



# Akraino White Paper



## Edge Cloud Game based on Arm architecture high performance CPU

<1st edition – March 2022>



## Applicable Users

The current white paper is intended for the following readers

- ◆ Akraino blueprint owners and developers
- ◆ Akraino blueprint integrators
- ◆ Akraino platform owners
- ◆ Cloud execution environment providers

## Abbreviations

FPS	frame per second
GPU	graphics processing unit
Guest OS	guest operating system
host OS	host operating system

# Table of Contents

## Table of Contents

<b>Applicable Users</b> .....	2
Introduction .....	1
Cloud-edge collaboration in the cloud game .....	1
The Main Process of Cloud Game .....	1
The Background Role Division .....	2
Challenges of Edge Computing and Cloud Gaming .....	4
Multi-terminal support .....	5
Delay .....	6
Operation And Maintenance .....	6
LF Edge Akraino Cloud Gaming Questionnaire .....	7
Overview and Structure of Questionnaire .....	7
Use Cases .....	9
LF Edge Akraino Cloud Gaming business feasibility and business model analysis .....	10
LF Edge Akraino Cloud Gaming Overall Architecture .....	11
Use Case .....	12
Business Drivers .....	12
Platform Architecture .....	14
Anbox Cloud Game Framework .....	14
LF Edge Akraino Cloud Gaming Standardization System .....	15
LF Edge Akraino Cloud Gaming User Experience Evaluation System .....	18
Next-generation Cloud-native ARM server chips help LF Edge Akraino Cloud gaming .....	19
Arm Server Players .....	19
Edge Computing Cloud Game Performance .....	19
Cloud game test architecture .....	20
Cloud game test tools .....	20
Cloud game performance test case .....	20
Cloud game performance test result .....	22
Conclusion .....	23

References .....	24
Authors .....	24
Contributors .....	24

---

# Introduction

## Cloud-edge collaboration in the cloud game

According to Newzoo's 2018 Global Game Market Report, the global game market reached a market size of US\$137.9 billion in 2018, of which China reached US\$37.9 billion, accounting for 28% of global game revenue. Newzoo also pointed out that in 2021, mobile games occupied about 59% of the global game market; By 2025, the gaming industry is expected to generate an estimated \$211 billion in revenue, with mobile gaming contributing \$116 billion.

Equipment will be one of the most significant issues the gaming industry needs to face. Behind the booming game market, there is a problem that game manufacturers cannot escape, games have higher and higher requirements for equipment. The root cause of this problem is that the game screen is getting richer and more realistic, and it has higher requirements for the performance of memory and processor. Taking the game "Final Fantasy 15" as an example, if players want to achieve the best gaming experience, they need to be equipped with a graphics card costing nearly 10,000 yuan. Faced with such hardware requirements, many players are unable to achieve them. Therefore, it is difficult to realize the comprehensive hardware independent update on the player side to achieve the game effect. For game manufacturers, what they need to face is the problem of traffic. Because game development has industry characteristics such as rapid development, user explosion, and short life cycle, if the server is pre-deployed in the traditional way, the variables faced by the actual application stage are unacceptable to manufacturers. Whether it is a player or a game manufacturer, equipment is an urgent problem for them to solve, which is also a bottleneck for the development of the game industry.

"Cloud gaming" is expected to become a weapon to break the bottleneck of development. The upgrade and replacement of the communication network have brought about a faster transmission speed and opened up the imagination space for the "cloudification" of games. "Cloud game" means that all programs are run on the cloud server, and players only receive the compressed and rendered game screen in the cloud through the relevant equipment. This change allows players to only need a device with basic video decompression and command forwarding functions, and does not need to configure high-end processors

and graphics cards. Telecom giants such as AT&T and Verizon, as well as IT giants such as Microsoft and Amazon, entered the industry in 2018 to test and deploy cloud games. Domestic mobile phone manufacturers OPPO and OnePlus also demonstrated related services at MWC 2019. According to forecasts by third-party agencies, the global cloud gaming market will increase from \$66 million in 2018 to \$450 million in 2023, with a compound annual growth rate of 47%.

Cloud-edge collaboration helps cloud games to upgrade. Taking AR as an example, the device needs to judge its position and face direction during use. This is achieved by the application combining the camera's view and positioning technology. And when the relative position is determined, more data will be provided to the player's terminal. Every action of the player means a change in data, and the frequency of sending and receiving data will be high. If the construction of edge computing is introduced, most of the computing tasks will be carried out on the edge service and mobile terminal, which will reduce the response time and reduce the average delay. The interaction of the foreground is placed on the cloud, the background is handed over to the mobile terminal, finally a complete AR experience is realized. For multiplayer games, the bandwidth and latency requirements are higher, and cloud-edge collaboration will be able to solve the problem more effectively. Players in the same area can reduce latency by connecting to the same edge node. Running the game in the cloud can also reduce the local data of the game, and the access speed of the game will be improved.

## The Main Process of Cloud Game

The cloud game operation process mainly includes the following 9 points:

**Command collection:** The user's local terminal side processing module collects the operation commands of the mouse, keyboard and other devices.

**Instruction upload:** The cloud game SDK deployed on the terminal uploads the collected instructions to the cloud game instance on the cloud through the network.

**Command parsing:** Cloud game instances receive and parse commands.

**Game logic calculation:** The game APP deployed on the cloud game instance performs game logic calculation according to the instructions.

**Screen rendering:** The cloud game instance performs

real time rendering of the screen according to the game logic calculation results.

**Frequency capture/encoding:** The cloud game instance captures the audio and video of the rendered game screen, then encode and compress it.

**Audio and video stream transmission:** The cloud transmits the encoded and compressed audio and video streams to the user's local terminal side through the network.

**Local decoding:** The cloud game SDK decodes the audio and video streams with the help of the decoding capability of the local terminal according to the configuration and requirements of the terminal.

**Display:** The local device display module, such as PC, large screen, etc., displays the decoded audio and video.

## The Background Role Division

The participating roles of cloud games can be divided

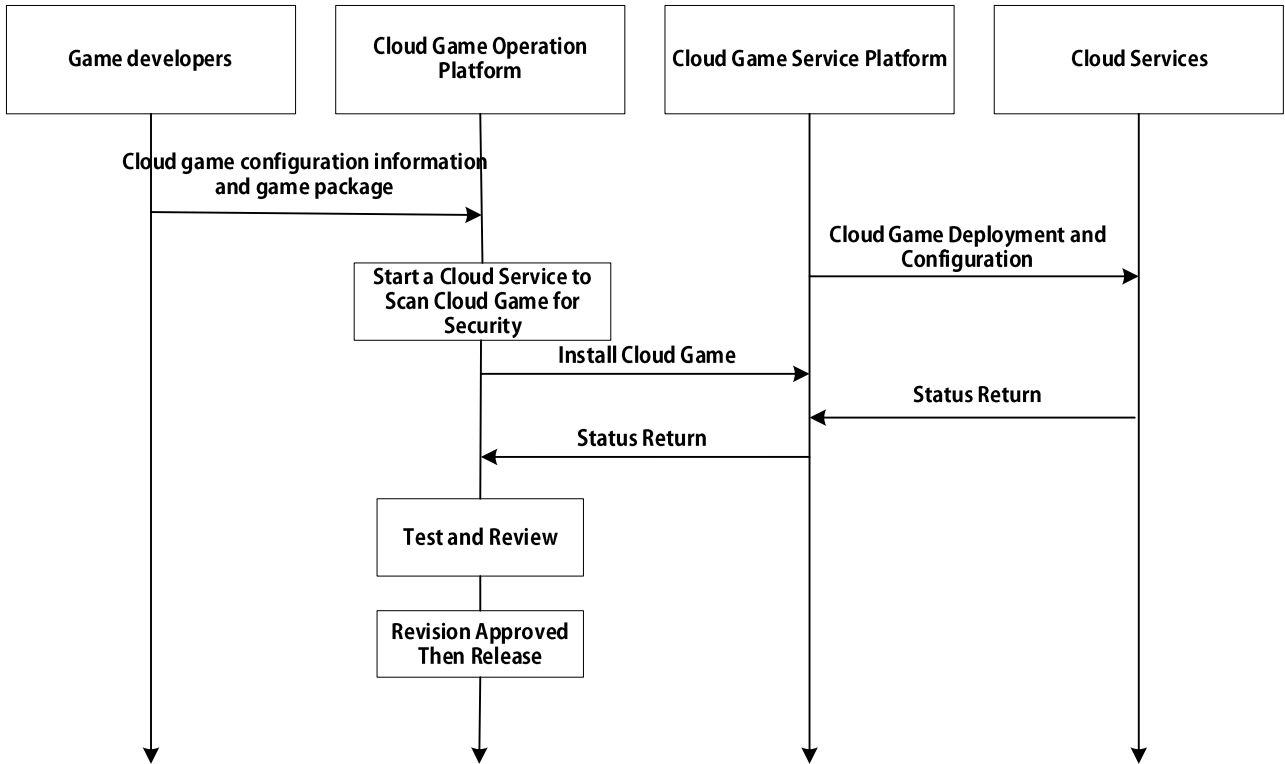
into game developers, cloud game operators, solution providers, network providers, terminal manufacturers and users. Service operators are also called cloud game platform providers or channel providers, and solution providers can be divided into hardware manufacturers and cloud service providers according to the level of cloud computing.

The demand for cloud games includes cloud game development platforms, cloud game operation platforms, cloud game service platforms, network resources, terminal equipment, and game applications. The behavioral relationship between participants and constituent elements is as follows: game developers complete the development and technical realization of game content on the game development platform. service operators publish and operate cloud games in the form of cloud game platforms or channels. Solution providers Provide business management services and cloud basic resources in the form of cloud game service platforms and cloud services. Network providers provide network resources. Terminal enterprises produce different terminal products that can be used in cloud games. Users use cloud game application products to play games.

