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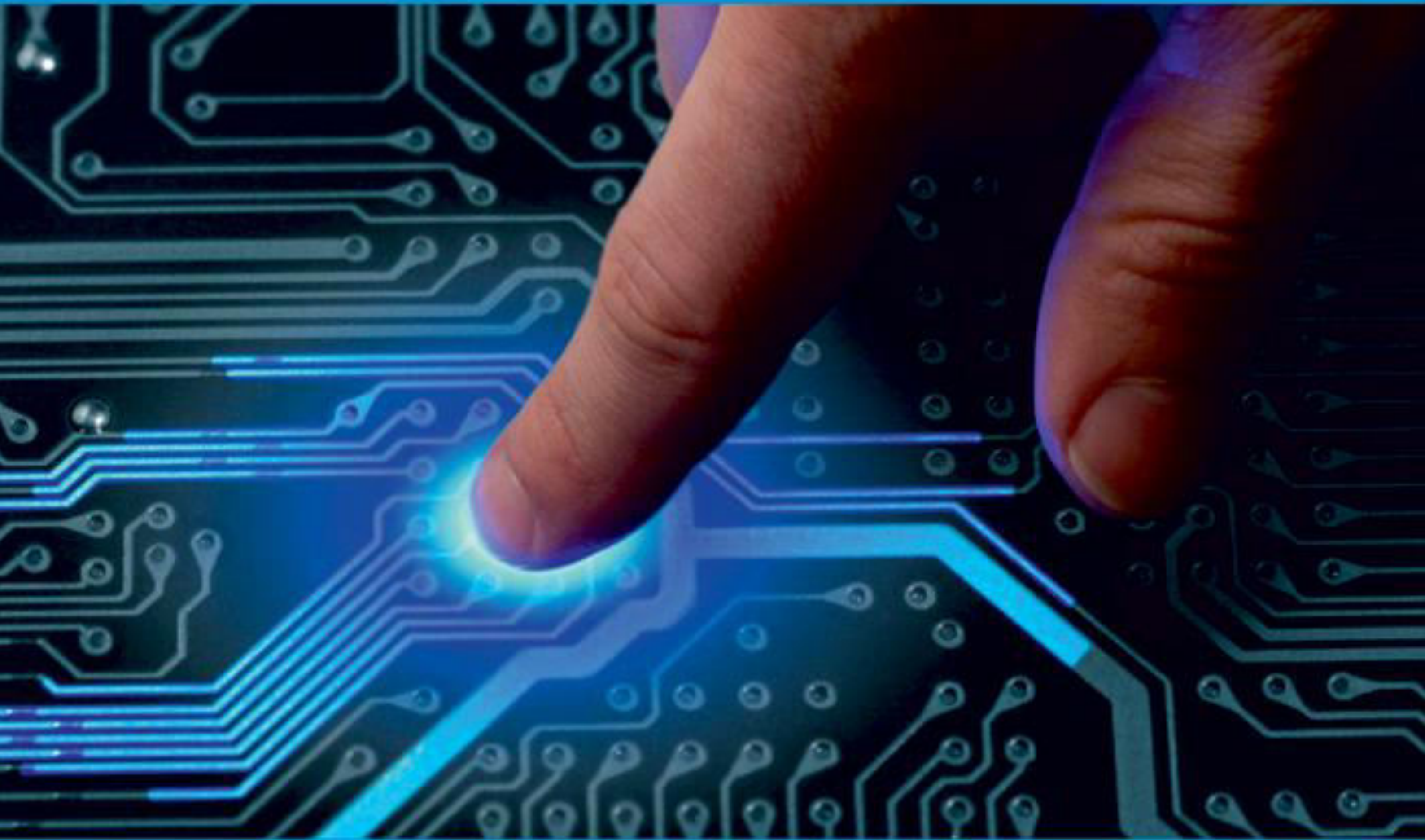

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Big Data in Smart Cities: Using Regional Computing to Optimize Cost and Performance

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ABSTRACT: The problem with smart gadgets in smart cities is that they must interpret data in real time while also permanently storing it in the cloud for later use. There is a significant conflict between the demand for long-term storage and the requirement for quick response. Although Cloud Computing (CC) offers an appropriate platform for handling and storing this data, it results in network congestion, delays, and longer response times. Real-time responses are required by Internet of Things (IoT) devices, but their data must also be accessible for analysis and decision-making in the future. While edge and fog computing models have been developed to address these issues, their resource limitations and scalability issues make them inadequate for the aforementioned criteria. Often, a hybrid paradigm is suggested to meet the limitations of cloud and edge computing. However, synchronization between cloud and edge can cause delays, reducing overall performance. The suggested system, Regional Computing (RC), tackles large data concerns in smart cities by offering a middle ground between edge (limited power) and cloud (distance) computing.

