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Comparative Analysis of Various Edge Computing Systems and Tools

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Abstract

Fast application development is made possible by edge computing platforms, which integrate compute, storage, and network resources at the edge of the network and are powered by 5G and IoT communications. In the IoE age, Edge Computing is essential to address problems like deployment, security, and service migration. But as Blockchain, AI, and Microservices have developed, their shortcomings are becoming more apparent. This survey addresses open issues for system analysis and design, compares open-source tools, explores energy efficiency and deep learning optimisation, and gives an overview of edge computing research, definition, model, and characteristics. It also gives an overview of current edge computing systems.

Keywords: Edge Computing system, IoT, Energy Efficiency, Deep Learning Optimization

INTRODUCTION

The development of the Internet of Things (IoT) and the widespread use of 4G and 5G in the post-Cloud age is challenging the cloud computing's capacity to grow linearly by gradually altering the public habits around data access and processing. A new paradigm for computing called edge computing processes data at the network's edge. Notwithstanding the fact that some of them may not be in widespread usage just yet, edge computing systems and tools are flourishing due to the rapidly increasing interest and demand in this field.Figure 1 shows the major building blocks of the proposed review.

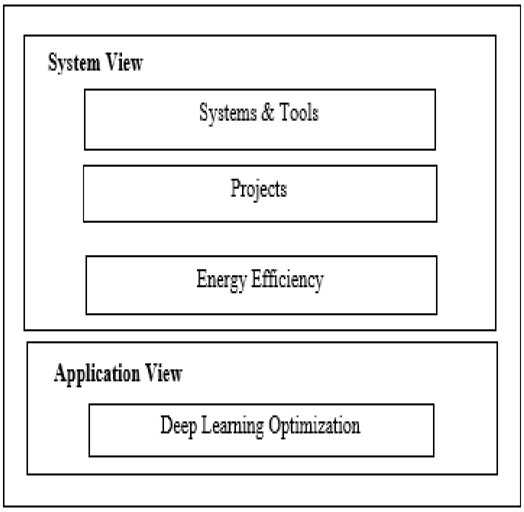

Figure 1: Major Building Blocks of the Work

Existing edge computing systems can be broadly divided into three groups according to distinct design requirements; these groups have produced improvements in system architecture, programming methods, and a range of applications as shown in table 1

Design	Architecture	Application	Programming model	Open source system
Push	Cloudlet,, CloudPath,AirBox	Cachier	Airbox	CORD, Akarino: Edge stack
Pull	Pcloud, ParaDrop, SpanEdge,FocusStack	FocusStack	-	EdgeX Foundery, Apache Edgent
Hybrid	Cloud Sea Computing	-	Firework	Azure IoT Edge

Table 1: Categorization of Edge Computing

I. Push Service

In order to take advantage of locality, speed up response times, and enhance user experience, cloud providers in this category push services and processing to the edge.

a).Cloudlet

A cloudlet is a reliable, powerful computer, or cluster of computers, that is reachable by surrounding mobile devices and has a strong Internet connection. The Cloudlet is a three-tier edge computing architecture that resides in the intermediate layer and can be deployed on a small cluster, low-cost server, or personal computer. It may consist of a single machine or tiny clusters made up of several units.

b).Cloudpath

Various resources, including processing and storage, are offered in this kind of system as it moves from the user device to the cloud DC.It facilitates dynamic multilayer architecture deployment and on-demand allocation. The primary goal of CloudPath is to apply "path computing," which is said to be able to enhance bandwidth utilisation and decrease reaction times in comparison to traditional cloud computing.

II. Pull

IoT apps handle the massive volume of data created by IoT devices by bringing services and computing from the distant cloud to the close edge. Representative system includes

a).Pcloud

Pcloud combines cloud-based and edge-based processing and storage resources to enable smooth mobile services. Additionally, PCloud makes the system more available overall and has the flexibility to select different resources in the event of equipment or network failure.

III. Hybrid

Modern sophisticated services and applications can now achieve lowest reaction times and global ideal.

A).ParaDrop

It is an edge computing platform that allows third-party developers to access the processing and storage resources near mobile devices and data sources. Its objective is to amicably introduce intelligence to the network edge. By replacing the current access point with an edge computing system, ParaDrop allows it to support programs and services just like a regular server. Using the lightweight container virtualisation approach, ParaDrop isolates programs under multitenancy scenarios.

B).Spanedge

Spanedge lowers network latency in WAN connections, combines the cloud and near-edge central nodes, and offers a programming environment that enables the application to execute close to the data source.Without taking into account the locations and distribution patterns of the data sources, developers may concentrate on creating streaming applications.

C).Cloud sea

The name "sea" in cloud-sea computing systems refers to the terminal side (the client devices, such as human-facing and physical world-facing subsystems), while "cloud" refers to the datacenters. The design of the project can be illustrated from three levels: the overall systems architecture level, the datacenter server and storage system level, and the processor chip depth.

