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## **A Report On**



# **EDGE COMPUTING**

*Solving Latency Challenges in Modern Networking*

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# INTRODUCTION

## Abstract:

Edge computing has become a powerful solution to the growing challenges of cloud computing, especially with the rise of IoT devices and data-heavy applications. As traditional cloud systems face problems like slow response times, limited bandwidth, and privacy risks, edge computing provides a more efficient approach by processing data closer to where it's created. This research paper explains the major issues with cloud computing, such as delays in real-time processing and network overload, and shows how edge computing reduces these problems by speeding up data processing, saving bandwidth, improving security, and lowering energy use. Key examples of its use include autonomous vehicles, smart cities, healthcare, and modern industries. The paper also looks ahead to the future of edge computing, focusing on how 6G, WIFI7, artificial intelligence (AI), and better collaboration between edge and cloud systems will push the technology forward. Although edge computing offers many advantages, it still faces challenges like security risks, scaling up, and resource limitations. This paper highlights these challenges and underlines the important role edge computing will play in shaping the future of networking technology.

According to research, the number of devices connected to the internet in 2026 would be more than thrice of the world's population (27 Billion Approx). The continuous growth of the Internet of Things (IoT) and data-hungry applications has exposed the shortcomings of traditional cloud computing, particularly regarding latency, bandwidth, and privacy concerns. Edge Computing has emerged as a promising solution, bringing data processing closer to the source and addressing many of these limitations.

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## Understanding the Problem

### 2.1 Latency in Cloud Systems

Traditional cloud computing architecture involves transferring data from devices to centralized data centers for processing. This can introduce significant latency, especially in applications that require real-time decision-making, such as **autonomous vehicles** or **remote surgery**. Data traveling over long distances experiences delays that can cause serious circumstances in these scenarios.

## 2.2. Bandwidth Limitations

With the rise of IoT devices, data generation has exploded. By 2028, it is predicted that IoT devices will produce 80 billion connected units. Sending all this raw data to the cloud not only strains network bandwidth but also results in inefficient resource utilization. The cloud computing model and the current network capabilities, built to handle large-scale centralized processing, struggle to keep up with the ever-increasing volume of data.

## 2.3. Security and Privacy Concerns

One of the most critical issues in cloud computing is data privacy and security. When sensitive data, such as health records or financial information, is transmitted to centralized servers, it becomes vulnerable to potential breaches during transmission. As privacy laws are becoming stricter day by day, the need to process data locally is increasing.

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# Edge Computing: A Revolutionary Solution

## 3.1. What is Edge Computing?

Edge Computing is a distributed computing paradigm that processes data closer to where it is generated, i.e., at the "edge" of the network. Instead of relying solely on distant cloud data centers, edge computing enables devices and local servers to analyze and act on data immediately, improving speed and reducing the need to transmit data to centralized systems. This is a major break through in the field of networking that will revolutionize the way cloud computing works and will increase bandwidth while decreasing the latency.

## 3.2. Key Components of Edge Computing

- **Edge Devices:**  
These are IoT-enabled devices equipped with processing power, such as sensors, cameras, or smart thermostats.
- **Edge Servers/Gateways:**  
These servers act as intermediaries, processing data before sending essential information to the cloud.
- **Local Networks:**  
Communication networks that support edge devices and servers, providing low-latency interaction

### 3.3. Comparison Between Cloud and Edge Computing

While cloud computing excels in providing massive storage and computational power, it often fails to meet the real-time processing needs of edge devices. Edge computing, on the other hand, focuses on decentralization, bringing computation closer to data generation sources, resulting in quicker decision-making and response times.

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## How Edge Computing Solves Cloud Challenges

### 4.1. Reduced Latency

By processing data locally, edge computing significantly reduces the time it takes for devices to receive actionable insights. In **autonomous vehicles**, for example, a delay of milliseconds could be the difference between avoiding or causing an accident. Edge computing ensures faster data processing and decision-making.

### 4.2. Efficient Bandwidth Utilization

Edge computing handles most data processing locally and only sends aggregated or essential data to the cloud, saving bandwidth. This minimizes the load on centralized networks, making them more efficient and reducing the cost of data transmission.

### 4.3. Enhanced Privacy and Security

Since data is processed closer to its source, it reduces the need to transmit sensitive information over long distances, thereby minimizing exposure to potential breaches. For industries like healthcare, where privacy is paramount, edge computing offers an added layer of protection.

