A Review of Edge Computing Nodes based on the Internet of Things

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Abstract: Due to the limitations of resources on the IoT device side, it is necessary to provide users with services not only by means of a long-distance cloud computing center node, but also by some edge computing nodes. If all the data on the device side is transmitted to the cloud center node, it will be returned to the device side after unified processing. This transmission method will bring great pressure to the network link and data center, and it will also cause the cloud center node to overload and refuse service. In order to speed up the data processing and reduce delay, we briefly summarize the edge computing node model in this paper. Firstly, considering the properties of privacy, security, trust and resource scheduling, etc., the edge computing is analyzed. Then, based on these properties, the definition, architecture, and collaboration with cloud-edge-net of edge computing are discussed. We also introduce the current key technologies used in edge computing, such as network, virtualization, isolation, deep learning, and access control technologies. Finally, we give a prospect of the possible application of edge computing in the future.

1 INTRODUCTION

Edge computing is an open platform based on edge nodes, which integrates network, computing, storage, application and other core capabilities of distributed computing. The United States is the birthplace of the concept of edge computing. In 2003, AKAMAI began collaborating with IBM on "Edge computing", providing edge-based services on Web Sphere (IBM & AKAMAI, 2003). In 2011, Cisco was the first one to proposed the concept of fog Computing, which extends the concept of Cloud Computing (BONOMI, 2011).

Compared with Cloud Computing, it is closer to the place where data is generated. Data, data-related processing and applications are concentrated in devices at the edge of the network. From fog computing to edge computing, mapping along the edge cloud network hierarchy. It makes possible for a variety of computing tasks to achieve different levels of intelligence at different costs and energy budgets (Martin and Diaz, 2018), as shown Figure 1. In May 2016, a team of professors at Weisong Shi state university in the United States came up with a formal definition of edge. Edge computing is a new network computing mode that performs edge computing.

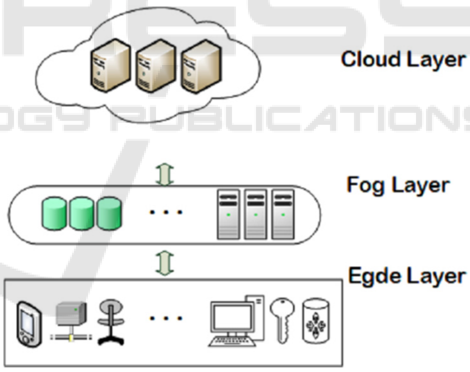

Figure 1: A simplified architecture of edge-to-cloud network with cloud computing.

The downlink data of edge computing represents cloud service and the uplink represents the interconnection of everything (Shi and Cao, 2016). Edge computing refers to the computing and network resources between the data source and any path to the cloud computing center.

In November 2018, the Edge Cross Alliance was established. The alliance was used a two-pronged approach to address the critical issues involved in accurately modeling data at the edge. The alliance

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also aimed to promote standardization of these data models to further pursue more precise and simplified the edge processing methods. They discussed the edge computing nodes based on the Internet of things (Boubendir and Guillemin, 2018).

This paper introduces the development history of edge computing node in section 1. The section 2, 3 introduce the reasons for the generation of edge computing nodes, and then give an overview from definition, architecture, and Cloud-Edge-Network Coordination. And then the key techniques to promote the development of edge computing are discussed in the 4th section, the 5th section is the the direction of application, the 6th is the summary and outlook.

2 EDGE COMPUTING NODE GENERATION

In daily life, when users use various applications on the network, the application will obtain all the user's data, including the private data. Most of the data is uploaded to the cloud center for storage. In the process of data transmission and storage, due to the openness of the application environment of the Internet of things, diversity of services, energy nodes limited and other characteristics, the risk of user privacy data leakage increases, so the security problem between nodes remains to be solved. When the two edge clouds interact, they need to be accessed through the edge trust node on the edge cloud. Under the condition of reaching a consensus, resources are allocated among the edge clouds. The framework for this interaction can be seen in Figure 2.

