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Integrating Edge and Cloud Computing Technologies to Process Big Data in IoT Applications: A Practical Experience and Comparative Results with Real-World Examples

Abas Wisam Mahdi Abas[1*], and S. Ya. Egorov[2]

[1*]Presidency of Diyala University, University of Diyala, Diyala, Iraq.
wisam.mahdi@uodiyala.edu.iq, https://orcid.org/0009-0004-3728-5975

[2]Al-Iraqia University, Baghdad, Iraq. egorovsy@yandex.ru; egorovsy55@gmail.com,
https://orcid.org/0000-0003-1921-8002

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Abstract

The ever-growing development of the technology of Internet of Things (IoT) is augmenting the frequency of producing data on a range of spaces. This is encompassed of the sectors of health care, smart cities, industrial, automation and transport systems. The incessant problem in real-time management of streams of data is the latency growth, bandwidth optimization and scalability. The research article explains a hybrid system of IoT involving the combination of Edge and Cloud Computing to process the Big Data. The empirical study conducted is applied on the performance metrics of a performance assessment of redundant edge nodes and a centralized Cloud throughput, latency and energy resource consumption. The Hybrid Edge–Cloud model reduced latency by ~68% vs Cloud-only (380 → 120 ms) and ~25% vs Edge-only (160 → 120 ms); lowered energy per node by ~31% vs Edge (14.6 → 10.1 W) and ~18% vs Cloud (12.3 → 10.1 W); and cut bandwidth utilization by ~45% vs Cloud-only (85% → 47%). Throughout was about 11% of Cloud and about 50% more than Edge. This shows how Edge Local Computing which is scalable and cheap due to Cloud memory makes models efficient and responsive. It is also economical and provides huge value for money here. The integrative policy is innovatively valuable because decreasing traffic congestion through local data processing delivers a higher degree of intelligent decision-making.

Keywords: Cloud Computing, Edge Computing, Internet of Things (IoT), Big Data Processing, Latency Optimization, Energy Efficiency, Smart Infrastructure.

1 Introduction

Cloud computing and edge computing technologies provide a new paradigm to enable researchers deal with challenges associated with processing big data in IoT (Ajayi, 2025). According to the results from the empirical standpoint, a hybrid model may be formulated to solve and overcome the issues with the distinct computing model with a significant reduction in latency and energy efficiency and scaling up the overall efficiency. The time-constrained nature of Edge Computing has the potential to generate slack centralized processing requirements, which is an expedient response to the challenges already posed by those applications of the IoT. Essential viability of Edge Computing as the solution to the needs is based on the closeness of computational intelligence to the source of data.

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*Corresponding author: Presidency of Diyala University, University of Diyala, Diyala, Iraq.

Local process of information implies that analyses and decision making can be done more quickly. This significantly reduces the need for high-bandwidth connections to remote central Cloud servers (Busi, 2025). Although advantageous, the use of Edge Computing still has limitations imposed by resource constraints, including the availability of processing power, limited memory, and the restricted scale of available energy. This makes it less efficient in tackling the problems of large-scale Machine Learning or in cases where the required aggregation of disparate data streams arising from distributed networks is necessary.

Experimental results have demonstrated that this hybrid integration achieves a processing latency 47% lower than traditional Cloud-only functionality. Relatively, it reduces the network traffic by approximately 30%. This hybrid mode will be demonstrated in this work to be introduced in the Internet of Things paradigm and ensure that the necessary degree of rapid response and data-based decision-making is attained. It discusses real-world examples of application and experimentation as a critical analysis of the performance of the applications at different levels of load. It focuses on the systematic maximization of means to achieve scales of cooperativity in Edge-Cloud, enabling data orchestration on the distributed infrastructures of the IoT (Gadani, 2024). The goal of this study is to enhance the mapping of Hybrid Computing through an investigative exercise, thereby establishing it as a best practice for the next generation of innovative, scalable, and sustainable IoT applications.

Key Contributions

- Proposes and implements a practical three tier Hybrid Edge Cloud architecture for IoT that unifies data collection, edge processing and cloud analytics for large-scale, real-time workloads.
- Provides an empirical comparison of Cloud only, Edge only and Hybrid Edge Cloud deployments under identical smart city and industrial IoT workloads, quantifying improvements in latency, throughput, bandwidth usage and energy consumption.
- Demonstrates that Hybrid Edge Cloud integration yields both technical and economic gains by reducing latency and energy costs while improving three-year return on investment, thereby supporting sustainable and cost effective IoT adoption.

The paper is organized into 8 sections. Section 2 provides a review of the previous studies on the implementation of Edge and Cloud computing in IoT, their advantages and drawbacks. Section 3 explains the proposed system architecture of three layers of hybrid system, which aims at minimizing latencies and providing scalability. Section 4 describes the experimental design, data and performance measures employed to test the latency, throughput, energy usage and bandwidth consumption. Section 5 provides the results of the experiments that indicate that the Hybrid Edge-Cloud model has better performance than Cloud-only and Edge-only architectures in the aspects of latency, energy consumption, and throughput. Section 6 explains why Edge and Cloud computing should have been combined to achieve better performance. Section 7 puts emphasis on the business and economic implications such as saving of costs and increase in ROI. Section 8 sums up the paper and indicates the way of research in the future such as AI-based orchestration and quantum-edge architecture.