Role		Components
Cloud game users		Cloud game instances or applications
Terminal manufacturers		Terminal products such as cell phones, PCs, VR/AR, large screens, joysticks, etc
Network operators		Network resources such as mobile network, fixed network
Solution provider	Cloud service provider	Cloud gaming service platform (central cloud, edge cloud)
	Hardware vendors	Cloud services (provide basic resources such as CPU, GPU and other hardware)
Cloud game operators		Cloud game operation platforms (various cloud game platforms, channels, etc)
Game developers		Cloud game development platforms

The entire life cycle of cloud games runs through game development, deployment and landing. The game development process is relatively closed, and every

company is different. Here, we break down all the elements involved in the three lifecycle nodes of cloud game deployment, user login, and game running.

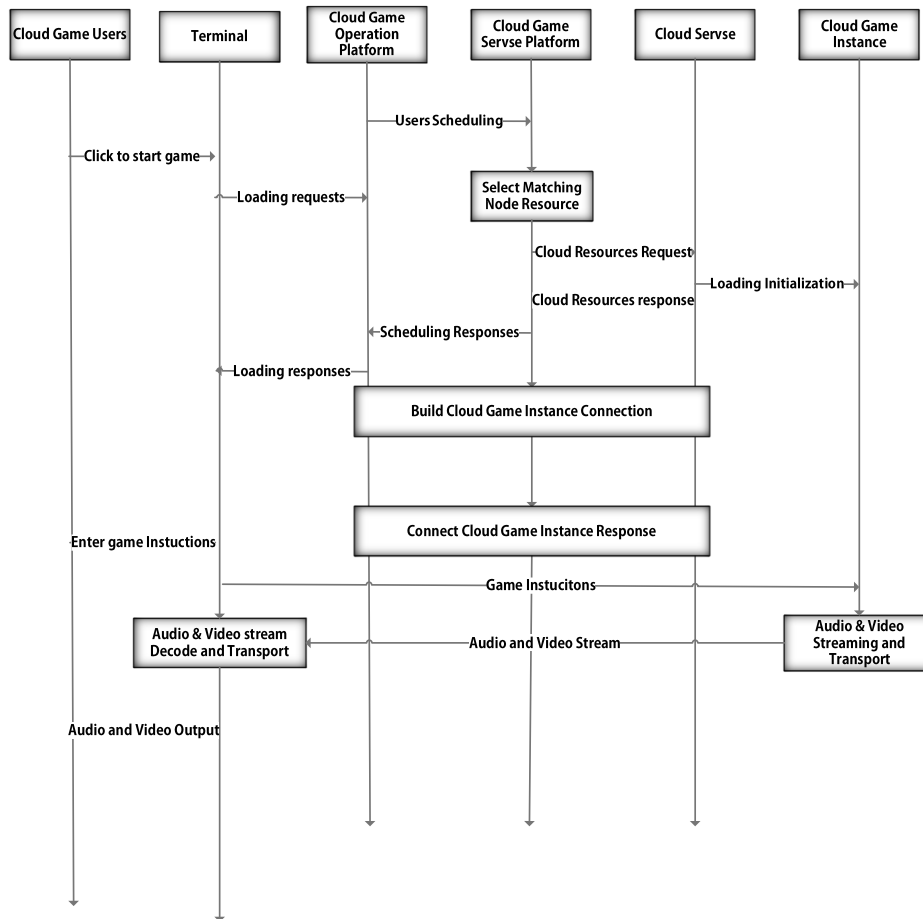


Key players in cloud game deployment activities include game developers and cloud game platforms (which can be further subdivided into operating platforms, service platforms, and cloud services). Its specific behavior can be described as follows:

- a) The game developer transfers the client package and related configuration information based on cloud game adaptation to the cloud game platform.
- b) The cloud game platform preprocesses the game package, such as security scanning, to make it meet the predetermined format,

security and other requirements.

- c) The cloud game service platform deploys and configures the game package to the corresponding node.
- d) Cloud game platform operators test and review cloud game content.
- e) After the review is passed, the cloud game platform will release the game and put it on the shelves.



The main participants in the process of cloud game operation activities include cloud game users, terminals, cloud game operation platforms, cloud game service platforms, cloud services and cloud game instances. Operational behavior can be decomposed into:

- a) Users click to start a game.
- b) The terminal carries the game, user speed measurement and address and other information loading requests and sends it to the cloud game platform.
- c) The cloud game platform requests user scheduling
- g) The terminal starts to establish a secure connection and transmission channel with the cloud game instance.
- h) The user inputs command through the terminal screen, handle, and other devices and transmit

- d) The cloud game service platform selects node resources according to the service node load, resource ratio and other information, and sends an application to the corresponding cloud service.
- e) The cloud service loads the corresponding instance and game.
- f) The cloud game service platform returns the instance information allocated to the user and transmits it to the terminal.

them to the cloud instance. The instance collects, encodes and transmits the local audio and video streams to the terminal, and the terminal realizes audio and video playback.

## Challenges of Edge Computing and Cloud Gaming

Edge computing is an extension of cloud computing and the point of contact where cloud computing sinks

to the home. Edge computing is different from traditional central computing. Nodes are deployed in small computer rooms close to users. Although these computer rooms are small in scale, they are widely distributed. Compared with deploying all resources to the central node, they can reach users and provide high-quality access resources. At the same time, edge computing relies on an open platform as a carrier to



---

provide users with a cloud environment, PaaS capabilities and corresponding edge services, to provide users with more secure and real time intelligent services.

Edge computing technology makes it possible for cloud games to reduce end-to-end latency while ensuring network bandwidth. In the full-process scenario of cloud games, the network latency and bandwidth to the client are undoubtedly the most important parts. How to ensure the stability of network latency and bandwidth has also become a key pain point for cloud gaming. Edge computing technology deploys computing nodes to edge computer rooms, making computing nodes geographically closer to users, thereby effectively improving physical transmission efficiency. Cloud gaming combines edge computing technology to sink some of the business capabilities of cloud gaming to edge nodes, and uses wireless access networks to provide cloud gaming services required by nearby users, reducing end-to-end latency while ensuring network bandwidth.

Edge computing is the fusion of operational technology, information technology and communication technology. Edge computing includes four fields: equipment, network, data and application. Its platform provider mainly provides software and hardware infrastructure in network interconnection, computing power, data storage and application. Its computing objects are composed of the device domain, network domain, data domain and application domain. Each field has its corresponding problems, which bring specific difficulties and challenges to the technical realization of edge computing and the integration of the industrial value chain.

Edge networking management, operation, and maintenance technology, and node cost control are not only the main problems faced by the development of

edge computing in cloud gaming scenarios, but also the problems faced by the development of edge computing itself.

The bandwidth quality of the edge computer room is not as stable as that of the BGP IDC, and the number of public network IPs is small. How to manage the network of the edge computer room is also a challenge in practice. Generally speaking, operators can use tinc, WireGuard, and ZeroTier SDN technologies to build internal management networks between edges to manage and upgrade edge nodes. However, such SDN technologies are usually only used in internal management networks, and in the cloud in-game scenarios, users need to connect directly to the server.

The solutions in the cloud game scenario mainly include the session traversal application (STUN) scheme and the relay traversal (TURN) scheme. Both solutions have certain defects. If the coverage of IPv6 edges and users can be improved in the future, it may be the most stable and reliable solution to directly use IPv6 for communication.

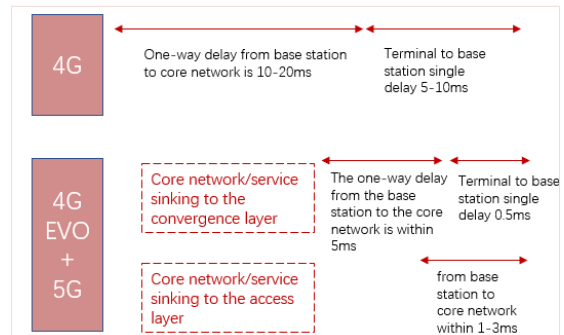
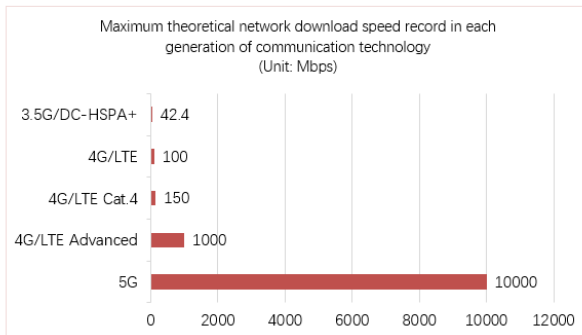
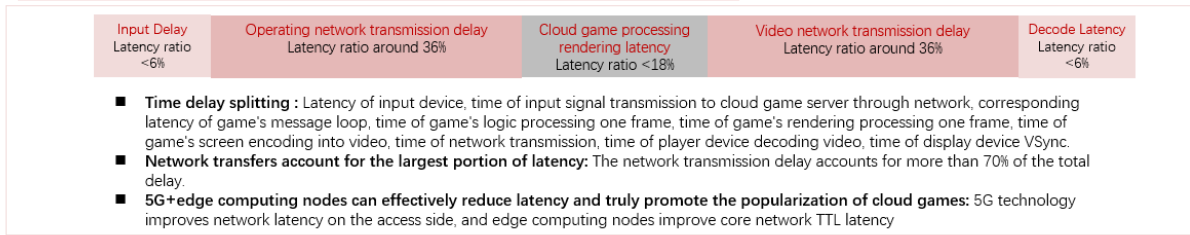
The main challenges currently facing the cloud gaming business, At present, cloud games mainly face challenges such as multi-terminal support, time delayed experience, cost, and operation and maintenance.