2.1 Privacy, Security and Trust

Saurabh proposed a framework where each sensor node maintains reputation metrics which both represent past behavior of other nodes and are used as an inherent aspect in predicting their future behavior. He employed a Bayesian formulation and combine with the beta reputation system, for the algorithm steps of reputation representation, updates, integration and trust evolution (Saurabh and Ganeriwal, 2008). Integrated comprehensive trust theory, rough set theory, analytic hierarchy process (AHP) and the combination of weight and grey correlation analysis, in order to improve user satisfaction and the success rate of node interaction (Wang and Wen, 2019).

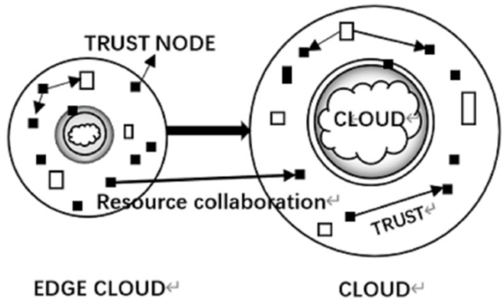

Figure 2: Trust and resource collaboration between edge nodes.

Resource efficiency and dependability are the most basic requirements of the trust model. The definition of a self-adapted weighted method for trust aggregation at CH level surpasses the limitations of the subjective definition of weights in traditional weighted method. The fuzzy degree of nearness is used to evaluate the reliability of the recommended trust values from the third-party nodes (Shao and Zhou, 2015). Based on service preference to identify user community effectively, a dynamic cloud service trust evaluation model based on service-level agreement (SLA) and privacy awareness is proposed, which improves the satisfaction of service requesters and avoids malicious interference (Wang and Wen, 2018). Shahzad provides a study of the issues related to the data sharing through these smart devices over service providing cloud. It proposes communication architecture by introducing an intermediate layer of data sharing control consisting of privacy agents. It used to define custom privacy policies for different personal attributes in different business models (Shahzad and Iqbal, 2017).

2.2 Resource Allocation

2.2.1 Global Delay

In order to achieve the minimize global delay, a flow scheduling policy based on link bandwidth proportional fair allocation was designed by Feng. The virtual forwarding space (VFS) of flood lighting is proposed to realize the fair allocation of link bandwidth and the minimum delay flow scheduling in the data plane (Feng and Bi, 2014). Considering dynamic changes in user requirements and limited available resources in Fog devices. Naha propose resource allocation and provisioning algorithms by using resource ranking and provision of resources in a hybrid and hierarchical fashion. Use the Cloud Sim toolkit to simulate a real fog environment. The performance of the proposed algorithms is better compared with existing algorithms in terms of overall data processing time and network delay (Naha and Garg, 2019). Zenith is a novel model for allocating computing resources in an edge computing platform which allows the service providers to establish resource sharing contracts with edge infrastructure providers (Xu and Palanisamy, 2017). The latency-aware scheduling and resource provisioning algorithm that enables tasks to complete and meet their latency requirements. A resource allocation model of edge cloud based on auction mechanism is proposed (Xu, 2016), and the time-delay requirement of application is effectively guaranteed by the use of delay-aware resource scheduling algorithm.

2.2.2 Quality-of-Service

Song presents an effective approach to periodically distributing incoming tasks in the edge computing network so that the number of tasks can be processed in the edge computing network is increased. In order to satisfied all the accommodated tasks quality-of-service (QoS) specifications required in the IoT applications (Song and Yau, 2017). To solve the problem of resource scheduling in edge applications, under the principle of not violating the service quality requirements, a resource scheduling method based on genetic algorithm is proposed (Skarlat and Nardelli, 2017).

In the context of smart cities, the concept of mobile edge computing (MEC) is taken as a key factor to improve the Quality of Service (QoS). Not only does it enhance the autonomous creation of MEC services, allowing data to be accessed any-where-anytime, with the best Quality of Experience (QoE), but it also reduced latency (Taleb and Dutta, 2017).