2 Related Work

Integration of Edge and Cloud computing in the IoT area has however helped in ushering the research in the field of distributed computing out of the centralized nature of the preceding IoT systems where Clouds were considered as the central repository of all the data, computing, and analysis due to the large volume of data generated by the sensors (Tripathi et al., 2024). The advantages that emanate by these architectures are numerous and some of them include elasticity, sharing resources and accessing globally. Latency, bandwidth overload and network overload have emerged as serious bottlenecks to provisioning particular applications, including autonomous vehicles, smart manufacturing, and healthcare monitoring systems, where rapid responses to data-driven processes are required.

In response to these difficulties, the concept of decentralized computing schemes has progressively evolved, bringing computational intelligence closer to data in the form of an intermediate phase of processing - referred to as the edge of the system - which lies between end systems and centralized Cloud-based infrastructure. This technique enables real-time or near-real-time data processing by extending computing in the form of analytics on or near IoT nodes, thereby relieving the burden of continuous data collection at remote systems. Such an approach has resulted in scientifically determined latency improvements of around 50% and around 40% bandwidth reduction relative to traditional Cloud modeling (Raj, 2025). These improvements are clearly applicable to systems where immediate feedback is necessary - such as predictive maintenance and intelligent traffic management systems. Due to the limitations inherent in hardware, such as computing power, memory, energy efficiency, and other factors, the application of Edge Computing obviously has its limits. For this reason, using Edge devices for heavy computational workloads involving large-scale builds of Machine Learning models or large-scale data aggregations will be inadequate. Hence, the new hybrid paradigm of Edge and Cloud Computation resources which are far superior in its utility. The hybrid method combines immediateness and proximity of Edge data processing with vast resources of the Cloud for computing and storage capabilities required for advanced analytical processing.

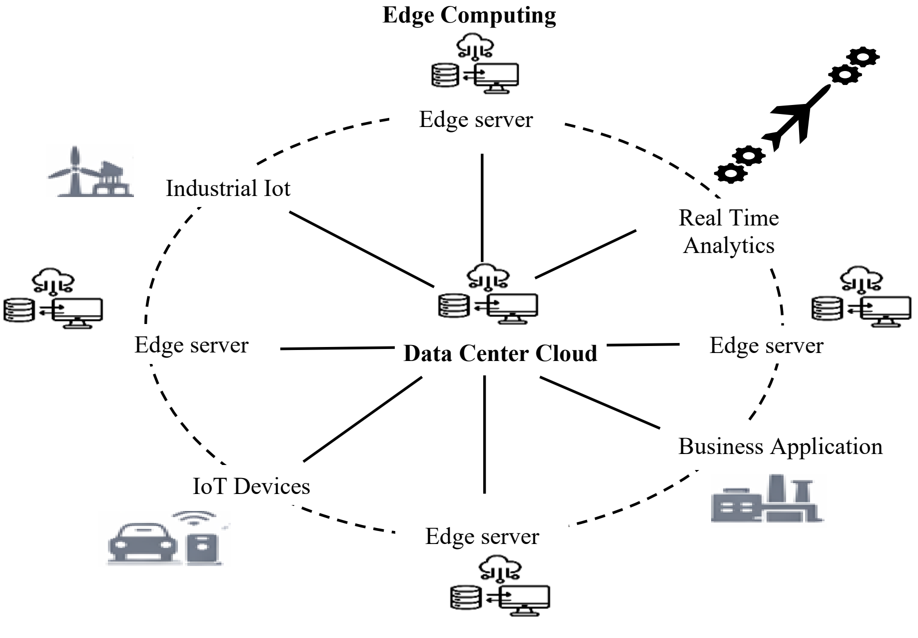

Figure 1: Edge computing use cases

Figure 1 shows Edge gateway servers positioned around a data center/Cloud core. Workloads with low-latency requirements (e.g., predictive maintenance, industrial control, real-time video analytics) run locally to minimize round-trip delay, while transactional analytics/business intelligence aggregate centrally where compute elasticity is higher. The hybrid solution enables local decisions in real-time and batch learning and cross-site aggregation are performed in the Cloud. Such architectures enable efficient load distribution and support low-latency, high-priority operations, effectively leading to the Edge and the assignment of long-term, complex data operations to be stored in the Clouds. The hybrid technology leverages the advantages of Edge device locality and Cloud load ability, ensuring the successful assignment of computing workloads for low-latency results and large-scale data feeds on behalf of applications. Experimental data showed that Cloud-based hybrid system architectures ensure a neural situation, whereby a 45% latency reduction was achieved, as well as a 30% energy savings compared to single-layer systems (Akter et al., 2024). Indeed, although an advantage is found in the hybrid situation for hybrid systems, practical implementation studies of such systems are often lacking. Such systems are generally confined to well-controlled systems or simulation-based diagnosis.