## Multi-terminal support

Supporting multiple terminals, cloud game players can play cloud games on any terminal (Web, Android, iOS, PC, TV, or VR) without downloading, installing or upgrading. Therefore, for cloud game service providers, it is necessary to do the following:

- ◆ Provide cross-platform, multi-terminal client SDK
- ◆ Support the access of different terminals of cloud

## Demo of an end-to-end latency decomposition in cloud game



game players

- ◆ Support cross-end control adaptation
- ◆ The control consistency of keyboard and mouse, mobile phone and handle
- ◆ Supports computing power requirements of various game types
- ◆ Support automatic game hot update processing,
- ◆ Automatically sync and save game status

## Delay

The experience of cloud gaming is roughly the same as that of local gaming. The difference is that cloud games introduce many links such as encoding and decoding, network transmission, etc. Its business experience is affected by cloud, network, terminal and other factors. Network quality and the capabilities of encoding and decoding will affect the audio-visual and interactive experience of cloud games, Network latency is a crucial factor affecting the quality of cloud game experience.

The famous GUI design pioneer Jeff Johnson pointed out in the book "Cognition and Design Understanding UI Design Guide (Second Edition)" that the bottom

line of time for the software to display feedback to user actions is 100ms. The button on the screen needs to be displayed within 100ms when it is clicked, otherwise the user will feel that he did not click and click again. In the game industry, this data is considered less than 100ms for player operation and screen response time. Currently, the average delay of cloud games in the industry can be around 50m

Currently, the main costs of cloud games include research and development, hardware, network bandwidth, etc., of which network bandwidth costs account for nearly one-third. The upstream and downstream of the cloud game industry chain consists of game developers, cloud computing service providers, software and hardware manufacturers, cloud game platforms and terminal equipment manufacturers. In other words, whoever has a lower cost and more efficient solution will likely have more advantages in future competition.

## Operation And Maintenance

Cloud game operation and maintenance mainly include: edge node management, game management,

---

automatic game update, account management, user security management, etc. Due to the need to maintain a large number of edge computing nodes and a wide variety of games, and game applications generally occupy a large amount of storage and update frequently, problems such as automatic game update, distribution, and synchronization need to be dealt with promptly. Therefore, there are also many technical challenges in operation and maintenance.

# LF Edge Akraino Cloud Gaming Questionnaire

## Overview and Structure of Questionnaire

Cloud computing, in the traditional sense (central cloud model), faces many challenges such as bandwidth, delay, connection quality, resource allocation, and security. To cope with the dilemma brought by applications and scenarios that traditional cloud infrastructure may not be able to meet, data can be collected, transmitted and processed more efficiently and in a more targeted manner on the device side. The concept of edge computing came into being. Cloud computing capabilities are migrated from "centralized" computer rooms to edge nodes for network access. In this way, a high-performance, low-latency, and high-bandwidth service environment are created, and the response speed of various content, services and applications in the network is accelerated, allowing consumers to enjoy an uninterrupted high-quality network experience.

As mentioned above, the biggest challenge for cloud gaming is real time (latency), which is closely related to the gaming experience. For the real time

performance of cloud games to reach a level acceptable to players (about 50ms), it not only depends on the performance of the hardware and the network itself, but also requires sufficient bandwidth.

Therefore, the combination of edge computing and cloud gaming is logical.

In the whole process, edge computing, as a supplement to computing resources, can effectively solve the delay, bandwidth, cost and other problems faced by cloud games.

Firstly, cloud game instances deployment on Edge to greatly reduce cloud game latency. Deploy cloud game instances on edge nodes widely distributed across the country and around the world. Through intelligent scheduling technology, according to the user's region, network, game computing power requirements, etc. the nearest cloud game instance is allocated to the user, so as to realize the nearest access, the nearest rendering, and reduce the transmission. This link greatly reduces the average latency of cloud gamers around the world.

Secondly, cost-effective edge bandwidth helps optimize cloud game traffic costs. Cloud gaming image quality is another key element of the cloud gaming experience. The higher the image quality requirements, the higher the requirements for resolution, frame rate, bit rate, etc., and the higher the requirements for network throughput, that is, the higher the requirements for network bandwidth. If the bandwidth is insufficient, packet loss will occur, resulting in screen freezes, tearing, and blurry screens. Only the network bandwidth  $\geq 1.6 \times$  average bit rate can basically guarantee the cloud gaming experience.

Taking "League of Legends" running at 1080P@144fps on a PC monitor as an example, at an average streaming bit rate of 30Mbps, a bandwidth of more than 48Mbps can provide a relatively stable and good picture experience.

Bandwidth cost is one of the main expenses of cloud gaming service providers. From the perspective of the

---

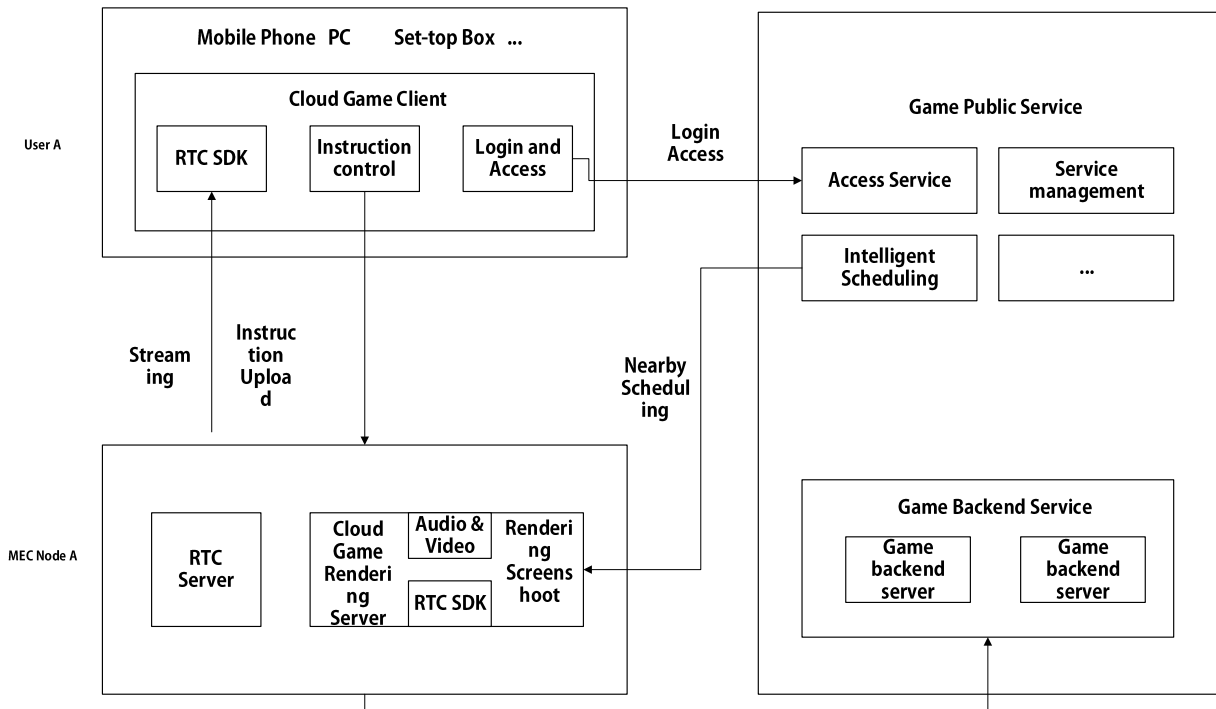
current bandwidth market, the bandwidth cost of edge nodes widely distributed in second-, third-, and fourth-tier cities is 1/6~1/10 of the bandwidth cost of the central cloud). Therefore, deploying cloud game instances through edge computing and utilizing edge bandwidth greatly reduces the demand for central cloud bandwidth, thereby effectively reducing cloud game bandwidth costs.

Thirdly, distributed deployment of edge computing to improve the overall concurrency capability. Similar to traditional games, cloud games will go through a start-up period, a growth period, a golden period and a recession period. Therefore, flexible on-demand resources are also required to meet business needs at different stages. At the same time, in unexpected scenarios such as big promotions, computing human resources and bandwidth resources can be quickly

expanded on demand. At present, the edge computing services of various cloud service providers not only support daily and monthly resource billing, but also support more fine-grained billing methods, helping cloud game service providers to refine on-demand operations at the resource level.

Fourthly, the rich cloud services of edge computing help the efficient operation and maintenance of cloud games. Cloud games need to maintain a large number of edge computing nodes, games of different versions and types, and games are generally relatively large and frequently updated. Problems such as automatic game update distribution and synchronization need to be dealt with in a timely manner. The rich cloud services of edge computing can help achieve efficient operation and maintenance of cloud games. For example, the grayscale release of cloud games can be accurately controlled through edge load balancing. With the help of edge custom mirroring and mirror preheating functions, multiple edge nodes can be specified to achieve rapid resource expansion, etc. Internet interoperability and other functions can quickly realize the update and distribution of cloud games.

# Use Cases



The general cloud game business architecture is mainly composed of local clients, cloud game public services, cloud game back-end services, cloud game edge nodes, etc.

**Client:**

Users need to install a client that integrates cloud game-related decoding, user management, operation control and other capabilities on local devices such as mobile phones and PCs. What the client needs to do is:

- ◆ Realize user registration, login authentication, etc., and request the cloud game business platform to obtain the corresponding cloud game service.
- ◆ Send local control devices such as keyboard and mouse commands to the cloud game instance.
- ◆ Receive video and audio streams from cloud gaming platforms, and implement decoding and display.