KEYWORDS: Smart cities, big data, regional computing, edge computing, cloud computing.

I. INTRODUCTION

The enormous expansion of big data, defined by its high volume, broad variety, and rapid velocity, presents major challenges to standard data processing techniques.Social media, autonomous vehicles, and sensor networks are major contributors to this data flood, all of which can create network delays and congestion. Big data is described by three Vs: volume (large datasets), variety (various data formats), and velocity (quick data generation). Addressing these difficulties requires novel techniques to data processing and offloading.

Urban Big Data (UBD) refers to the information generated by smart devices and IoT systems in urban areas, also known as Smart Cities Big Data. This data contains a wide range of information, as shown in Figure 1, and is used in a variety of fields to improve urban living. For example, video data acquired continually by security cameras is critical for public safety and traffic management. Smart parking systems assess parking availability and usage, resulting in more efficient space management and less traffic congestion. Similarly, data from smart lighting systems provides insights into energy use and lighting conditions, hence facilitating effective energy management and adaptive lighting solutions.

Furthermore, air quality monitors provide environmental data to help measure pollution levels and support public health programs. Furthermore, utility management devices monitor resources like water, electricity, and gas to ensure they are distributed and consumed efficiently. Together, these diverse data sources comprise comprehensive information warehouses that are critical to the operation and development of smart cities.

Smart devices in smart cities confront a unique challenge: they must do real-time data processing while simultaneously storing data permanently in the cloud for future use. This dual requirement poses a substantial difficulty, as the needs for instant reactivity and long-term storage sometimes conflict.

IoT devices generate over 70% of all data in smart cities. While CC is a suitable platform for processing and storing this data, it also causes delays, slower response times, and network congestion. IoT devices require immediate

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reactions, but their data must also be accessible for analysis and decision-making. Although edge and fog computing models have arisen to address these concerns, they are limited in resources and have scalability issues, making them unsuitable for long-term data management. As a result, to avoid cloud delays, network congestion, and scalability issues, some systems may choose not to save data for later use.

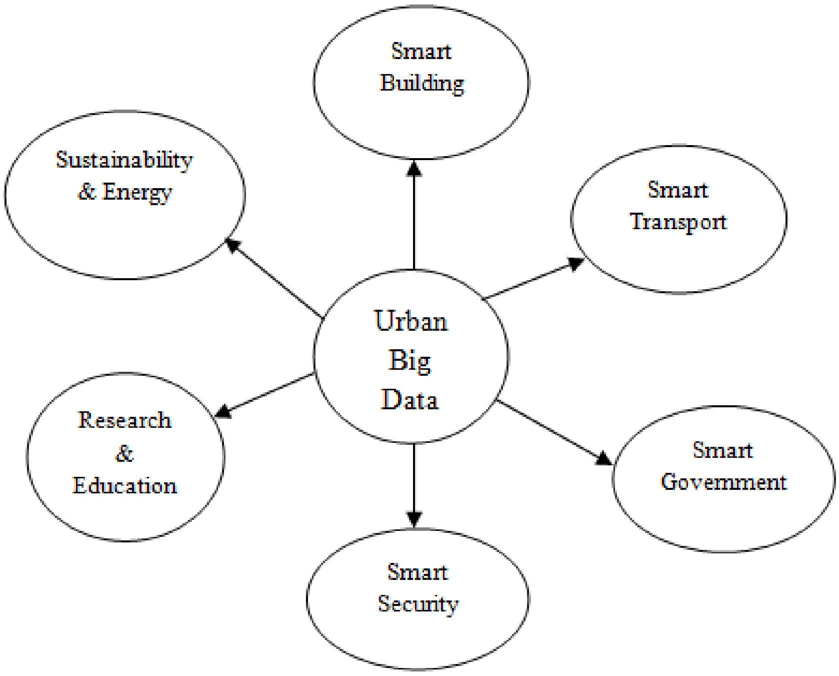

FIGURE 1.The structure of Urban Big Data (UBD).