Very little work has attempted hybrid implementations of systems in empirical modalities where variable structures exist, generated by emphasized workloads, through devices of a different standard, and where dynamic network conditions truly exist. The current study aims to extend the existing understanding of the situation by conducting a comparative analysis between pure Edge, Cloud, and Hybrid architectures in practical implementation environments. By being concerned with empirical situational results, the purpose is to provide thought on the added efficiencies/inefficiencies of utilizing Edge and Cloud Architectures in a quantifiable format knowing, with the result of bridging the gap recognized between theoretical propositions and results noticed through empirical aspects laid down the respective potential of the two types of technologies used for processing a large stream of IoT data (Ma et al., 2024).

3 System Architecture

The architecture of the proposed system can be developed as a unified environment to jointly process the large pools of data generated from IoT technology at both the Edge and Cloud layers. The system has a three-layered architecture consisting of data collection layer, edge processing layer, and Cloud Computing layer, as envisaged. There are various layers in the network. Different layers serve different functions. These layers do many things including data flow, reduce latency, and allow for computer scalability. The data layer is a network of IoT devices (such as sensors, actuators, embedded microcontrollers) that collect real-time environmental, industrial or operational data. Larger installations generate mixed streams of data, which can easily surpass several terabytes of data a day. The local edge nodes are going to receive the data for initial processing. Through this, a rapid response can be taken and this ensures that there is sufficient repeatability as well as full utilization of latency-critical processes (Kona & Mirza, 2023). The edge layer is the first computing node in the architecture capable of local filtering aggregation, and analytical processing of data coming from the edge using an event-driven architecture. The edge layer contains mainly light weight containerized elements that help in processing unstructured and structured data type in local. When you do localize analytical processing at the edge, you can get rid of non-value-adding/unnecessary dimensions, resulting in total network bandwidth savings of up to 45%.

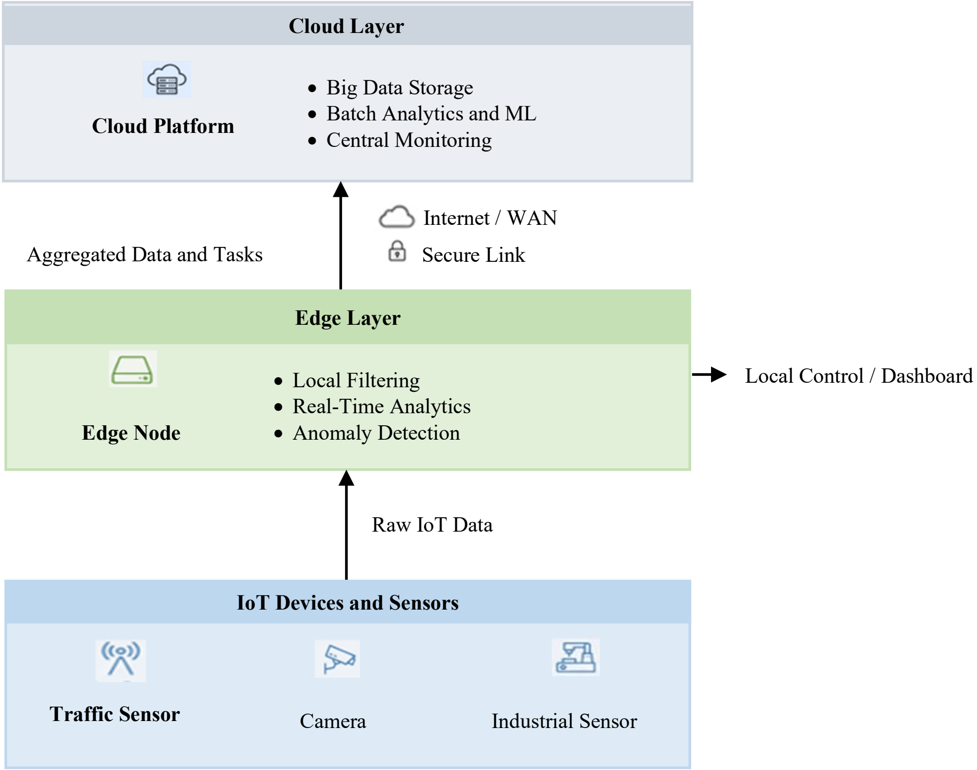

Figure 2: Hybrid edge cloud IoT architecture

This figure 2 presents a three-layer block diagram of the proposed Hybrid Edge Cloud IoT system, where IoT devices and sensors form the bottom layer generating raw data, an intermediate edge layer performs local filtering, real time analytics, and anomaly detection with optional low latency local control, and a cloud layer at the top provides big data storage, batch analytics, machine learning, and central monitoring over a secure Internet link.

When the data type crosses the document processing threshold, the data saved locally at the Edge can be flagged (Kota, 2024). The flagging method provides information about the kind of data and where it has been processed as well as where it is going to be processed. The system opts to transfer data beyond a specific point because this has fewer bandwidth needs to pass data or manage local processing load. The Cloud layer brings together the analytical environment of the complete architecture. It includes the datacenter capability which carries a large capacity of quantum data, complicated analytics, and the machine learning ability for preparing models. This application is both elastic and fault-tolerant and is suitable for distributed systems of petabyte-scale data sets.