What the Cloud game public services need to do is

services can meet the latency requirements of game services, and can be deployed on the central cloud or individually at each edge.

Cloud game edge nodes mainly use multi-region edge computing node instances as resource pools to

- ◆ game access services, operation management, intelligent scheduling, etc., mainly deployed in the central cloud.
- ◆ User account opening and management, service subscription and settlement, etc.
- ◆ Operation of business scenarios, game applications, instance capacity management, etc.
- ◆ Appropriate cloud game instances are allocated to users from the cloud game instance resource pool according to the user's region, network, and game computing power.

Game background services are responsible for receiving the input of the cloud game server on the cloud game edge node for logical calculation, and returning the result to the cloud game server. Game backend

provide a running environment for cloud games. The

cloud game business platform intelligently schedules nearby cloud game instances for users based on information such as region, network, and game computing power. The platform provides instances

---

such as X86+GPU, ARM, etc., and provides various instance specifications for different cloud games.

The game application runs on this instance. After parsing the user's local client-side instructions, it performs logical operations, rendering, screen capture, and encoding, and then pushes the stream to the user's local client through audio and video transmission such as RTC.

## LF Edge Akraino Cloud Gaming business feasibility and business model analysis

Microsoft's record \$68 billion acquisition of Activision Blizzard and its latest investment in Epic Games, which valued the company at \$32 billion, underscore the rapid growth of the video game industry and its proliferation of consumer entertainment. Mobile gaming has become a platform for casual gaming and is poised to grow further with the help of 5G and edge computing to deliver new cloud gaming value propositions.

As mobile devices transition to the cloud, all the capabilities of the same Android smartphone you can hold in your hand can now be delivered from the cloud as a fully functional virtualized smartphone-as-a-service. Any app or mobile game that can be downloaded and played on a smartphone can now be delivered through the cloud. Just as Virtual Desktop Infrastructure (VDI) technology became the technology layer for Desktop as a Service and expanded in consumer and enterprise markets, Virtual Mobile Infrastructure (VMI) is now a definite reality and will be powered by Arm with GPUs Server acceleration, and 5G Mobile Edge Computing (MEC) technology.

Game developers and publishers no longer need to worry about the complexity of physical mobile devices and the fragmentation of the mobile OS versions needed to support their games in the marketplace. Game developers can focus on a single operating system with the best features to support the game that best delivers the intended gaming experience, regardless of the device or operating system the player

is using. This simplifies development, testing, quality assurance, release and support. It also provides a "level playing field" experience for gamers. This balance means that gamers with relatively low-end or older devices will compete with rivals with the latest, advanced, high-end smartphones, while delivering the gameplay designed by developers and expected by gamers.

Streaming cloud gaming from the edge would eliminate the reliance on traditional app stores, transferring revenue-sharing models, in-game sales, inventory and marketing control to game developers or publishers. Games can be streamed directly to mobile browsers or custom players. No need to download through the app store front desk. Games are available directly from the channels players go to most, without distribution restrictions or paying storefront "taxes."

Today, mobile gaming generates more than \$70 billion in global revenue, with traditional mobile smartphones and tablets growing 10% yearly. The shift to cloud gaming has the potential to go beyond casual gaming experiences, offering more games to a wider audience and delivering console gaming performance to any connected device.

Although there are multiple cloud gaming services available today, they still follow the traditional, subscription-based business model. So who can to create new business models around cloud gaming? Of course, there are also 5G mobile network operators, fiber/cable providers and even media companies that exist as cloud service providers. Bundling cloud gaming as a component of wireless, internet or media services can leverage existing infrastructure, billing systems, support and customer service. Cloud gaming can be a differentiated marketing tool for attracting new customers, and it can also be used as a loyalty tool to reduce churn.

There are other models that might leverage live sporting events to provide a real time interactive gaming experience, bringing fans closer to the action both live and remotely. These models can also step into stadium naming or broadcast partnership agreements, adding value to existing traditional brand marketing programs.

# LF Edge Akraino Cloud Gaming Overall Architecture

The architecture of cloud games is mainly divided into three parts: user local side, network transmission, and cloud side.

## User's local terminal side:

The user accesses the portal of the cloud game platform, mainly receives video streams and audio streams from the cloud game platform, and displays and presents them. at the same time, uploads the input instructions of the operating device to the cloud platform. The user's local terminal side includes a display device and an operation device. The display

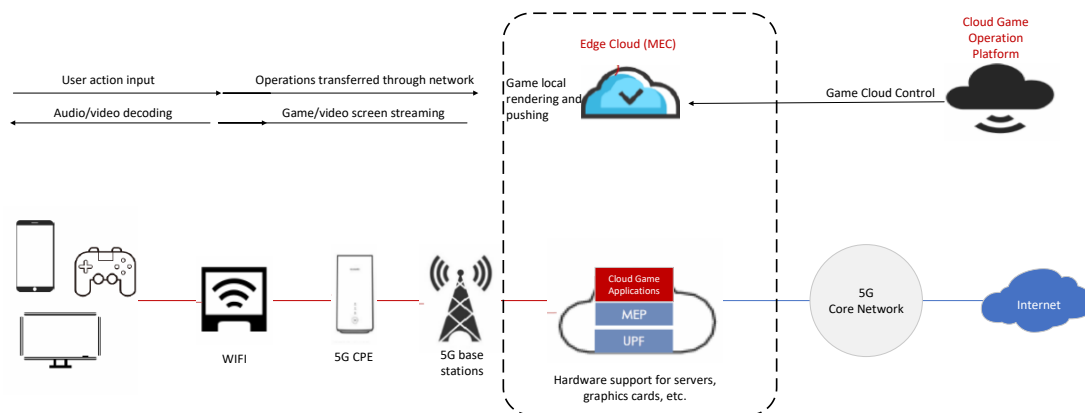
device mainly includes a mobile phone, a PC, a PAD, a large screen, etc.. the operation device includes a keyboard, a mouse, and a game handle.

## Network transmission:

It mainly involves backbone network, metropolitan area network, access network and home network, 5G network, etc. The network transmission is responsible for connecting the cloud platform and the terminal, transmitting the real time audio and video in the cloud to the user terminal in real time and maintaining stability.

## Cloud game platform side:

The cloud game platform side receives instructions from the client to implement logical computing, real time rendering, encoding, video streaming, audio streaming, etc.



The terminal connects to the cloud game server through the 5G base station, and the cloud game server allocates game users to the nearest MEC according to the location information carried by the user. The nearest MEC provides game rendering acceleration services and provides game services with low latency and good experience.

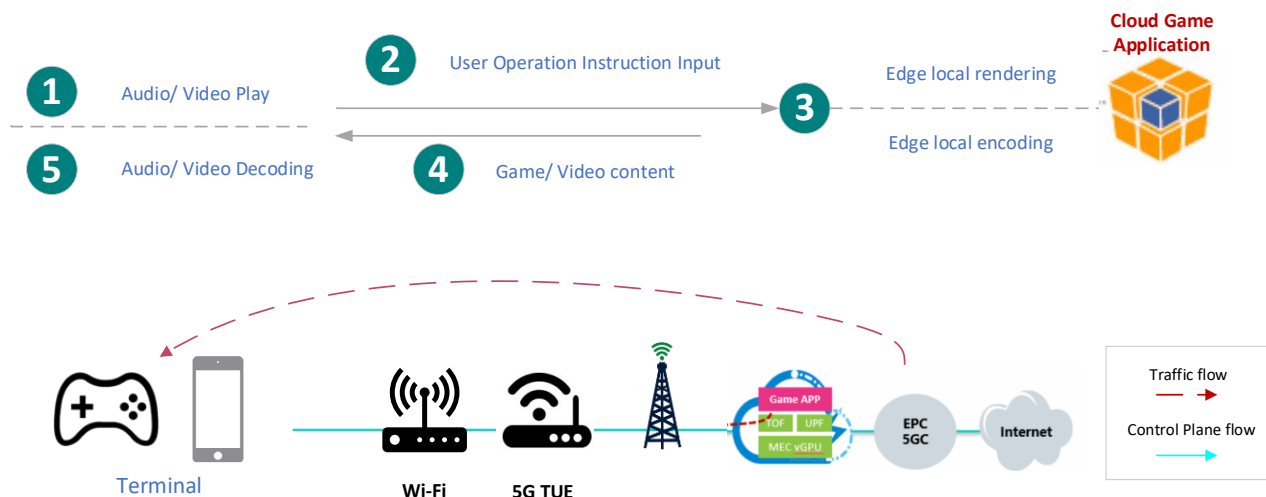
Integrated Edge Cloud(IEC) is an Akraino approved blueprint family and part of Akraino Edge Stack, which intends to develop a fully integrated edge infrastructure solution. The project is completely focused on Edge Computing. This open source software stack provides critical infrastructure to enable high performance, reduce latency, improve availability, lower operational overhead, provide scalability, address security needs, and improve fault management. The IEC project will address multiple edge use cases and industry, not just Telco Industry. IEC intends to develop solutions and support of carriers, providers,

and IoT networks.