D).Cachier prolog

The Cachier system proposes that edge nodes can be used as “computable cache devices,” which can cache recognition results, reduce matching data set size, and improve response time. By analyzing the response delay model and requests’ characteristics, the system can dynamically adjust the size of the data set on the edge nodes according to the environment factors, thus ensuring optimal response time. Precog is an extension of Cachier. The cached data are not only on the edge nodes but also on the end devices that are used for selection calculation in order to reduce the image migration between the edge nodes and the cloud.

E).Focusstack

It enables the installation of sophisticated apps on a range of possible IoT edge devices. Even while edge devices have limited resources in terms of processing, power consumption, and communication, they are mobile in nature. Therefore, having a system that can locate and arrange the edge resources that are available is crucial. One such system is FocusStack, which can identify a group of edge devices with enough power,

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install apps, and execute them in line with those devices' needs. This allows the developers to concentrate more on the application design rather than tracking down and locating edge resources.

Application scenario	*Edge Computing system*	*End Devices*	*Edge nodes*	*Computation Architecture*	*Targets/Feature*
General usage scenario	Cloudlet	Mobile device	Cloudlet	Hybrid	Lightweight VM Migration
	PCloud	Mobile Device	Mobile Device, Local servers, PC	Hybrid	Resource integration, dynamic allocation
	ParaDrop	IoT Device	Home gateway	Hybrid	Hardware developer support
	Cachier & precog	Mobile Device	Mobile Device, Local servers, PC	Hybrid	Figure recognition, identification
	FocusStack	IoT Device	Routers, Servers	Hybrid	Location based info, Openstack extension
	SpanEdge	IoT Device	Local Cluster, Fog, Cloudlet	Hybrid	Streaming process, local/global task
	Air Box	IoT Device	Mobile Device, Local servers, PC	Hybrid	Security
	Cloud Path	Mobile devices	Multi-level data centers	Hybrid	Path computing
	Firework	Firework node	Firework. Node	Two layer scheduling	Programming model
	Cloud-sea	Sea	Seaport	Hybrid	Minimal extension, transparency

Table 2: Summary of Edge Computing System

OPEN SOURCE EDGE COMPUTING PROJECTS

Recently, a few open-source edge computing projects have also been introduced, in addition to edge computing systems that are specifically tailored for particular uses. In 2017 and 2018, the Linux Foundation released two projects: EdgeX Foundry and Akraino Edge Statck. One initiative that the Open Network Foundation (ONF) started is called CORD. Apache Edgent was released by the Apache Software Foundation. Azure IoT Edge was released by Microsoft in 2017 and made available as an open source project in 2018. Among them, EdgeX Foundry and Apache Edgent concentrate on the Internet of Things and seek to address issues that impede the practical applications of edge computing in the IoT; Azure IoT Edge offers hybrid cloud-edge analytics, which aids in the migration of cloud solutions to IoT devices; and CORD and Akraino Edge Stack concentrate on offering edge cloud services. Table 3 compares the Open edge computing projects

A).CORD

CORD is an open-source project of ONF started by AT&T that is intended for network operators. It aims to slice the computing, storage, and network resources so that these datacenters can act as clouds at the edge, providing end users with agile services. CORD plans to reconstruct the edge network infrastructure to build datacenters with software-defined network (SDN) , network function virtualisation (NFV) , and Cloud technologies.

B).AKARINO

Akraino Edge Stack, launched by AT&T and now hosted by Linux Foundation, is a project to provide a holistic solution for edge infrastructure so as to support high-availability edge cloud applications.From the application layer to the infrastructure layer, Akraino Edge Stack covers a lot of ground. Akraino Edge Stack requires edge apps and seeks to establish a virtual network function (VNF) ecosystem at the application layer. The second layer comprises of middleware that supports applications in the top layer. The goal of edge media processing is to create a network cloud that will allow for low-latency edge media AI analytics and real-time media processing.

C).EdgeX Foundry

Edge nodes including hubs, routers, and gateways are the sweet spots of EdgeX Foundry, a standardised interoperability architecture for IoT edge computing [36]. Through a variety of protocols, it can establish connections with a wide range of sensors and devices, manage them, gather data from them, and export the information to a local application at the edge or the cloud for additional processing. The purpose of EdgeX's design is to provide hardware, CPU, operating system, and application environment diagnostics. It has two operating systems: native and Docker containers.EdgeX is intended for usage in scenarios involving large numbers of sensors or devices, such as automated manufacturing plants, automated machinery, and numerous other Internet of Things scenarios.

D).Apache Edgent Previously known as Apache Quarks, Apache Edgent is currently an Apache Incubator project. It is an open-source programming approach for runtime data analytics that is lightweight and is utilised in small devices like edge gateways and routers. With an emphasis on edge data analytics, Apache Edgent seeks to quicken development.Edgent is appropriate for Internet of Things use cases like automated industries, intelligent transportation, and so forth. Furthermore, the data in Edgent apps can also be files or logs in addition to sensor readings. Edgent can therefore be used in additional use situations. When integrated with application servers, for instance, it can carry out local data analysis, analysing error logs without affecting network traffic.