2.2.3 Bandwidth Allocation, Offloading

Distributed gradient-push algorithm can solve the bandwidth allocation problems over WLAN with directed typologies. Compared with the existing distributed algorithms, we use weighted running average bandwidth to replace the current state variables meanwhile, the convergence performance is improved and the robustness against noise is enhanced (Shi and Zhou, 2019). Ascigil proposes a set of practical, uncoordinated service placement policies. Through a large number of simulations using synthetic and real trace data, it has been demonstrated that the uncoordinated strategy performs better than the optimal placement solution, satisfying the maximum amount of user requests (Ascigil and Phan, 2017).

For the power delay trade off of multi-user moving edge computing system, an online algorithm for determining local execution and calculating unloading strategy is presented based on Lyapunov optimization algorithm (Mao and Zhang, 2016). Lyapunov optimization-based dynamic computation offloading algorithm named low-complexity online algorithm, which jointly decides the offloading decision, the CPU-cycle frequencies for mobile execution and the transmit power for computation offloading. A unique advantage of this algorithm is that the decisions depend only on the current system state. The implementation of the algorithm only requires to solve a deterministic problem in each time slot, for which the optimal solution can be obtained either in closed form or by bisection search (Mao and Zhang, 2016).

3 DEFINITION OF EDGE COMPUTING

3.1 Definition

Edge computing is a new computing model. It can be seen from the definition of edge computing that edge computing is not to replace cloud computing but to supplement cloud computing, providing a better computing platform for mobile computing and Internet of things. "Edge" in edge computing refers to the computing and storage resources on the edge of the network. The edge of the network here is opposite to the data center, which is closer to the user both in terms of geographical distance and network distance.

Professor Satyanarayanan describes edge computing as: "edge computing is a new computing model that deploys computing and storage resources (e.g., cloudlets, micro data centers, or fog nodes) on the edge of the network closer to the mobile device or sensor"(Satyanarayanan, 2017). Wayne state university in the United States WeiSong Shi et al (Shi and Cao, 2016). The calculation is defined as: "edge of computing refers to the network edge perform calculations of a new type of computing model, in computing the edge on the edge of the downstream data cloud services, uplink said that everything connected, and the edge of the edge of computing refers to from the data source to cloud computing center path between any of the computing and network resources."

Edge computing is the technology of using these resources to provide services to users on the edge of the network so that applications can process data near the data source. ISO think edge computing is a main business processing and data storage in the network edge node of the distributed computing form (Arndt, 2017). However, the Edge Computing Consortium (ECC) is defined margin calculation is close to the network edge side of data source, integrating core ability of network computing storage application development platform, etc (ECC, 2017).

3.2 Architecture

Resources and information are gathered to the center by cloud computing, realizing the centralized computing with complete control over user information and behavior. Edge computing is a distributed operation that transfers applications, data and services from network center nodes to network logical edge nodes for processing, you can see the difference between Figure 3 and 4. Large services originally handled entirely by cloud center nodes are decomposed by edge computing, cut into smaller and more manageable parts and distributed to edge. Based on the previous work, λ-CoAP architecture, a new edge computing architecture is proposed. Edge computing deployments that cover the entire field of vision, from IOT devices, edge smart gateways to the cloud infrastructure (Martin and Diaz, 2018).

3.3 Cloud-Edge-Network Coordination

There is force synergy between edge computing and cloud computing at the center. Force network refers to the realization of cloud network collaboration, cloud edge collaboration, and even edge collaboration between edge computing and cloud computing and networks, in order to realize the optimization of resource utilization. On the basis of studying the demand of edge computing force distribution and dispatching, a deep fusion of cloud-network-edge computing force network is proposed. This scheme can effectively deal with the multi-stage deployment of computing storage network and even algorithm resources as well as the flexible scheduling among nodes (Lei and Liu, 2019).

4 KEY TECHNOLOGY

The rapid development of edge computing is due to technological advances. Promote the development of core technologies of edge computing including network, isolation technology, virtualization technology, deep learning technology, access control technology, algorithm execution framework security and privacy, data processing platform, etc.

Figure 3: Cloud computing.