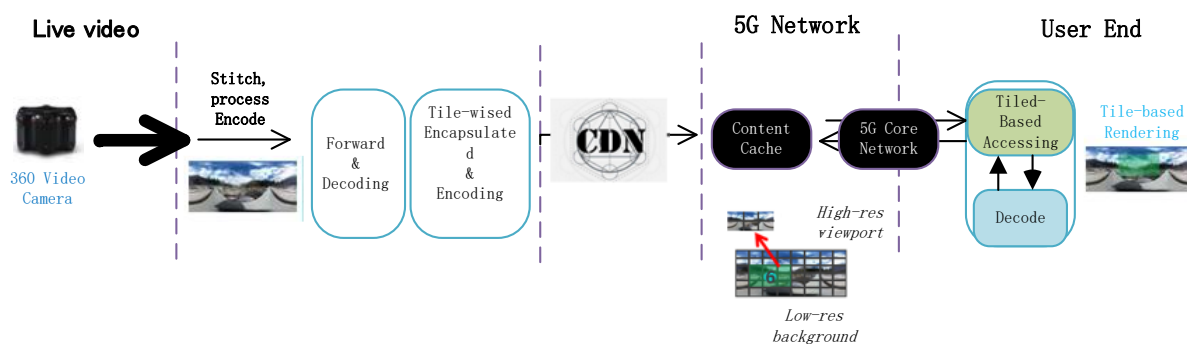
IEC Type3 mainly focus on Android Application running on edge ARM Cloud architecture with GPU/vGPU Management. Also, ARM cloud games need to have the basic features of "cloud", such as flexibility , availability everywhere. Based on cloud infrastructure optimized for android application, providing ARM applications services such as Android cloud games and VR/AR live video.

# Use Case

<use case 1: Android Cloud Game>



<use case 2: VR/AR Android Application> (to be discussed in the future)



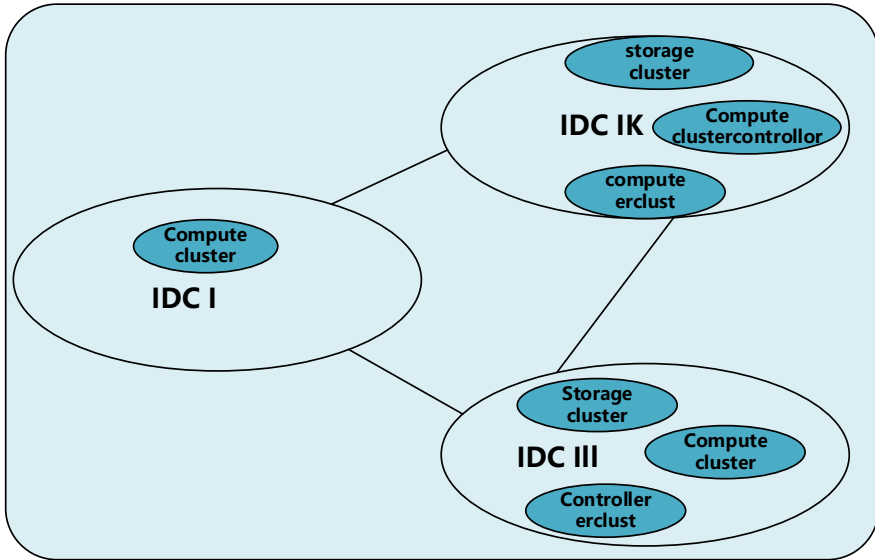
## Business Drivers

- Edge cloud requires initiatives for cloud gaming on the Android platform
- 5G + edge brings low latency and high

throughput for cloud gaming, which improves user experience

- More and more Android applications will migrate into the edge computing platforms. Building an android platform is necessary, and it's rigid demand.

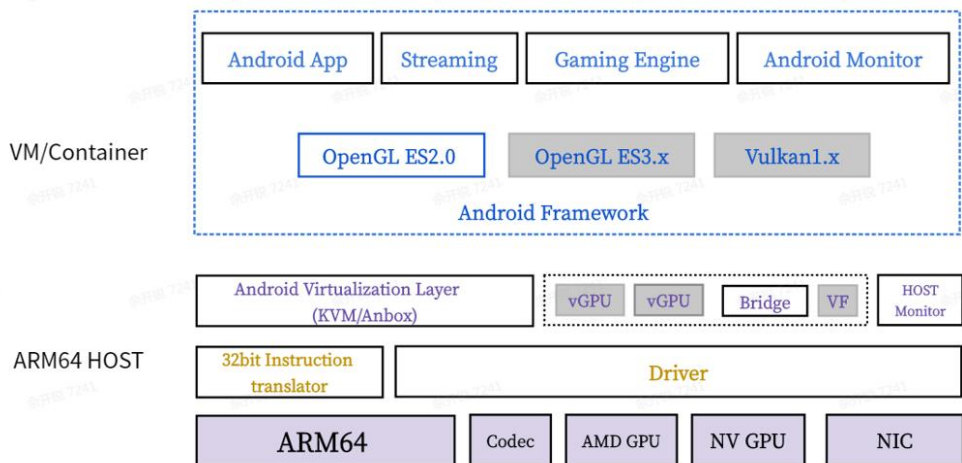




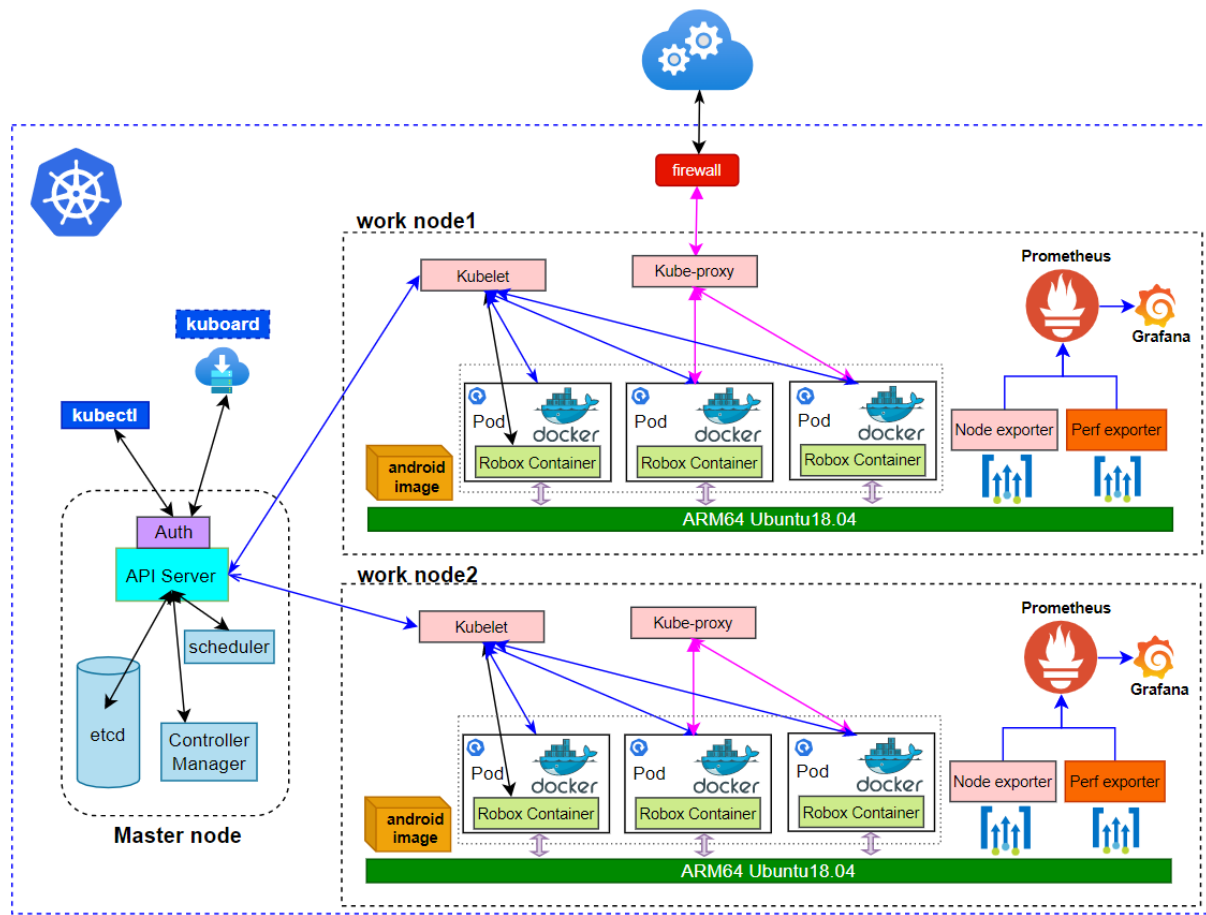
# Platform Architecture

The cloud game platform architecture can be divided into two parts, the host side is a complete arm64-based

Linux system, and the container side is a complete Android system image. Since the bottom layer of the Android system is a Linux system, the container is just an Android software stack, and the virtual peripherals provide the necessary environment for the Android system to run.



# Anbox Cloud Game Framework



The core framework of the project is shown in the figure on the top: a cluster is composed of multiple

hosts, and multiple robox pods can be deployed on the work node through the master node, and each pod is a

---

container running anbox.

The whole project mainly includes the three major blocks on the left, the architecture foundation, pod node instance deployment and work node performance analysis.

1) For basic deployment, you first need to be familiar with the Android software stack, compile the Android firmware, After the robox components are ready, you can start the container firmware through the provided script, and finally the Android window will pop up on the desktop. At this point, you can install different Android applications on this container. You can start multiple containers. For the server, you need to connect remotely with VNC at this time, and access different containers through different ports.

2) To deploy node instances, we first need to build a k8s system, and then we can run robox on different pods through k8s by writing software. Then you can view the status of the cluster with the kubectl visualization component.

3) Performance analysis of nodes, each pod on a node can run an instance of an Android game. In order to get closer to the usage scenario, more than 20 instances are started here, and then various times of the system are extracted through perf, and then converted into a flame graph, the bottleneck of the system can be analyzed on the flame graph. At the same time, we use the popular prometheus component here to monitor and analyze the system, and then use the grafana component to display the results in a better way to control the platform.