To overcome these issues, a hybrid system that combines edge and cloud computing has been proposed. Presented a strategy for distributing smart city tasks between fog computing and cloud servers. Similarly, used a hybrid method for workload execution that used fog, cloud, or both. This model can be effective. When cloud servers are close to end customers, it becomes impractical to have them thousands of miles distant.

when we all know, when the distance between locations rises, so do delays and congestion. Edge Computing (EC) aims to reduce these delays and respond to devices and applications in real time. However, in hybrid systems where workloads are processed across both edge and cloud platforms, apps may incur delays in the cloud prior to synchronization, making CC less efficient.

Therefore, the biggest issues with smart cities big data are:

- The current network infrastructure limits the ability to migrate, store, and process enormous amounts of data generated by smart cities.
- The predicted increase in data in smart cities raises worries about network congestion, particularly during peak hours. Offloading the same data to the cloud across public networks may exacerbate the problem.
- Smart city services demand real-time reaction, but cloud-based offloading causes delays, congestion, greater prices, and other difficulties, making them unreliable.

To address the aforementioned issues connected with big data in smart cities, this study seeks to accomplish the following goals:

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- Manage vast amounts of data created by smart cities.
- Minimize smart city big data's impact on public networks to prevent congestion and ensure real-time application availability.
- Provide real-time responses for applications and services that require it.

We add the RC, to the middle layer to meet the issues given by smart city big data. Unlike EC, which is often closer to the client, RC operates on a bigger scale, spanning a state or national area. RC servers provide more processing and storage power than edge servers but less than cloud servers. However, due to limited capacity, RC must offload data to the cloud during non-peak hours.

Non-time-sensitive data is held on regional servers during peak hours and transmitted to the cloud at off-peak times, including backups. In contrast, during peak hours, time-sensitive data is sent to the cloud. Initial findings indicate that local workload filtering by RC servers reduces the strain on the main network while relieving the demand on cloud servers, resulting in lower costs and delays.

The majority of large data sets do not require immediate transmission to the cloud during peak hours. Instead, information can be saved on regional servers and then uploaded later. This method helps to balance network resource utilization during peak and off-peak periods.

FIGURE 2. Integrated Computing Layers in Smart Cities: Cloud, Regional, and Edge

As a result, this work makes the following contributions:

- Figure 2 illustrates how RC can reduce latency between processing servers and data sources. These servers are carefully positioned in various zones to offer coverage throughout the area.
- Using regional servers to store smart city data allows for cloud transfer during off-peak hours. This improves future data analytics, decision-making, and research.

II. LITERATURE SURVEY

The number of internet-connected devices and the volume of data they produce are growing at an unprecedented rate. By 2030, there will be over 75 billion internet-connected gadgets, resulting in 175 zettabytes of data. the current infrastructure and design are not prepared to handle such rapid expansion.

The issue with edge utilization is that these frameworks have extremely limited capacity and almost no scalability, rendering them unreliable. While they are useful in certain time-sensitive applications, they are not suitable for handling large volumes of data.

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We suggest a hybrid approach that integrates edge and cloud computing to address the aforementioned problems. The proposed a method for allocating cloud servers and fog computing workloads in smart cities. Concurrently, employed a hybrid approach that combined cloud, fog, or both for task execution. When cloud servers are located close to end users, this method might work, but when they are thousands of kilometers away, it is not feasible. Before synchronizing the output, the workload running on local servers will wait for the cloud response.