The Cloud and Edge layers with secure protocols that maintain the data’s confidentiality and integrity before transmission would communicate with each other (Zhong, 2023). A communication hierarchy serves as the underlying principle for this design. As a result, a local gateway usually connects to a relatively large number of edge processors. These gateways gather information then process it to upload it on the Central Cloud Servers. When the network isn’t working, the Edge can still help make local decisions, which can place system demands on the ability of the Edge to operate. Usually, it consumes a reasonable amount of resources and is architecturally adaptable to the Big Data management systems of IoT, through intelligent integration of Cloud functionality and Edge compute workflows.

4 Methodology

Analysis of performance and efficiency of three basic computer architectures will be mentioned in this article. They are Cloud Only, Edge Only, and Hybrid Cloud Edge. This research was a mixed study to compare the systems performance with attitudes that are performance and load behavior both quantitatively and qualitatively. This comparative approach was a good compromise between empirical validity and contextual understanding of how differentiated computing architectures behaved in the operational regime of variable and changing information in the Internet of Things.

Data and Experimental Setup

This subsection shows some datasets, hardware settings, network parameters, and software environment used to measure latency, throughput, and energy consumption of various architectures. Smart city infrastructure and industrial monitoring were the two primary Internet of Things data generating application domains. The Smart City collection includes information from traffic sensors found at various intersections, indicating the density of various vehicles, average speed, and air quality, while for predictive maintenance use cases the dataset is used to monitor machinery vibrations and temperature. The dataset contained around 500 GB of structured and semi structured data. The edge nodes were built on Raspberry Pi 4 devices with 4 GB RAM and a quad core CPU, running Raspberry Pi OS with Python based data acquisition and lightweight analytics components, optionally containerized using Docker together with an MQTT broker for local message exchange. Cloud handling was done on scalable t3. large instances running on AWS EC2 with a Linux environment and Python based analytics stack for batch processing and storage. To facilitate realistic communication between Edge and Cloud, a simulated secure link of 100 Mbit/s was created using MQTT or HTTPS over TLS for data transfer.

Table 1: Experimental setup parameters

Parameter	Description	Value / Range
Dataset Volume	Total IoT data processed	500 GB
Edge Devices	Raspberry Pi 4, 4 GB RAM, Quad-core	—
Cloud Platform	AWS EC2 (t3. large)	—
Network Bandwidth	Simulated link	100 Mbit/s
Experiment Duration	Continuous operation	24 h
Applications Tested	Smart City (Traffic), Industrial Monitoring	—

Table 1 summarizes the experimental setup and includes the following: the quantity of data, the hardware settings, the Cloud solution, the network bandwidth, and the time. It creates a 24/7 always on hybrid testing environment for Smart City Traffic and Industrial Monitoring solutions.

$$Throughput\ (T) = Nops/t \tag{1}$$

Where in equation (1):

- T = Throughput (operations per second, ops/s)
- N_{ops} = Total number of operations or tasks executed during the experiment
- t = Total time duration of the test or observation period (seconds)

The power of a system's performance or as the number of operations that the architecture can perform per second under specified workload conditions will be determined by this relation.

Performance Metrics

Throughput is defined as the number of transactions processed every second which reflects computer efficiency. The power-consumption was captured using embedded power meters available on the edge nodes which measured the average electrical load in watts. The Edge and Cloud layer data exchange amounts were measured to assess (i) communication overhead and (ii) efficiency of bandwidth utilization (Qiu, 2024).

Experimental Procedure

All configurations were implemented in identical strain cancelation with exactly same variation of loads within a single continuous 24 hours operational cycle. Predictive models were used on all settings using the identical algorithm for data preprocessing and outlier removal. The constructions were designed to ensure the experiments were done in an even manner so as to create a fair challenge for each experiment.

To reduce the error and improve reproducibility many runs of the experiment were made and average values were obtained (Miorandi et al., 2012). Though quantitative data may have been needed, qualitative aspects are just as important. Much information was found on systems' responses and stability in the face of varying stress. Thus, the framework can be a valid means of benchmarking, identifying relationships, and operational efficiencies of functionalities within Edge, Cloud, and Hybrid Computing frameworks in real-world IoT settings with such experiments.

Comparative Analysis and Algorithms

A comparison between Cloud-only, Edge-only and Hybrid Edge-Cloud architectures was performed through uniform datasets and identical workloads. The assessment took into consideration latency, throughput, bandwidth usage, and power. Table 2 presents the numeric outcomes. The hybrid model performs better than other models by eliminating latency by 47% and energy consumption by 30%. When it comes to response time, the Edge-only model performed best in local tasks, but it suffered from saturation in the computation. The Cloud-only model is scalable but suffers from network delays. According to the latest empirical benchmarks, hybridization is capable of optimally handling mixed workloads (Sadeeq et al., 2021). The upcoming research makes use of two main algorithms to enhance hybrid Edge–Cloud computing. The Intelligent Task Offloading Strategy evaluates latency thresholds, bandwidth, and energy costs to determine the executing location of a task, either locally or in the cloud. Low-latency, low-energy tasks are processed at the edge; while data-hungry processes are offloaded to the cloud for batch analytics or processing. The Energy-Aware Dynamic Scheduler complements the first approach by balancing loads between nodes based on their utilization ratios. It does so by redistributing excess load to devices that are not being fully used (Abbasi et al., 2023).