E).Azure

Microsoft Azure, a cloud service provider, offers Azure IoT Edge, which aims to bring cloud analytics to edge devices. These edge devices may be gateways, routers, or other computational resource-supplyingdevices.

Because Azure IoT Edge uses the same programming architecture as other Azure IoT services [38] in the cloud, users can transfer their current Azure apps to the edge devices in order to reduce latency. The ease of use makes creating edge apps simpler. Furthermore, sophisticated processes like machine learning, picture recognition, and other AI-related tasks may be implemented on edge devices using Azure services like Azure functions, Azure ML, and Azure stream analytics.

Aspect	*EdgeX Foundry*	*Azure IoT Edge*	*Apache Edgent*	*CORD*	*Akraino Edge Stack*
User access interface	Restful API/EdgeX UI	Web service, Command line	API	API/ XOS-GUI	N/A
OS support	Various OS	Various OS	Various OS	Ubuntu	Linux
Programming framework	Not Provided	Java,.NET,C,Python, etc.	Java	Shell script, python	N/A
Main purpose	Provide with interoperability for IoT edge	Hybrid cloud-edge analytics	Accelerate the development process of data analysis	Transform edge of the operator network into agile service delivery platform	Support edge clouds with an open source software stack
Application Are	IoT	Unrestricted	IoT	Unrestricted	Unrestricted
Deployment	Dynamic	Dynamic	Static	Dynamic	Dynamic
Target user	General users	General Users	General users	Network operators	Network operators
Virtualization technology	Container	Container	JVM	VM and Container	VM and Container
System Characteristics	A common API for device management	Powerful Azure services	APIs for data analytics	Widespread edge clouds	Widespread edge clouds
Limitation	Lack of programmable interface	Azure Service is chargeable	Limited to data analytics	Unable to be offline	Unable to be offline
Scalability	Scalable	Scalable	Not scalable	Scalable	Scalable
Mobility	Not support	Not support	Not support	Support	support

Table 3: Comparison of Open Edge System Characteristics

ENCHANING EFFICIENCY OF ENERGY IN EDGE COMPUTING SYSTEM

Modern edge computing systems have incorporated energy-efficiency-enhancing techniques. These mechanisms are reviewed in this work from the perspectives of the top cloud layer, middle edge server layer, and bottom device layer, respectively.

A).Uppermost Edge Server Layer

A centralised data centre (CDC) for cloud computing may consist of thousands of computers, resulting in high energy consumption. Does the edge/fog computing paradigm use more or less energy as a substitute for cloud computing? Various opinions have been expressed: some contend that the edge computing architecture's decentralised data processing and storage are more energy-efficient, while others demonstrate that the distributed content distribution method may use more energy than the centralised one.

B).The Middle Device Layer

Energy is also considered a critical component at the intermediate layer of the edge computing paradigm because edge servers can be installed in residential settings or run on batteries. Thus, to guarantee a higher availability, numerous power management techniques have been implemented to restrict the energy consumption of edge servers while still ensuring their performances. We cover two prominent approaches that are employed in modern edge computing systems at the edge server layer.

C).In the Lower Device Layer

It is a well-known fact that IoT devices used in edge computing typically have stringent energy requirements, such as short battery lives and low energy storage capacities. Powering a large number of IoT devices at the edge—up to tens of billions—remains a significant challenge, particularly for resource-intensive applications or services . We go over the energy-saving techniques used at the edge computing diagram's device layer. In particular, we discuss three main strategies for obtaining great energy efficiency in various edge/fog computing systems.

DEEP LEARNING OPTIMIZATION AT THE EDGE

Deep learning tasks are now being moved to the edge due to the explosive growth of edge computing. Thus, it asks for new strategies to support the deep learning models at the edge. These technologies are divided into three groups in this section: hardware, deep learning packages, and systems and toolkits.Table 4 shows the comparison of the deep learning systems on Edge.

Features	*AWS IoT Greengrass*	*Azure IoT Edge*	*Cloud IoT Edge*
Developer	Amazon	Microsoft	Google
Components	IoT Greengrass Core, IoT Device SDK, IoT Greengrass SDK	IoT Edge modules, IoT Edge runtime, Cloud based interface	Edge connect, Edge ML, Edge TPU
OS	Linux, macOS, windows	Windows, Linux, macOS	Linux, macOS, Windows, Android
Target device	Multiple platforms	Multiple platforms	TPU
Characteristic	Flexible	Windows friendly	Real-time

Table 4: Comparison on Deep Learning Systems on Edge

CONCLUSION

Research on edge-based intelligence services is further supported by the combination of edge computing and deep learning methodologies. In addition to presenting various energy-efficiency-enhancing strategies for performance consideration and technologies for deploying deep learning models at the edge, this paper introduced representative systems and open-source projects for edge computing and proposed a few research directions during the system design and analysis.

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