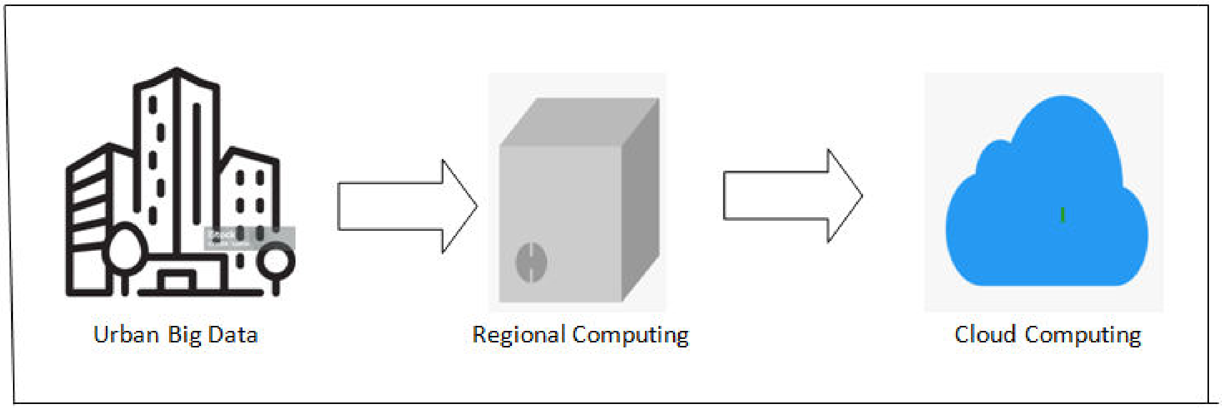

FIGURE 3. The big data flow with Regional Computing (RC).

Building on the previously discussed problems, researchers created a thorough architecture that is similar to the method previously indicated for tying IoT devices to the cloud. This paradigm combines fog computing and EC, as recent work shows, and processing is done on micro servers and tiny servers. Edge-only, fog-only, cloud-only, and hybrid approaches—which process data on the edge and in the cloud—are among the options for data processing. However, this combined method has a typical drawback. Some procedures demand greater processing times when outsourced to the cloud, whereas others have less delay when run on the edge. Because of this, local tasks on the edge are often delayed while awaiting cloud answers, which makes them inappropriate for IoT devices that need real-time responses.

In order to further develop these concepts, researchers in proposed a similar technique whereby IoT devices initially look for resources at the fog layer. In the event that resources are unavailable, processing is shifted to the cloud. On the other hand, the creators of employed an approach that combined cloud and edge management. They employed artificial intelligence algorithms to determine the optimal execution location for the application data, accounting for data size and delay requirements. Additionally, this research offers a new strategy for edge data centers. Maintaining latency and resource capacity constraints, it optimizes application placement according to cost (cloud fees, data transfer). The most economical option is determined by the algorithm.

The difficulty of balancing cost and delay in fog computing for time-sensitive Internet of Things applications is discussed in the study. They suggest employing integer linear programming to offload tasks dynamically. Compared to current methods, this strategy prioritizes jobs to reduce fog node latency and energy consumption, which eventually lowers system delay and power consumption. However, in highly dynamic contexts, the real-time application of integer linear programming may be limited due to its complexity.

Likewise, the research suggests a novel approach to fog computing that balances workload and optimizes profit. Utilizing an Optimized Matching Theory (OMAT) framework, it distributes the burden evenly among fog nodes, in contrast to other approaches. Throughput, resource use, and data processing speed (latency) are all enhanced while user quality of service is preserved. This situation is limited by the possible overhead that the OMAT framework introduces, which may have an impact on performance in situations when workloads change quickly.

The method optimizes task offloading (Fog or Cloud) for variables including latency, resource availability, and energy consumption using fuzzy logic. Additionally, they provide a scheduling approach for effective job distribution

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in the fog layer. When compared to current approaches, evaluations reveal notable gains in delay (latency), cost (energy consumption), and overall system efficiency. However, in large-scale deployments, the fuzzy logic-based method could have trouble with complexity and scalability.

A Mobile Edge Computing (MEC) system with multiple users was introduced. This system consists of a base station with an integrated MEC server that provides data caching and compute offloading. The effectiveness of resource allocation and total cost reduction are the goals of these services. The authors also concentrated on cutting expenses by effectively offloading computations from the edge to the cloud. Their method addresses the varying communication costs related to jobs using a heterogeneous model, which is backed by algorithms that produce less-than-ideal results.

Expanding upon this framework, it presents a dynamic task allocation approach for edge cloud computing that aims to reduce user expenses. Coalitional R-learning (CR-learning), a dynamic coalition formation method, and server coalitions are used in this strategy. This method solves the problem of accessing a vast solution space while simultaneously successfully reducing user expenses.