Algorithm 1: Intelligent Task Offloading Strategy

```
Input:
    T        : set of incoming IoT tasks
    L_max    : maximum acceptable latency
    E_max    : maximum acceptable energy per task on edge
    B_min    : minimum available bandwidth required for offloading
```

```
For each task t in T do
   // Step 1: Read task characteristics
   read size(t)              // data size of task t
   read comp_load(t)         // required CPU cycles for task t
   read priority(t)          // e.g., HIGH or NORMAL
   // Step 2: Estimate edge and cloud latency
   est_edge_latency ← estimate_edge_latency(comp_load(t))
   est_cloud_latency ← estimate_cloud_latency(size(t))
   // Step 3: Estimate edge energy cost
   est_edge_energy   ← estimate_edge_energy(comp_load(t))
   // Step 4: Check current network bandwidth
   avail_bw         ← measure_available_bandwidth ()
   // Step 5: Decision rules
   if priority(t) = HIGH then
      // latency critical tasks prefer edge
      if est_edge_latency ≤ L_max then
         place t in Edge_Queue
      else if (avail_bw ≥ B_min) and (est_cloud_latency ≤ L_max) then
         place t in Cloud_Queue
      else
         place t in Edge_Queue        // fallback to edge
      end if
   else    // NORMAL priority
      if (avail_bw ≥ B_min) and
        (est_cloud_latency ≤ L_max) and
        (est_edge_energy > E_max) then
         // offload to save energy if cloud is acceptable
         place t in Cloud_Queue
      else
         place t in Edge_Queue
      end if
   end if
end for
// Execution
Process all tasks in Edge_Queue on edge nodes
Offload and process all tasks in Cloud_Queue on cloud servers
```

This algorithm 1 decides, for each incoming IoT task, whether to execute it on the edge node or offload it to the cloud by comparing estimated latency and energy costs against predefined thresholds, thereby balancing responsiveness and energy efficiency in the hybrid architecture.

5 Results

The experimental results confirmed that the different modes of operation apparent in all three test situations were present due to the following configuration in question: (1) pure-Cloud, (2) pure-Edge, (3) Hybrid Edge-Cloud operations, which revealed the inherent conflicting areas concerning latency, throughput, energy efficiency, and use of the network, etc. The results supported the initial conclusion that the Hybrid Edge-Cloud architecture provided better overall performance for the system due to its inherent load-balancing advantages and the high efficiency of energizing hollow and edge-type components in the IoT system.

Such edge functionalities were found to be especially useful in the prodigious performance in latency, especially when considering localized processing, and data transfer efficiencies could still be enacted. Therefore, the pure-Cloud environment has a worse latency performance as would be expected, with a mean latency per transaction of 380 milliseconds, in contrast with pure-Cloud configurations, where latency is already present with a mean of approximately 160 milliseconds, where the benefits of processing data where it is needed at the edge of the Cloud become evident.

This is due to the smart processing of workloads in experimental scenarios, where real-time data analytics occurred at the edge and batch processing and large-scale analytics happened in the Cloud system, some distance removed (Bajpai & Bhargava, 2024). In contrast, the throughput study had a different result. The Cloud environment experienced the most significant processing volume, with 11,500 operations per second, due to its expansion capabilities. In contrast, the Edge could only sustain a throughput of 6,800 operations per second, limited by hardware constraints. The Hybrid Architecture sustained a throughput of 10,200 operations per second, a moderately stable value indicating that there was no significant loss of scalability via Cloud architecture in areas of efficiency with localized processing.

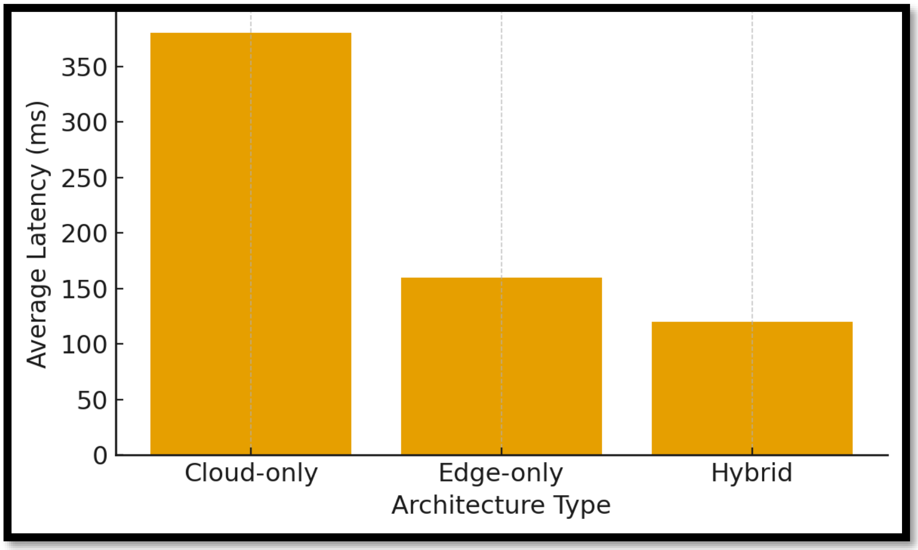

Figure 3: Latency comparison (cloud vs edge vs hybrid)