### 4.4. Energy Efficiency at the Edge

Processing data locally helps reduce energy consumption associated with sending vast amounts of data to centralized data centers. By offloading computation from the cloud to the edge, energy consumption is spread across the network, making it more sustainable.

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# Use Cases of Edge Computing

## 5.1. Autonomous Vehicles

In autonomous driving, edge computing plays a crucial role by processing real-time sensory data from cameras, radars, and LIDAR systems. Immediate local computation allows vehicles to make split-second decisions, enhancing safety and reliability.

## 5.2. Smart Cities

Edge computing powers **smart city** initiatives by enabling real-time monitoring of traffic, energy consumption, and public services. Localized processing ensures quicker responses to changes in urban environments.

## 5.3. Healthcare Applications

Edge devices in healthcare, such as wearable sensors, can monitor vital signs and detect irregularities in real-time, notifying medical staff instantly. This decentralized approach improves response times in emergency situations.

## 5.4. Industry 4.0

In manufacturing, edge computing helps optimize production by analyzing data from machinery in real-time. This predictive maintenance reduces downtime and enhances operational efficiency

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# The Future of Edge Computing

## 6.1. The Role of 6G and WIFI7 in Expanding Edge Capabilities

The rollout of **6G networks** and **WIFI7** Protocol will expand edge computing capabilities by providing higher speeds, lower latency, and more bandwidth. This will enhance not only real-time processing in applications such as **virtual reality (VR)** and **augmented reality(AR)** but also the current cloud computing and VPS servers.

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## 6.2. Edge AI: Enhancing Intelligence at the Edge

**Artificial Intelligence (AI)** at the edge will allow devices to make even more intelligent decisions locally. For example, smart cameras in security systems can detect threats and respond autonomously without relying on cloud servers all the time.

### 6.3. Edge-Cloud Collaboration: The Next Evolution

In the future, we can expect seamless collaboration between edge and cloud computing. Workloads will be intelligently distributed between the edge and the cloud, with cloud handling large-scale data analysis and storage, while edge devices handle real-time computations

### 6.4. Energy and Sustainability in Edge Computing

Edge computing can also contribute to a more sustainable future by reducing the energy load on massive data centers. Distributed networks that rely on edge processing will consume less power, aiding global efforts to minimize the environmental impact of technology.

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## REAL LIFE EXAMPLE

Edge Computing is a crucial part of Tesla's technology, especially in its autonomous driving systems. Tesla cars are equipped with an array of sensors, cameras, and AI-powered hardware that process vast amounts of data in real-time. This processing needs to happen locally (at the edge) within the car itself to ensure fast decision-making, which is critical for functions like Autopilot and Full Self-Driving (FSD).

#### How TESLA Uses Edge Computing:

1. **Real-time Data Processing:** Tesla vehicles use edge computing to process data from cameras, radar, and ultrasonic sensors directly in the car. This allows immediate reactions to obstacles, road conditions, and traffic, reducing the latency that would occur if the data had to be sent to a cloud server.
2. **Autonomous Driving:** For autonomous features like lane-keeping, object detection, and emergency braking, edge computing ensures that the car can make split-second decisions without relying on cloud servers. This is essential for safety, as sending data back and forth to the cloud would introduce delays that could result in accidents.
3. **Neural Networks on Edge:** Tesla's cars run complex AI models directly on the onboard hardware, enabling them to interpret and analyze the environment. The **Tesla Full Self-Driving (FSD) chip** is a powerful processor specifically designed to run these neural networks at the edge.

4. **Software Updates and Learning:** While edge computing handles real-time tasks, Tesla cars also periodically send large scale data to the cloud for broader updates and improvements. Tesla uses this data for **fleet learning**, where insights from millions of miles driven by Tesla cars worldwide help improve the algorithms that run on each individual car and in turn, improves the overall eco system of TESLA.

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## CONCLUSION

Edge computing has emerged as a critical advancement in computer networking, addressing the limitations of traditional cloud architectures. By processing data closer to the source, edge computing reduces latency, optimizes bandwidth, enhances privacy, and improves energy efficiency. As technology advances, the integration of 5G, AI, and edge-cloud collaboration will shape the future of this paradigm, opening up new possibilities for industries ranging from healthcare to smart cities. However, overcoming challenges related to security, scalability, and resource management will be crucial in fully realizing the potential of edge computing. As industries increasingly adopt this technology, edge computing is poised to play a pivotal role in driving innovation and enhancing the efficiency of modern networks.

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### NOTE:

You can scan this Qr code to get the links of the original Research papers.

