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Quantum and Blockchain based Serverless Edge Computing: A Vision, Model, New Trends and Future Directions

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Summary

Serverless computing has become an important cloud model delivering service to users based on the amount of resources consumed by the Internet of Things (IoT) applications. Edge computing can be utilized for Serverless computing to process small or deadline oriented jobs efficiently at edge devices helping to reduce latency. Furthermore, security and computation speed have become important challenges for Serverless edge computing. Blockchain and Quantum computing can be used to provide secure and reliable edge Serverless service while also improving security and computation speed respectively. This letter identifies and integrates various emerging paradigms to develop a conceptual model for Quantum and Blockchain based Serverless edge computing. Promising future research directions and open challenges are also discussed.

KEYWORDS:
Quantum Computing, Blockchain, Serverless, Edge Computing, Internet of Things, Artificial Intelligence

1 | INTRODUCTION

Prominent cloud providers are now utilizing Serverless computing as a cloud model to provide cloud service to the end users in an efficient manner[1,2]. The emergence of edge computing can help Serverless computing to improve the latency for processing of jobs at run-time[3,4] and delivers service to the end users based on the consumption of resources by different Internet of Things (IoT) applications[5] such as healthcare, smart city, agriculture and weather forecasting[6,7,8]. Due to big data processing, security and computation speed becomes a challenge for Serverless edge computing[9,10,11]. Quantum computing[12] and Blockchain[13,14] are two new important paradigms which can be used to provide large computation speed and security respectively[15]. Further, there is a need to develop secure and reliable conceptual model for Serverless edge computing, which can utilize Artificial Intelligence (AI) to provide effective service[16].

1.1 | Serverless Edge Computing

Edge computing is a paradigm to manage data of IoT applications which is near to edge devices instead of processing at cloud data centers[3,8]. The computation close to the logical edge of the network reduces the latency and response time[15] but data generation is increasing day by day requiring high computation power[5,16].

It is latest execution model for cloud computing to offer service to the end users based on the consumption of resources by IoT applications instead of pay-per-use[4,16]. Further, Function as a Service (FaaS) performs the division of server into functions which

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are independent to manage the resources and scale automatically[2]. Furthermore, latest machine learning and AI techniques can be used to optimize the performance of computing systems[17].

The integration of serverless computing in edge computational model improves the computational speed of processing data coming from IoT applications installed on edge devices[6,16]. This concept divides the server into resources for independent execution increasing the scalabilty of computing systems for better performance[1]. For effective working of the system, there is a need of large computational power which can be provided by the utilization of quantum computers[7,10].

1.2 | Blockchain

Blockchain technology is open distributed ledger and processes the IoT application data in chain of blocks[14]. This technology is very effective in processing data for Serverless edge computing in a secured manner but it reduces the computational speed of data processing because data is processed in blocks[13]. Blockchains have a component of computation built into their architecture for calculating the nonce values and hashes for each data-block of the complete chain. To verify the Proof-Of-Work (POW), this process needs to run in parallel across several nodes of a distributed architecture[15]. Microservices could aid in the integration of such processes in a Faas platform which could be deployed on a serverless pipeline. To solve this problem, quantum computers can be used to provide large scale computation for resource management[15].

1.3 | Quantum Computing

Quantum computing performs computation by using two important concepts of quantum physics such as entanglement and superposition[12]. Nowadays, edge computational paradigm is using the concept of Serverless computing to provide function as a service, which requires quantum computing to process large-scale computation for load balancing and dynamic provisioning[15]. Furthermore machine learning[11] and AI-based techniques[9] can be used to enable automatic execution, which can train models and improve computational speed of quantum computers[18].

2 | PROSPECTIVE MODEL: A VISION

Figure 1 shows the proposed model, which has been divided into three different layers: IoT, management and service.

2.1 | IoT Layer

IoT layer enables the interaction of edge devices or end users with computing systems through gateway devices. In this layer, various IoT applications (e.g. healthcare, smarty city, agriculture and weather forecasting) will interact with the system to get services in an efficient manner.

2.2 | Management Layer

The main components of the management layer are resource monitor, Serverless manager, application manager, Blockchain service and quantum computing module. Resource monitor consist of three different sub-components such as QoS manager (to identify and manage Quality of Service (QoS) requirements of the IoT applications), Service Level Agreement (SLA) manager (to maintain the SLA negotiated between cloud provider and user) and Database manager (which manages the data of IoT applications effectively). Blockchain service is integrated to ensure the secure transfer of application data during workload execution. Servlerless manager manages the cloud resources which IoT applications are using during workload execution at run-time[16]. Quantum computers can provide large-scale computation to edge computational paradigm which is integrated with serverless data pipelines and it helps for effective load balancing and dynamic provisioning. Application manager is a centralized module which handles the execution of IoT application and provides data for resource scheduling. Placement module is acting as an interface between application manager and application placement module to exchange data between them.