Additionally, it tackles financial issues by creating a work offloading policy that balances execution cost and device utility. Inspired by Social Cognitive Optimization (SCO), a meta-heuristic approach called SCOPE is used to address this policy, which is formulated as a subset selection issue. SCOPE offers a possible path toward cost optimization in task-offloading scenarios by effectively navigating this problem terrain and achieving wanted trade-offs.

Even though these studies show great promise in reducing costs in cloud offloading scenarios, issues like long distances, congestion from heavy workloads, excessive use of network and computer resources, the need for cooling systems, lengthy delays, and complexity continue to be major roadblocks.

Similar to time and cost considerations, energy consumption presents a major offloading challenge. Provide a fog computing node dual energy source solution that combines grid and solar power to minimize carbon emissions and maintain operational dependability. Moreover, it presents a Lyapunov optimization-based energy-efficient offloading-decision technique that minimizes mobile device energy usage while satisfying reaction time requirements. provides an analytical framework for balancing local processing and offloading while decreasing in-device energy usage through the best offloading choices for numerous user devices. Cost-driven workload offloading has been thoroughly studied, but issues still exist, especially with mobile devices where processing big datasets locally drains battery life and offloading to the cloud causes latency. It is still imperative that these issues be addressed.

A paradigm that tackles the challenges of edge and cloud computing is necessary, as the aforementioned discussion and offloading issues demonstrate. RC was suggested as a way to handle large amounts of social data. Under their approach, social big data is processed at the regional level during peak hours and then transferred to the cloud as needed or during off-peak hours. The RC idea was also applied to handle under- and over-utilization during peak and off-peak hours. By using regional servers to handle workloads during peak hours, RC successfully addresses these problems. Vehicle large data management was done using the same idea. As these contributions show, RC can be a game-changing approach for processing large amounts of data.

III. SUGGESTIVE FRAMEWORK

1. Framework Layers

Edge Computing (EC) Layer

The Edge Computing layer is positioned closest to the IoT devices distributed across the smart city. This layer collects data from various sensors, cameras, and other smart devices deployed in urban environments.

- **Data Collection and Pre-processing**: Edge nodes (e.g., gateways, micro-data centers) capture data from IoT devices, performing essential pre-processing operations like filtering, aggregation, and compression.
- **Real-Time Response**: EC nodes handle time-sensitive applications, such as public safety alerts and traffic management, by providing immediate responses without requiring cloud interaction.

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Regional Computing (RC) Layer

The Regional Computing layer serves as an intermediate processing stage, bridging the Edge and Cloud layers. RC centers are strategically placed within urban zones to provide efficient data handling at a regional scale.

- **Data Aggregation and Intermediate Processing**: RC servers aggregate data from multiple edge nodes, enabling localized processing and analysis to reduce data load on the cloud.
- **Temporary Data Storage and Load Management**: Non-critical data is temporarily stored at RC centers and transferred to the cloud during off-peak hours. This method reduces peak-hour network congestion and optimizes bandwidth usage.
- **Resource Balancing**: The RC layer balances the load between Edge and Cloud layers, ensuring optimal resource utilization and minimizing latency for applications requiring near-real-time processing.

Cloud Computing (CC) Layer

The Cloud Computing layer serves as the primary data repository and analytics hub, providing comprehensive storage and analysis capabilities.

- **Long-Term Storage**: The cloud stores vast amounts of data generated by smart city devices, supporting historical data analysis and decision-making.
- **Advanced Data Analytics**: Cloud resources are utilized for complex analytics, machine learning, and predictive modeling to support smart city planning, resource management, and policy-making.
- **Data Archiving**: Cloud servers also maintain backups and archives for long-term data retention and regulatory compliance.

2. Data Processing and Offloading Workflow

- **Data Collection and Immediate Processing**: IoT devices generate data that is immediately collected and partially processed at the Edge Computing layer to support real-time responses.
- **Regional Aggregation and Processing**: Processed data from edge nodes is forwarded to the RC layer, where additional aggregation and filtering occur. RC temporarily stores non-urgent data and prioritizes critical data for immediate transfer to the cloud.
- **Scheduled Offloading to Cloud Layer**: During off-peak hours, non-urgent data is offloaded from RC to the cloud, where it undergoes advanced analytics and is stored for future use. This approach minimizes peak-hour network congestion and optimizes data transfer costs.
- **Feedback Loop for Continuous Optimization**: Insights from the cloud are relayed back to both the RC and EC layers, allowing the system to adapt dynamically and optimize data processing in real-time. This feedback loop enhances performance by adjusting processing priorities and load distribution based on current network conditions and application needs.

