, processing, and the subsequent command transmission back to the originating device for execution.

CONFUSION MATRIX A pivotal tool for evaluating classification algorithms, showcasing the performance of a model by delineating correct and incorrect predictions in tabular form, aiding in the analysis of its accuracy.


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