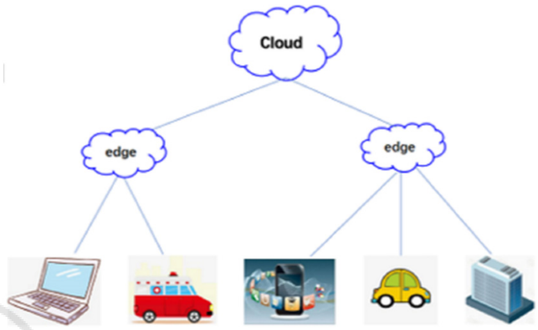

Figure 4: Edge computing.

4.1 Network

Edge computing pushes the computation closer to the data source, and even deplores the entire computation to nodes on the transport path from the data source to the cloud computing center.

Edge devices generate a large amount of data, while edge servers provide a large number of services. Therefore, according to the edge servers and network conditions, how to dynamically schedule these data to the appropriate computing service providers, load balancing will be one of the core issues in edge computing. The maximal uniform distribution of the load across closer and simpler nodes can help managing and providing the big data and large workloads more easily. Verma proposed an efficient load balancing algorithm for a Fog-Cloud based architecture. The ultimate goal is to balance load through Fog networks and make internet less Cloud dependent by having data available closer to the user end (Verma and Yadav, 2016).

Edcs are used for reduce latency and network congestion by processing data streams and user requests in real time. The new load balancing technology implements authentication of the edcs and finds less heavily loaded edcs for task assignments. Load balancing techniques enable workload redistribution between edcs to improve resource utilization and job response time (Puthal and Obaidat, 2018).

4.2 Virtualization Technology

Virtualization technology includes memory virtualization, storage virtualization, hardware virtualization, software virtualization and other technologies. It is a process of turning a physical unit into multiple logical units. It is applicable to multiple applications to achieve efficient utilization of resources and efficient management of various resources.

Virtualization technology provides high availability for critical applications and simplifies application deployment and migration. It performed well in terms of cost, time and energy savings (Ding and Ghansah, 2015). The virtualization technology can achieve the rational utilization of hardware resources through virtual software and assigns these resources into corresponding application software (Kong 2014). Container is a new virtualization replaces the traditional virtual machine technology. Changes have been made in the architecture of Infrastructure as a Service (Iaas) and Platform as a Service (Paas) platforms (Wu, 2017).

4.3 Isolation Technology

Isolation technology is a research technology that supports the robust development of edge computing. Edge equipment needs effective isolation technology to ensure the reliability and quality of service.

1) The isolation of computing resources, that is, the applications shall not interfere with each other;

2) Data isolation, that is, different applications should have different access rights.

The core idea of Docker is to use the extended LXC (Linux Container) scheme to achieve a lightweight virtualization solution. By using kernel namespace, Docker realizes isolation of container to ensure the operating environment isolation among each virtual machine service. The isolation mechanism of Docker can reduce the memory overhead and ensure the virtual instance density. (Liu and Li, 2015).

Containers are constantly gaining ground in the virtualization landscape as a lightweight and efficient alternative to hypervisor-based Virtual Machines, with Docker being the most successful representative. This strategy allows developers to easily pack applications into Docker image layers and distribute them via public registries. Ioannis proposed and demonstrate a mechanism for secure Docker image manipulation throughout its life cycle: The creation, storage and usage of a Docker image is backed by a data-at-rest mechanism. (Giannakopoulos and Papazafeiropoulos，2017).

4.4 Deep Learning Technology

Deep learning (DL) is a promising approach for extracting accurate information from raw sensor data from IoT devices deployed in complex environments. Because of its multilayer structure, deep learning is also appropriate for the edge computing environment (Li, Ota and Dong, 2018).

DL as the representative technique of artificial intelligence, it can be integrated into edge computing frameworks to build intelligent edge for dynamic, adaptive edge maintenance and management. Promoting the fusion of edge intelligence and intelligent edge, Edge Deep Learning (Han and Wang, 2019). Figure 5 is a frame about combine deep learning with edge computing. Deep learning technology require substantial computation resources to run quickly. Edge computing is a viable way to meet the high computation and low-latency requirements of deep learning on edge devices and also provides additional benefits in terms of privacy, bandwidth efficiency, and scalability (Chen and Ran, 2019).