FIGURE 4.Structure of Regional Computing (RC) for Urban Big Data (UBD)

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The structure of Regional Computing (RC) for Urban Big Data (UBD) provides a multi-layered approach to efficiently manage data generated by smart city devices. At the foundational level, the Edge Computing layer collects and preprocesses data from IoT sensors and devices, handling immediate responses for critical events. This data then flows to the RC layer, strategically located in urban zones to aggregate, process, and temporarily store non-urgent data, which reduces network congestion by offloading to the cloud during off-peak hours. Positioned as an intermediary between edge and cloud, the RC layer optimizes resource use and balances workloads. Finally, the Cloud Computing layer performs long-term storage and complex analytics, supporting advanced decision-making. This hierarchical model supports the efficient flow and processing of data, enhancing urban infrastructure and service efficiency.

IV. WAY FORWARD AND CHALLENGES OF USING REGIONAL COMPUTING WITH CLOUD COMPUTING FOR BIG DATA IN SMART CITIES

The adoption of Regional Computing (RC) in smart cities is promising but poses a range of challenges in integrating RC with cloud computing effectively. Key areas for future focus include:

- **Network Scalability and Congestion Control**: As IoT devices increase in cities, it's crucial to ensure quick responses and manage large data loads. Expanding RC infrastructure to handle these demands and using strategies like dynamic load balancing and smart data routing can help prevent congestion.
- **Interoperability and Data Integration**: For smooth operation, regional and cloud computing layers need to work seamlessly despite differences in data formats and communication protocols. Improved standards for data sharing and compatibility can help reduce delays and ensure smoother data flow.
- **Security and Privacy**: As data moves across edge, regional, and cloud layers, secure communication is essential. Strengthening encryption and privacy measures, especially for sensitive data in the RC layer, is vital. Adhering to data regulations will also be key.
- **Cost Efficiency and Energy Consumption**: Implementing RC solutions needs to balance performance with cost. Future research could explore energy-efficient regional servers, resource sharing, and using renewable energy sources to lower the environmental impact of data centers in smart cities.
- **Dynamic Workload Allocation**: To manage data across edge, RC, and cloud layers, intelligent workload distribution is needed. Adaptive algorithms that predict data flow and shift workloads based on network congestion, processing power, and storage can improve responsiveness and reduce delays.

V. EMERGING TRENDS AND FUTURE OF BIG DATA MANAGEMENT IN SMART CITIES

- **Federated Learning for Data Privacy**: Federated learning allows decentralized data processing across edge and regional nodes, where only insights are shared rather than raw data. This reduces data transfer needs, preserves user privacy, and alleviates network congestion, making it ideal for managing sensitive smart city data.
- **Quantum Computing Integration**: Quantum computing, while still in development, offers significant potential for rapid data analysis and solving complex urban challenges. When integrated with RC, it could handle vast amounts of smart city data quickly, supporting advanced decision-making in urban planning and real-time service optimization.
- **Block chain for Secure Data Sharing**: Block chain can enable secure and transparent data exchanges between IoT devices, RC nodes, and cloud servers. Its decentralized ledger provides a trustworthy system for managing data access and ensuring data integrity, which is crucial for the reliability of smart city applications.

VI. CONCLUSION

This study has examined the challenges encountered by UBD in smart cities, highlighting the necessity for real-time responsiveness alongside continuous cloud storage. Smart city applications require sophisticated computing and analytical tools to process data for various functions. To meet these demands, we introduced the RC framework, which processes data closer to the edge by utilizing robust computing resources. The RC framework proves particularly effective at filtering data at the regional level during peak usage times, reducing the reliance on cloud data offloading and mitigating congestion on primary networks. This strategy not only minimizes delays, costs, and energy use but also significantly lessens congestion on mainstream networks. Preliminary results indicate notable advancements in managing delays, lowering costs, and tackling energy consumption issues.

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