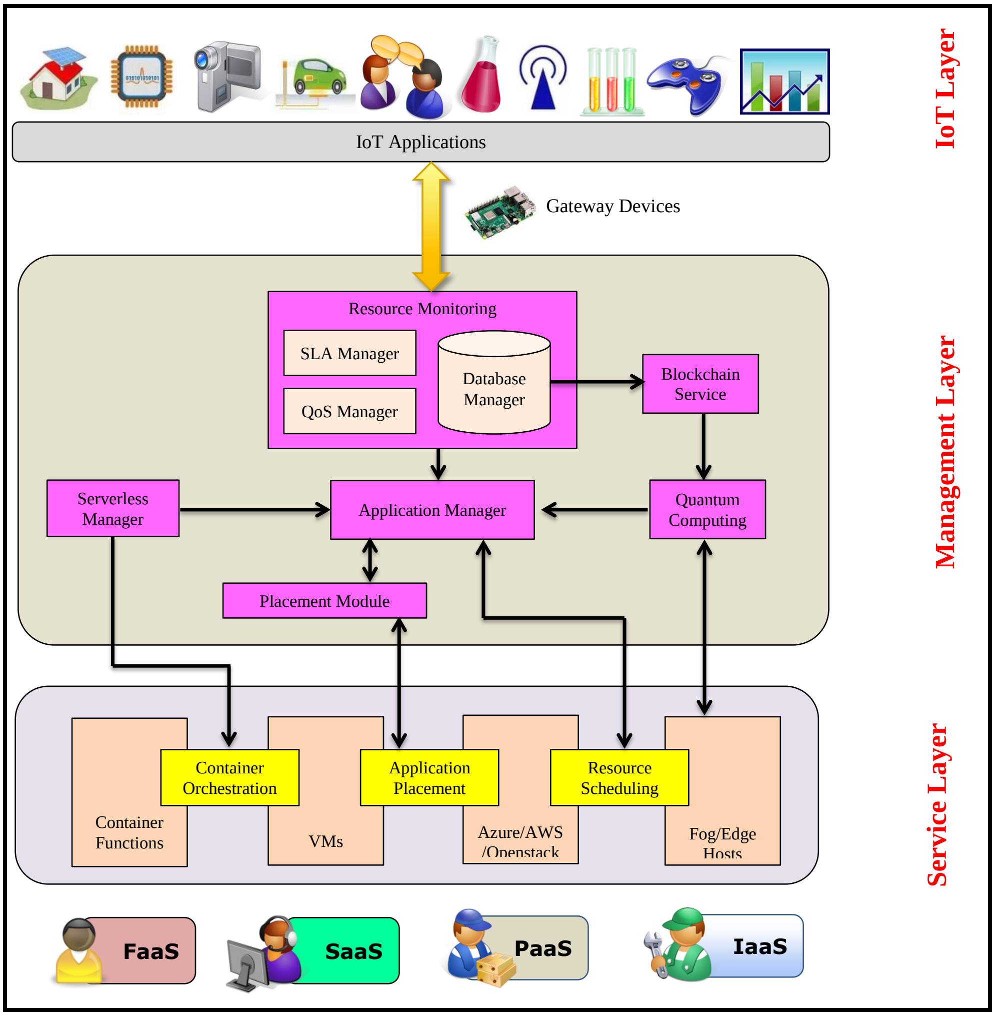

FIGURE 1 A Prospective Model

2.3 | Service Layer

Service layer contains of four different types of services: Function as a Service (FaaS), Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). FaaS achieves the virtualization via different function containers, which are working in an isolated manner to improve the scalabilty of computing systems automatically. SaaS provides the cloud services using the concept of virtualization based on Virtual Machines (VMs). Microsoft Azure, Amazon Web Service (AWS) or OpenStack can be used to provide platform as a service. Fog and Edge computing can be utilized to provide the infrastructure service, which is very effective in processing data at edge devices by reducing latency and response time. Container orchestration is an interface between FaaS and SaaS, and automates the scaling, processing, implementation and networking of containers. Application placement is an interface between SaaS and PaaS, and performs the placement of the IoT applications for resource provisioning and scheduling. Resource scheduling is an interface between PaaS and IaaS, and schedules the cloud resources based on latest machine learning and AI based techniques. For nonce or PoW calculation, the model leverages quantum technologies for quick consensus decision making.