## LF Edge Akraino Cloud Gaming Standardization System

Mobile edge computing provides the radio access network (RAN) with the radio access network (RAN) closest to the user's mobile terminal, as well as cloud computing capabilities. The purpose is to further reduce delay/delay,improve network operation efficiency,and improve services. Distribution/transport capabilities to optimize/improve end-user experience.

Edge computing is the integration of core capabilities such as network, computing, storage, and applications at the network edge to achieve digital transformation in agile, real time business, data optimization, and applications.

Edge computing is a form of distributed computing that places processing and data storage on the edge nodes of the network. It can be seen that although the concept of edge computing has not yet been unified, all parties believe that edge computing provides services at the edge closer to the terminal.

Edge computing power network and its standardization progress.

In order to solve the problem of unified resource supply under the coexistence of multi-level computing resources (cloud computing, edge computing, terminal computing), the computing network distributes the computing power of service nodes through network control planes (such as centralized control planes, distributed routing protocols, etc.) Power, storage, algorithm and other resource information, combined with network information and user needs, provide the allocation, association, transaction and deployment of computing, storage, network and other resources to achieve the optimal configuration and use of the entire network resources.

The generation of a computing power network is closely related to edge computing, which can focus on solving two important problems after the generalization of resource nodes: user experience consistency and flexible dynamic deployment.

The computing power network solves the problem of user experience consistency: users do not have to worry about the location and deployment status of various basic resources (computing power, memory, etc.), and coordinate various resources through the network to ensure a consistent user experience. Second, the computing power network can solve the location and deployment status of various basic resources (computing power, memory, etc.), and flexibly coordinate various resources through the network to ensure the user's network experience. Third, the computing power network can dynamically schedule the most Excellent resource node.

The cloud game standard system is divided into four parts: basic, general technology, security, and evaluation. There are eight standards in total, and the standard system framework is shown in the figure below.

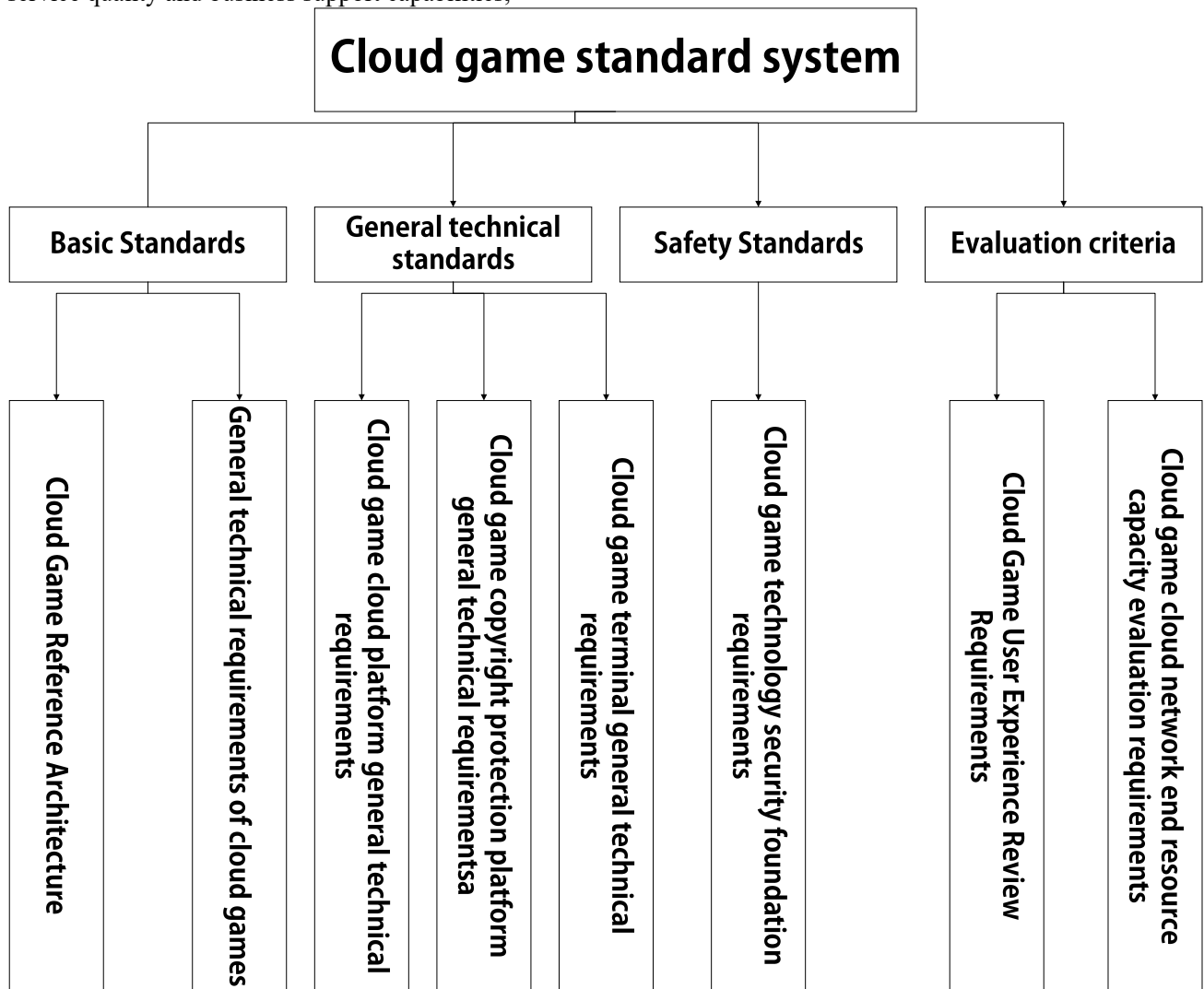
1. Basic standard. It mainly regulates the overall technical architecture of cloud games, Including cloud game reference architecture, general technical requirements and other standards.
2. General technical standards. Mainly standardize the technology of the whole business process of cloud games technical requirements, including cloud gaming

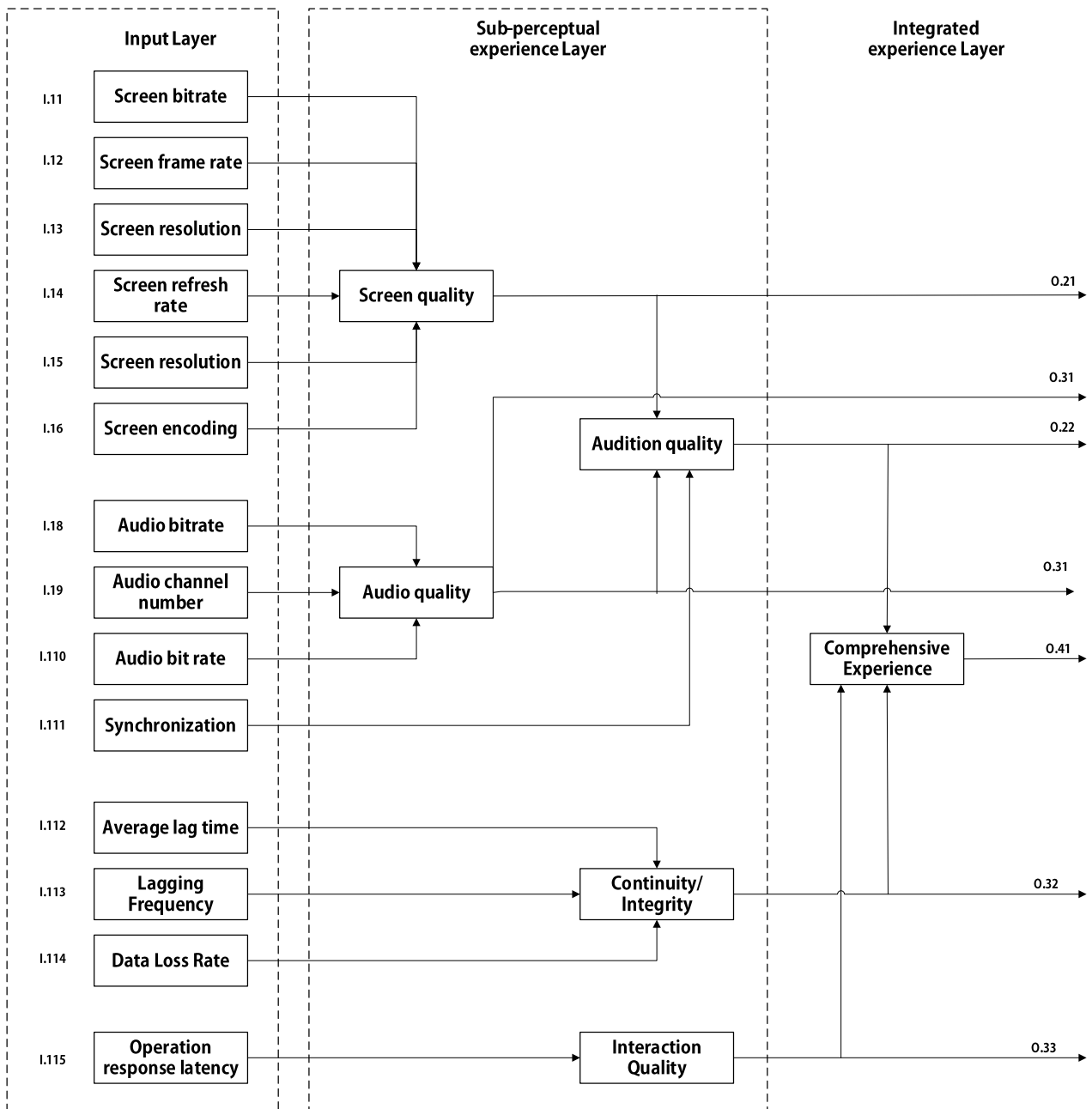
cloud platform, copyright protection platform, terminal and other standards.