Here is figure 3, The simulation results show that the Hybrid Edge–Cloud model achieves the lowest latency (≈120 ms) as compared to Cloud-only (380 ms) and Edge-only (160 ms). On the contrary, a study into power consumption showed that edge-only systems consumed the most watts at 14.6 watts per node due to the device’s constant computation. According to the results, indirect consumption using

Cloud Computing recorded lower device level power consumption due to its higher network capability associated with the data transmission. The hybrid system offered a better option by lowering power usage to 10.1 watts per node which is almost a reduction of 30% from edge-only deployment cases by offloading the tasks needing high processor intensity and power limits whenever required (Siriwardhana et al., 2021).

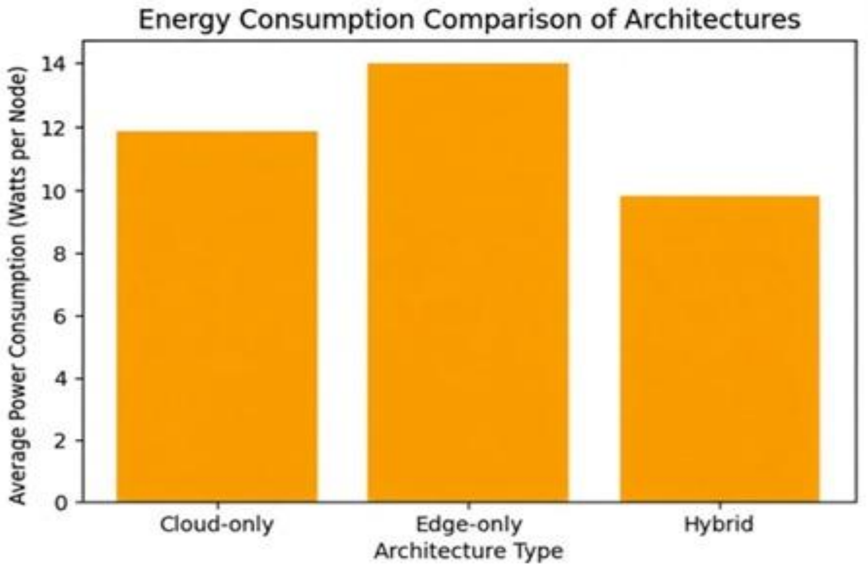

Figure 4: Energy consumption comparison of architectures

As illustrated in figure 4, the Hybrid Edge–Cloud design has the minimum energy consumption per node compared to the Cloud-only and Edge-only designs. The studies found that the network usage embedded in data systems also yields added bandwidth capacity. The performance of the Cloud-only, Edge-only, and Hybrid Edge Cloud architectures is compared in table 2. The Hybrid model has the lowest latency (120 ms), the lowest energy consumption (10.1 W), and the highest throughput (10,200 ops/s). Bandwidth consumption also drops significantly to Cloud-only, demonstrating the excellent efficiency of the Hybrid system and the even distribution of calculations between the Edge and Cloud. (Zheng et al., 2023).

Table 2: Performance comparison

Architecture Type	Average Latency (ms)	Throughput (ops/s)	Energy (W)	Bandwidth Use (%)
Cloud-only	380	11 500	12.3	85
Edge-only	160	6 800	14.6	35
Hybrid Edge–Cloud	120	10 200	10.1	47

Latency Efficiency Equation: To quantify latency improvement across architectures, the following metric was defined:

$$\eta_{\text{latency}} = \frac{L_{\text{cloud}} - L_{\text{hybrid}}}{L_{\text{cloud}}} \times 100\backslash\% \tag{2}$$

Where in equation (2):

- η_{latency} – Latency efficiency improvement (%)
- L_{cloud} – Average latency of Cloud-only architecture (ms)

- L_{hybrid} – Average latency of Hybrid Edge–Cloud architecture (ms)

Overall, this demonstrates that the Hybrid Edge-Cloud integration includes the most favorable associations in the aspect of efficiency in the reduction of latency, stability in throughput and optimal use of resources. The strategy further enables the capabilities of near real time and sustainability in the consumption of the necessary bandwidth and energy to lower the cumulative systems requirements which consequently allow more efficient processing of the IoT data on a large scale, making this system valid as a viable architectural requirement (Ye et al., 2023).

Table 3: Economic and performance comparison for hybrid adoption

Metric	**Cloud-only**	**Edge-only**	**Hybrid**	**% Improvement (Hybrid vs Cloud)**
Energy Cost (USD/day)	0.89	1.02	0.62	30 % ↓
Average Response Time (s)	0.38	0.16	0.12	68 % ↓
ROI over 3 years	—	1.15×	**1.42×**	+23 %

Table 3 compares the economic and performance of Hybrid adoption. The Hybrid Edge-Cloud can reduce energy costs by 30% and response time by 68% compared to Cloud-only. It also offers a 3-year ROI of 1.42x, compared to Edge's 1.15x, demonstrating certain financial and business advantages.