3 | NEW TRENDS AND FUTURE DIRECTIONS

As Serverless data pipelines are integrated with edge computational paradigm, the FaaS platform requires large-scale computation for load balancing and dynamic provisioning requiring quantum computers [15,12]. Robust micro-service computational platforms can only be achieved by developing novel AI techniques that can incorporate big-data on super scalable platforms requiring the efficiency of quantum computational systems to quickly adapt in non-stationary environments[4,9]. This can be realized via AWS Lambda or Google Cloud Functions[19]. Further, super-scale data integrity requires quick hash calculation in Blockchain based frameworks which can further leverage quantum computers to develop systems that are versatile to data characteristics[13,20,14,21]. For volatile IoT environments, multi-agent AI and flexible learning frameworks are required[11,6,22].

3.1 | Artificial Intelligence (AI)

To improve the performance of the computing systems, there is a need to utilize latest reinforcement learning and artificial intelligence techniques to enable volatile IoT environments[11,23]. These techniques can improve the scalability of the Serverless edge computing and enhance the computation capacity to process the data of IoT applications[17]. Furthermore, AI can aid in optimizing QoS and reduce SLA violations of the services leveraging resource optimization policies and scalable machine learning methods[16]. The current scheduling and provisioning techniques do not consider the computational capabilities for quantum architectures and hence more informed resource management strategies are required which are able to leverage such novel architectural platforms.

3.2 | IoT and 5G/6G Technologies

Latest IoT applications such as healthcare, smarty city, agriculture and weather forecasting need quick processing of data with minimum latency and response time[6]. 5G/6G is the acronym for fifth/sixth generation mobile telecommunication services which has the capabilities of providing the data transfer rates of high capacity with extremely low latency and energy consumption. The increase in mission-critical and sophisticated applications in 5G networks requires greater attention in the future as the applications needs to communicate in real time with the resources for sharing their requirements. Serverless edge computing can utilize quantum computers to enable large computational power for fast processing of data at edge devices[3] with 5G/6G technologies for quick data collection and result delivery.

3.3 | Energy Management

The effective utilization of proposed model can improve the service in terms of security, reliability and computational speed using quantum computers and the concept of Blockchian. It requires large amount of energy to run the required big infrastructures[2]. To improve the energy efficiency of cloud data centers, there is a need of AI-based energy efficient techniques, which can reduce energy consumption and cooling requirements by maintaining the temperature of data center dynamically[5]. Modern computational paradigms with novel memory architectures could aid in bringing down the energy consumption to levels amenable to energy scavenging approaches and renewable resources[24].

3.4 | Security and Privacy

Blockchain based frameworks can provide higher level of security to the Serverless edge computing systems but to offer super-scale data integrity requires quick hash calculation[18]. To solve this problem, there is a need to leverage quantum computers in developing systems that are versatile to data characteristics[1]. Quantum Dot architectures can aid development of novel encryption and hashing mechanism that exacerbate hacking and loss of data integrity[25]. The trust and privacy models developed for serverless computing needs a prime attention in order to provide all the stakeholders a safe environment facilitating this paradigm shift. Thus, the introduction of trust and privacy constraints into the scheduling of tasks to limited number of resources in the serverless can be an open research challenge in future.

3.5 | Quality of Service (QoS)

For Serverless edge computing, there is a need to fulfill the required QoS requirements while optimizing the performance parameters such as response time, latency, energy, security and network bandwidth[7]. The achievement of desired QoS can help to fulfill the SLA signed between user and provider[10].

3.6 | Application Design

There is a need to design innovative IoT applications for healthcare, weather forecasting and traffic management, which offer more independence during the execution[8]. This will require generic application refactoring techniques which are applicable for cognitive models that can be adopted in ubiquitous edge systems based on quantum architectures[26]. These type of applications runs on different edge resources to reduce the latency and response time at run-time and improve resource utilization[6].

3.7 | Dynamic Scalability and Autoscaling

The utilization of Serverless computing or FaaS for fog and edge computing can satisfy the volatile demand of various IoT applications dynamically[1]. Further, the concept of autoscaling can improve the self-confirmation of resources, self-optimization of QoS parameters, self-protection from attacks and self-healing from occurrence of software, hardware or network faults without manual intervention[22].

4 | SUMMARY

In this letter, various emerging paradigms such as edge computing, serverless computing, quantum computing and Blockchain are discussed and proposed. A conceptual model which utilizes these paradigms effectively to deliver reliable, secure and fast cloud service is shown. As per Figure 1, all different paradigms of serverless computing, blockchain technology and quantum computing are brought together to provide a holistic computational platform that encompasses devices at service, management and IoT layers. The IoT layer which is an embodiment of end devices like sensors and actuators which collect data or carry out resultant actions or provide application outputs to the users. The Management Layer monitors resources and provides an interface between the IoT devices and computational platforms. This umbrella layer consists of management modules for the serverless pipelines, blockchain services and provisioning of quantum resources. Further, the Service layer executes the raw computational functions on legacy or quantum resources under the serverles FaaS abstraction. Finally, promising future research directions and open challenges are highlighted.

5 | DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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