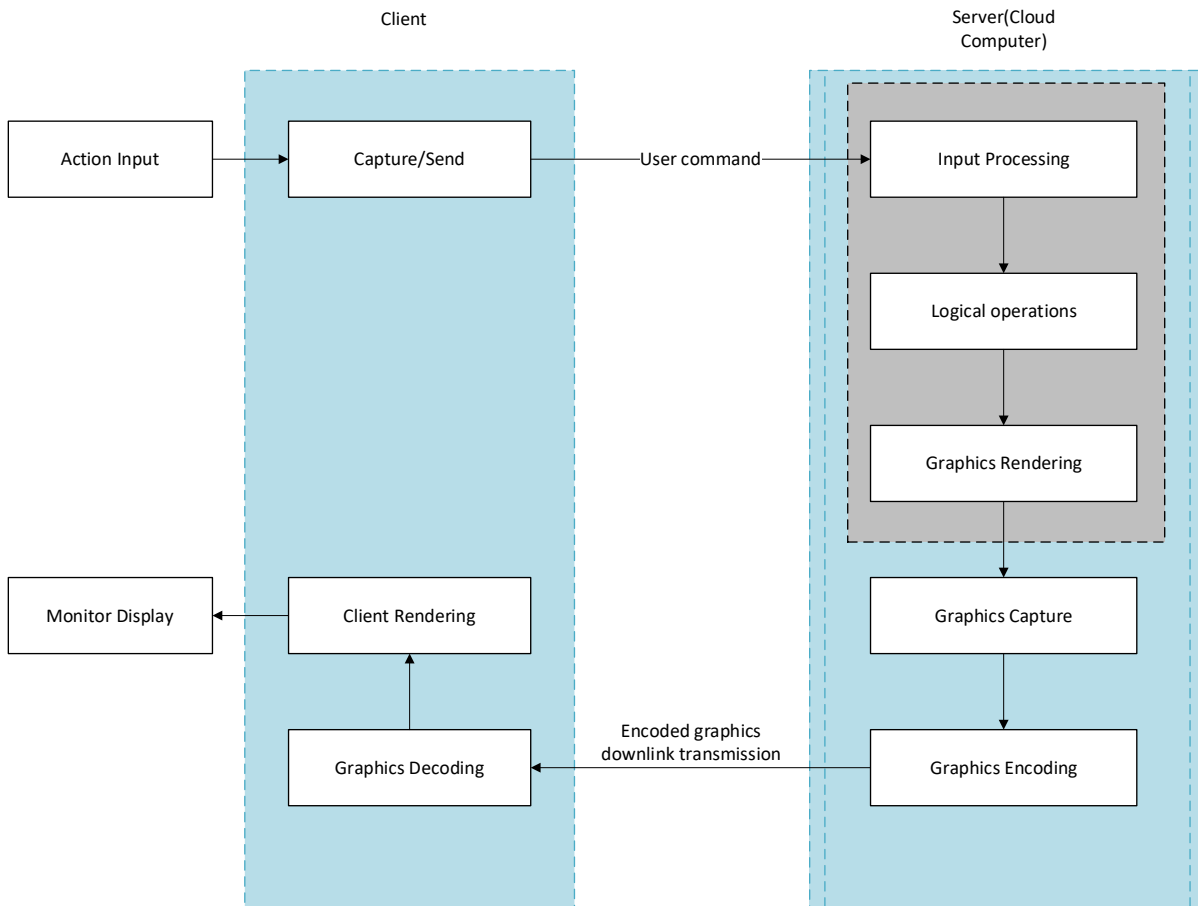
3. Safety standards. It mainly regulates the basic requirements of cloud game technology security,It is used to ensure the safe and reliable operation of cloud games.

4. Evaluation standards. Mainly regulate cloud game service quality and business support capabilities,

including cloud game user experience evaluation, cloud network resource capability evaluation and other standards







real or virtual phone can be used for gaming.

## LF Edge Akraino Cloud Gaming User Experience Evaluation System

Cloud gaming can leverage sensor matrices from mobile devices to develop new gaming experiences that were previously too complex or impossible to achieve. The physical device in the gamer's hand becomes the remote sensor feed to the server-based virtual mobile device to execute the game in the data center.

Local cameras, GPS, inclinometers, and other hardware sensors are fed into the game running on a server-based virtual mobile device. For example, a gamer's physical phone GPS sensor could be the virtual location of thousands of gamers who are physically separated but actually in the same location. Even apps like Google Maps recognize GPS information on virtual mobile devices as real satellite GPS signals. This new concept of "sensor matrix" opens up a whole new realm of input for next-generation gaming experiences, as any sensor from any

Gamers no longer sacrifice performance to capture their gameplay for distribution through media outlets. High-quality full-motion video can be streamed or stored in real time at no additional cost and with no latency impact on gameplay. Additionally, what was once a single-user experience can now become a multi-user experience. For example, professional gamers can coach novice clients in real time in the same mobile game. Professional players can control entire characters or parts of the game in real time, providing real time guidance to novice client players as they play together. This ability has never been offered in a mobile game before.

Many alternatives to the traditional storefronts or subscription services can change the gaming experience before a single title is played. Cloud gaming opens opportunities for game makers, publishers and virtually any digital brand to offer cloud games wherever they see fit. A beverage company could offer a seasonal sports game, accessible only by scanning a QR code placed on their product. The scan immediately opens a stream to the gameplay.

# Next-generation Cloud-native ARM server chips help LF Edge Akraino Cloud gaming

## Arm Server Players

Both cloud games and mobile cloud applications use ARM servers, and games and mobile applications are run on the ARM servers in the cloud.

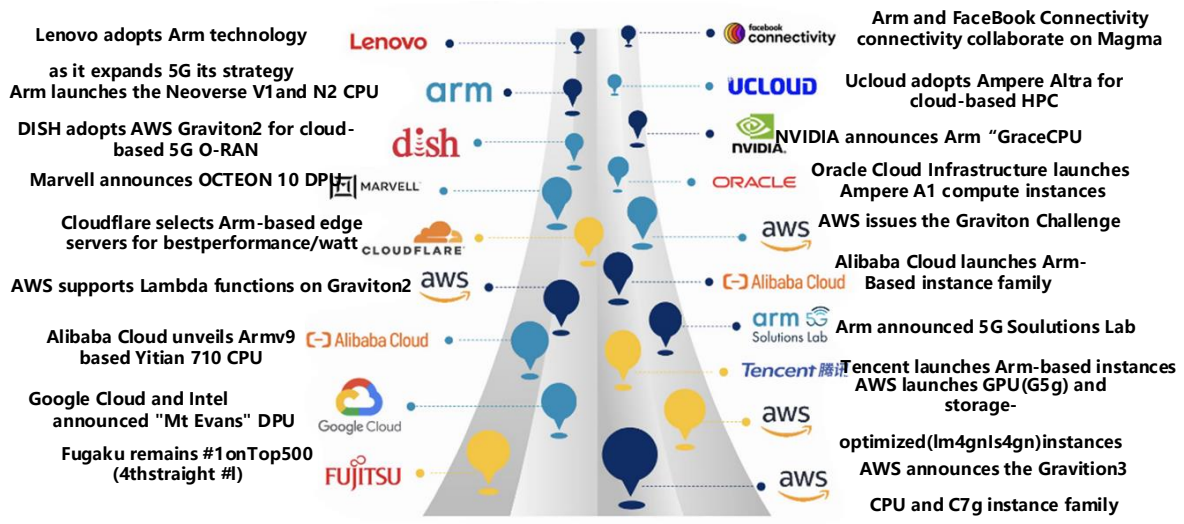
ARM general server is developed based on dedicated

multi-core (32-core, 64-core, 80-core, etc.) ARM architecture server processors, and peripherals are equipped with PCI-e GPU Card, Memory Card and other IO Cards.

ARM array server (also known as ARM cluster server, Android cloud server) is designed in the server chassis with multiple (such as 60, 64, 128) based on high-performance ARM SoC (such as Rock chip RK3399, Qualcomm Snapdragon 865, etc.) to communicate with each other or externally through high-speed networks.

At present, cloud game and cloud mobile phone operators are using servers of these two architectures, including some leading Internet manufacturers. ARM general server processor manufacturers include FeiTeng, HuaWei, Ampere, Amazon, etc. Among them, Amazon's processors are only for their own use.