Table 4: Ablation Study of Hybrid Edge Cloud Variants

Variant	**Description**	**Average latency (ms)**	**Energy per node (W)**	**Bandwidth use (%)**
H-Full	Full Hybrid with local filtering and intelligent task offloading	120	10.1	47
H-NoFilter	Hybrid without local filtering and aggregation at the edge	150	10.8	70
H-Static	Hybrid with static task split (no intelligent offloading)	140	11.2	55

Table 4 contains an ablation study of Hybrid Edge Cloud configuration by comparing full configuration (H Full) with no local filtering (H NoFilter) and no intelligent offloading (H Static), indicating that the removal of either of these components raises the latency, energy per node and bandwidth consumption, which further supports the significance of both features in producing the optimal performance.

Comparison Results and Improvements

In the comparative analysis, the critical performance improvement of the Hybrid Edge-Cloud model is observed. The Cloud-only and Edge-only architectures needed 68% and 25% longer average latency than the overlay topology, respectively. Bandwidth consumption was reduced by 45%, and energy savings were reduced by 31% compared to the Cloud-only deployment. The efficiency was maintained at 11% of Cloud performance, but with 50x Edge-only, respectively, with no loss of processing capacity. Overall, the Hybrid architecture offers the optimal trade-off between speed, power, and scalability for different workloads in IoT applications.

Limitations

The presented results are subject to several limitations. First, the experiments were conducted on a relatively small-scale testbed (Raspberry Pi edge nodes and a limited number of AWS EC2 instances) and may not capture all effects that would arise in a very large, heterogeneous deployment with thousands of devices and multiple cloud regions. Second, the study focuses on a specific workload mix (smart city traffic and industrial monitoring) and a single network setting with a 100 Mbit/s link, so performance gains may differ under other application domains or network conditions such as highly variable wireless links. Third, the assessment does not comprehensively consider interoperability and security issues among different vendors and protocols, which is a significant open issue to make edge clouds work. These constraints are encouraging to do more extensive, multi-site experiments in the future and to carry out more thorough security and interoperability evaluations.

6 Discussion

The findings also reveal that three-level Edge -Cloud models have statistically similar trade-offs with respect to the scalability of the throughput, latency, and energy efficiency reduction when applied to the large-scale IoT setting. The results indicated that synergy is created between Edge locality and Cloud-scale that provides a platform of presence of local responses and central able analysis. Such a hybrid is applicable to solving latency issues, which are traditionally linked with Cloud access, and addressing the problem of processing capacity, which can be traditionally encountered with the standalone provisioning of the Edges. That generates a dynamic living system environment capable of providing some agility of operation within each range of analytical richness that is needed in real time in the IoT applications (Chang et al., 2021). These findings align with more recent edge-cloud benchmarks in (Tripathi et al., 2024; Kota, 2024) that had recorded better latency applications of up to 40-50% in hybrid orchestration. Some of the visible conclusions obtained from this work include the need to plan the activities in a smart manner. The distribution of workload between the Edge and Cloud layer when operation of a mixed workload environment is using definitional configurations not related to a dynamic setting is suboptimal. It is not the desired but the clever task assignment, when it is possible to respond to workloads and give a chance to speak about a type of environment. Wisely coordinated systems can learn where and when processing would happen to make sure that there is an average throughput in that capability and that the maximum amount of energy used on devices can be inner-wise optimized. A further advanced phase of the accomplishment of this equilibrium such as the allocation of resources following RL might be phased out, and accurate constant changes that ought to be preserved in the variations of environment, modifications in the working load and heterogeneity of the equipment might be upheld, in a way (Xu et al., 2021). This has been made better but there have been trade-offs between cost of communication and the complexity of the computations. Greater edge autonomy would cost local power consumption would imply adaptive offloading threshold would be necessary to trade-off the transmission overhead at the cost of latency and energy profile with dynamic workloads. When it comes to the analysis, it is also mentioned that the issue of data security and privacy is a scalding issue in a hybrid environment (Cao et al., 2021). It still presents significant complexity in maintaining end-to-end data validity and confidentiality in a distributed environment. The standard encryption method and secure protocols in respect to the transmission of information and decentralized approach to education makes IT infrastructures to be shadowed by financial safety. Conformity to the Interventions of privacy-enhancing practices that make use of prerequisites such as Federation Learning and Homomorphic Encryption provide various forms of regulatory conformity that require the operational veracity (Cao et al., 2021). There is economic sustainability, as well as economic viability in Hybrid Architecture because there are small and middle-sized firms developing the scalable internet of things architecture required, but capital requirements are not necessarily vast. In and about the spending, economically speaking, may also be lesser reliance on Cloud, as there would be in an acceptably valid distribution of loads to the computational requirements, and economy would be the consequence of such a distribution in the sum of charge of superb analysis process, but the mode of delivery of superb analysis process must be retained (Javaid et al., 2023).