4.5 Access Control Technology

Access control technology is based on satisfying users' demands for maximum enjoyment of resource sharing, in order to achieve the management of user access rights, prevent information from being tampered with or abused by unauthorized users. It is a reliable tool to ensure system security and protect user' privacy. In edge computing, access control becomes more difficult, mainly because in multi-user access environments, access control functions need to be provided by edge computing service providers. Secondly, access control supports remote provision of user basic information and policy information, and also supports regular update of access control information. Finally, access control for highly distributed and dynamically heterogeneous data is an important challenge in itself.

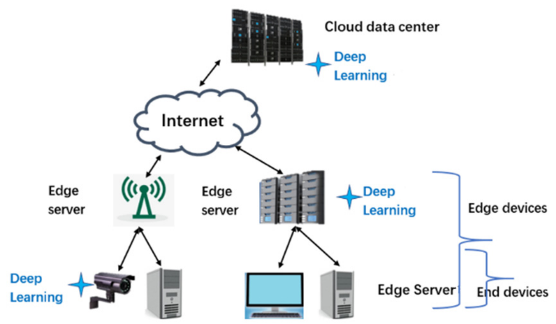

Figure 5: Combine deep learning with edge computing.

5 DIRECTION OF APPLICATION

5.1 Content Delivery Network

The combination of content distribution network and edge computing is the future development trend. With the evolution of CDN technology, the initial content cache needs to be upgraded to smart edge computing. The combination of CDN and mobile edge computing device can fully reuse its nodes and provide edge computing services. CDN USES global load technology to direct user access to the nearest working cache server.

Because of CDN distribution of nodes in the network edge, service providers can take advantage of the existing CDN further down to near the user's network edge node, make each CDN nodes near the user into edge mobile computing devices, to achieve operational and support for various applications, in order to meet the high frequency, the fragmentary IOT equipment demand of calculation and transmission. Amazon s AWS Lambda shows how custom processing can enhance standard content delivery networks (CDNs) without incurring additional latency (Klas, 2017). A CDN with the help of distributed denial of service (DDoS) mitigation can enhance and maintain the website security from DDoS attacks (Alrowaily and Lu, 2018).

5.2 5G

As the most important innovation scenario in the 5G era, edge computing can provide customers with multiple business guarantees such as low delay and large bandwidth. According to IDC's data times 2025 report, 50% of data will be analyzed, processed and stored on the edge of the network by 2025 (Tran and Hajisami, 2017). At the same time, edge computing is also considered as an important combination point of 5G, industrial Internet and Internet of things, which can promote relevant industries to bring about rapid development. However, with in-depth research and practice, the concept of edge computing is not limited to 5G, it has been extended to PON, wifi, 4G, etc., that is, multi-access edge computing.

5.3 Industry 4.0

Edge computing can play an important role in the virtualization and business management of industrial intelligent manufacturing systems. Firstly, through the real-time connection and perception of edge devices, an independent and reconfigurable digital device model is established to enable the virtual modeling and relational retrieval of production resources. Secondly, adaptive allocation of network resources is realized through SDN technology to provide effective information transfer means for reconfigurable devices.

6 CONCLUSIONS

The so-called Internet of everything extends on the X-axis of time. The largest network is the Internet of things. The huge scale of the Internet of things requires fast computing power. If cloud computing is the coordinator, edge computing is the executor. Cloud computing is responsible for long-term big data analysis. Edge computing is the calculation, processing, optimization and storage of data close to the edge of the Internet of things. Edge computing and cloud computing work together and complement each other. Edge computing is close to the device, which also contributes to cloud data collection and supports big data analysis of cloud applications. In addition, trust is the foundation of secure interaction between edge computing nodes. Edge compute nodes control trust relationships and sensitive information flows in a secure manner. Integrate distributed computing into edge computing in a centralized cloud computing architecture to reduce reliance on the cloud center. Through the core technology of edge calculation, the calculation efficiency is greatly improved. Edge computing is still a work in progress.

In the future, the technical standards and standardization of edge computing can be improved, and the development of edge computing technology can also be combined with the new generation of information technology, so that the research on edge computing will be more in-depth.

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