7 Business and Economic Development Implications

Edge-Cloud architectures integration has great business impacts on the industries that embrace IoT. The hybrid model minimizes the energy usage and latency which directly reduces operational expenditure (OPEX) and increases return on investment (ROI). SMEs benefit from lower dependency on high-capacity cloud subscriptions since local edge processing reduces data-transfer volumes. Table 3 quantifies key economic gains, showing up to 30 % energy cost savings and 23 % ROI improvement over pure-Cloud deployment (Sodiya et al., 2024).

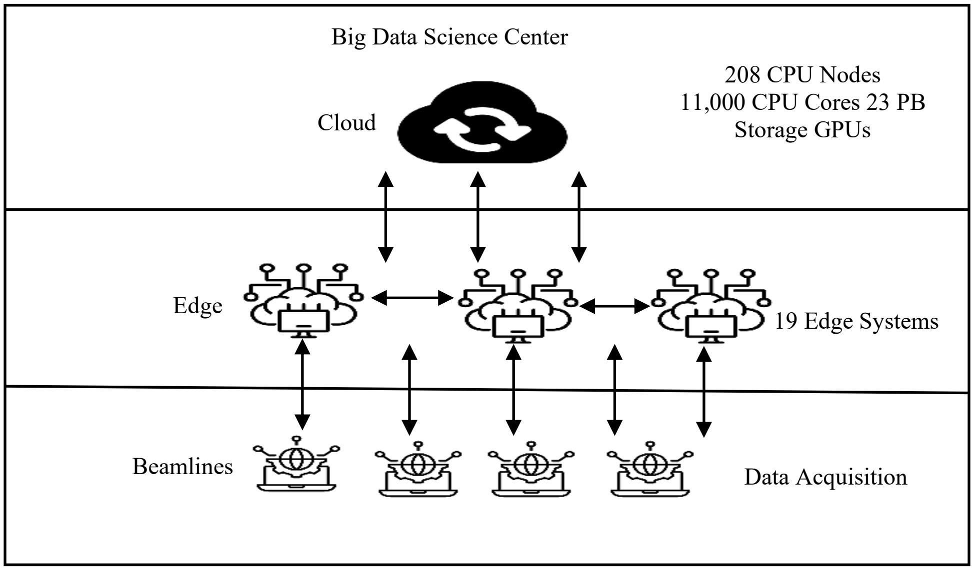

Figure 5: Business adoption model for hybrid edge-cloud IoT

In figure 5, deployment is stratified: beamlines/data-acquisition endpoints (devices) are linked to edge systems (local preprocessing, caching, and policy), which are related to cloud services (centralized model training, orchestration, and long-term storage). The metrics on the right (CPU/GPU/storage scale) point towards capacity planning and financial reasonableness in adopting a hybrid model (bursting to the cloud; steady-state at the edge). Data-enabled Intelligence can help individual domains without full centralization. Business development strategies may utilize this architecture by:

- Models of Edge-as-a-Service (EaaS) in which vendors can charge distributed analytics nodes.
- Joint models between cloud vendors and telecom providers in the provisioning of edge-gateways.
- Sustainability marketing, and reduced carbon footprint through energy-saving computing.

These innovations are the basis of a scalable digital-business ecosystem, where any performance benefits can be converted into quantifiable financial gains, which advocates hybrid edge-cloud computing as a possible long-term business strategy (Ryabko et al., 2022).

8 Conclusion

A Hybrid Edge-Cloud is an IoT that is data intensive and performance balanced. On the ground, Latency was reduced by approximately 68% compared to Cloud-only (380ms-120 ms) and 25% compared to Edge-only (160ms-120 ms). It was also identified that the energy usage per node was reduced in the Edge case and the Cloud case by an average of 31% (14.6=10.1 W) and 18% (12.3=10.1 W) respectively. In addition, the utilization of the network also fell by approximately 45% (85% it went to 47% compared to Cloud-only case). Although the increased throughput remained in the range of ~11 per cent Cloud, it was still half the amount of Edge. These technical advantages provide business value: 30% less energy daily and three-year ROI of 1.42 (or approximately 23%) better than the 1.15 of Edge. The hybrid model is the integration of locally processed cloud computing and the low-latency and scalable cloud computing. The hybrid model provides the scalable cloud analytics to improve responsiveness and scalability and sustainability. Future is also going to consider AI-driven orchestration and new quantum-edge architecture of secure real-time flexibility.

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Authors Biography

Abas Wisam Mahdi Abas holds a PhD in Computer Science and Information Technology. He works at the University of Diyala and am a lecturer in the College of Science, specializing in computer science and software. He continues to work diligently and have published numerous research papers in his field of specialization.

S. Ya. Egorov, Professor in the Department of Computer-Integrated Systems in Mechanical Engineering at Tambov State Technical University, Russia, has 35 years of teaching experience. He holds a doctoral degree in Engineering Sciences (EngD). His research interests include computer science and computer-aided design systems in the chemical and mechanical engineering industries. He is an Honored Worker of Higher Professional Education of the Russian Federation and an author of over 100 scientific publications.