### Arm Neoverse momentum in 2021



## Edge Computing Cloud Game Performance

5G + MFC  
 5G + Local Server Room with Cloud Service  
 300M Fixed Broadband + Local Server Room with Cloud Service  
 4G + Local Server Room with Cloud Service

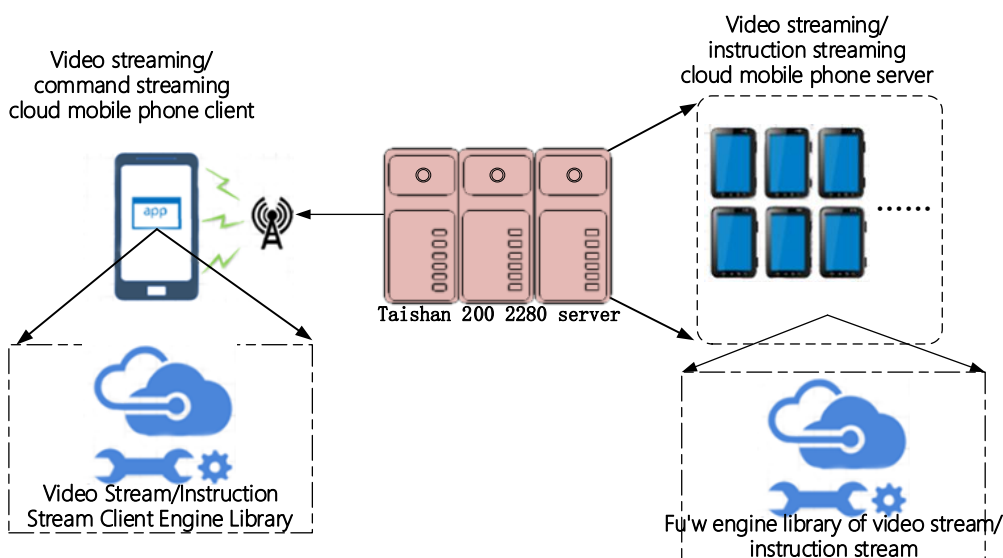
	720P+2Mbps	1080P + 6.5Mbps	Standard Deviation
Network Delay			Network Delay
	<b>8ms</b>	<b>9ms</b>	<b>2.99</b>
	<b>27ms</b>	<b>30ms</b>	<b>12.84</b>
	<b>46ms</b>	<b>55ms</b>	<b>104.88</b>
	<b>42ms</b>	<b>103ms</b>	<b>145.30</b>

ARM cloud-native mobile phones are an emerging industry. Currently available test methods and tools include open source test frameworks and test tools. It has CTS (Google's official website Android compatibility test suite), dEQP (drawElements quality plan (deqp) GPU test suite), Potplayer (third-party app), GFXBench (mobile graphics performance test tool), Perfdog (mobile full-platform performance test analysis) tool) to conduct comprehensive testing for cloud mobile phone testing standards.

The GCC Alliance is mainly based on the server ARM native cloud mobile phone scenario test standard, covering basic function testing, performance testing, compatibility testing and experiential testing. The test

network is shown in the figure below. The infrastructure is an ARM server. The basic cloud phone is virtualized in the underlying data center, and the instruction stream engine/video stream engine is deployed on the basic cloud phone to form the instruction stream/video stream cloud phone service. At the same time, the user needs to deploy the command stream/video stream cloud mobile phone client APP on the terminal mobile phone, access the Internet after deployment, and click to enter the cloud mobile phone. Then use the relevant test tools on the server/cloud phone to test the single instance/cluster. The following tables and graphs list test architecture , test tools , and test result based on a typical hw config.

### Cloud game test architecture



### Cloud game test tools

Test tool name	purpose
Gfxbench	In this document, it is used to test the performance of images, videos, etc. displayed on the cloud mobile phone client
CTS	In this document, it is used to test the compatibility of cloud mobile phone system API
Deqp	Used in this document to test the compatibility of the graphics library API
Perfdog	Used in this document to collect cloud mobile phone fluency indicators
Potlayer	Used in this document to collect cloud mobile touch indicators

### Cloud game performance test case

Number	Use case	Test indicators	Test requirements
		CPU usage	Run subway Parkour with 1 container started on the same



1	Comprehensive performance test of cloud mobile phone		GPU card
		Memory usage	Run subway Parkour with 1 container started on the same GPU card
		GPU occupancy	Run subway Parkour with 1 container started on the same GPU card
		Disk IO data	Run subway Parkour with 1 container started on the same GPU card
		Frame rate data	Run subway Parkour with 1 container started on the same GPU card
		Bandwidth data	Run subway Parkour with 1 container started on the same GPU card
2	Cloud mobile phone image performance test	Gfxbench performance score(high-level test)	Gfxbench does not crash and the container is normal
		Gfxbench performance score(low-level test)	Gfxbench does not crash and the container is normal
		Gfxbench performance score(special test)	Gfxbench does not crash and the container is normal
Number	Use case	Test indicators	Test requirements
3	Stress performance test of cloud mobile phone	720Cloud mobile phone deployment density under p/30fps display	Continuously increase the deployment density of cloud mobile phones, and each cloud mobile phone runs subway Parkour games until the server performance bottleneck
		720Cloud mobile phone deployment density under p/60fps display	Continuously increase the deployment density of cloud mobile phones, and each cloud mobile phone runs subway Parkour games until the server performance bottleneck
		1080Cloud mobile phone deployment density under p/30fps display	Continuously increase the deployment density of cloud mobile phones, and each cloud mobile phone runs subway Parkour games until the server performance bottleneck
		1080Cloud mobile phone deployment density under p/60fps display	Continuously increase the deployment density of cloud mobile phones, and each cloud mobile phone runs subway Parkour games until the server performance bottleneck

## Cloud game performance test result

Test content	Test specifications	CPU	Memory	GPU	Disk IO	Frame rate	Bandwidth
Cloud phone comprehensive performance test	Solo GPU, 2 Containers, 3 cores(VCPU 1.5 cores)	0.60%	1.37%	4.28%	27/sec	30.02fps	691.68KB/s

Test content	Test Object	CPU	Memory	Bandwidth	Disk IO	Frame rate	Density
Cloud Phone Stress Performance Testing	720p/30fps	55.60%	33%	1G	667.8/sec	NA(Stress test to server bottleneck, frame rate is not an examination item)	112channels
	720p/60fps	60.07%	53.70%	1G	1113.1/sec		74channels
	1080p/30fps	62%	53.50%	1G	1026.7/sec		113channels
	1080p/60fps	61.10%	53.10%	1G	1099/sec		65channels

Indicator items	Data values
Average Frame Rate(fps)	30.2
Frame Jitter(fps)	1.9
Low Frame Rate(%)	0.7
Frame Interval(ms)	33.1
Jank(10 min numbers of jams)	40
Stutter(stall rate)	1.7
Cloud phone launch success rate(%)	100%
Cloud phone set-up time(ms)	2417
Cloud phone exit time(ms)	411
Click Sensitivity(%)	100%
Touch screen response time delay(ms)	195
Display Resolution	1080*1920 DPI480
Audio quality figures	PASS
Synchronization difference between sound and picture	-312
ARM Native Cloud Phone Experience Total Score	3.75

Test content	Test specifications	GFXbench test results								
Cloud Phone Image Performance	2 containers 3 cores (vcpu1.5 cores)	High level testing								
		Car Chase	1080p Car Chase Offscreen	Manhattan 3.1	1080p Manhattan 3.1 Offscreen	1440p Manhattan 3.1 Offscreen	Manhattan	1080p Manhattan Offscreen	T-REX	1080p T-REX Offscreen

Test	cloud games		n		en	en		en		een	
		1775 Frames (30 FPS)	6095 Frames (109 FPS)	1861 Frames (30 FPS)	8401 Frames (136 FPS)	4783 Frames (77 FPS)	1862 Frames (30 FPS)	12234 Frames (197 FPS)	1681 Frames (30 FPS)	20105 Frames (359 FPS)	
		Low level testing									
		Tessellation	1080p Tessellation Offscreen	Arithmetic logic unit 2	1080p Arithmetic logic unit 2 Offscreen	Driver Overhead 2	1080p Driver Overhead 2 Offscreen	Texturing	1080p Texturing Offscreen		
		902.5 Frames (30 FPS)	23428 Frames (390 FPS)	902.4 Frames (30 FPS)	24327 Frames (405 FPS)	901.8 Frames (30 FPS)	4459 Frames (74 FPS)	4390 Frames Mtixel /s	25269 Frames Mtixel/s		
		Special Tests									
		Rendering quality				Rendering quality (high precision)					
		4373 (mB PSNR)				4373 (mB PSNR)					

## Conclusion

In the past 2-3 years, although the cloud game industry has developed rapidly, and the user scale and market scale have increased significantly, it still faces challenges such as further improvement of user experience and further reduction of operating costs. Through the advantages of widely distributed nodes, high-performance multi-type computing power, cost-effective large bandwidth, flexible on-demand, and rich cloud services, edge computing enables cloud gaming scenarios to improve the experience (low latency, high image quality), cost, and operation and maintenance. And other major optimizations to help the commercial feasibility and commercial take-off of cloud games.

Edge computing nodes can be created on demand and flexibly expanded, with sufficient inventory levels, supporting a variety of CPU, GPU, and other instance specifications, which can meet the needs of different scenarios such as mobile games and client games.

Edge computing has multi-tenant instances and network security isolation, advanced automatic operation and maintenance capabilities, and complete monitoring and service systems. In addition, edge computing has rich functions such as load balancing, custom mirroring, and mirroring warm-up to help cloud games operate efficiently and maintain.

Edge computing applications, power consumption is indeed a key indicator due to the large number of devices deployed. ARM has always been known for its low power consumption, high energy efficiency ratio, and tailoring.

And for edge computing applications, power consumption is indeed a key indicator due to a large number of devices deployed. ARM has always been known for its low power consumption, high energy efficiency ratio, and tailoring. These advantages are just right for edge computing. Edge computing gateway adopts high-end processors based on ARM architecture, and there are suitable products for different selection requirements from optimal cost, optimal performance, and high-cost performance.

ARM cloud games need to have the basic features of "cloud", such as flexibility, availability everywhere. Based on cloud infrastructure optimized for android application to provide ARM application services such as Android cloud game and VR/AR.

And with the help of high performance NextGen arm server chip, edge cloud gaming will enter a new area, more and more players will join in this area.

---

## References

[1]	GCC-7007-2022 "Server Application Scenario Performance Test Method Arm Native Cloud Mobile Phone"
[2]	Cloud Gaming White Paper(Huawei)
[3]	5G Cloud Gaming Key Technology White Paper 2020
[4]	云游戏行业深度报告 ( 66 页 ) : 中国云游戏之路
[5]	<a href="https://www.chinacatv.org.cn/site/content/1683.html">https://www.chinacatv.org.cn/site/content/1683.html</a> 5G 高新视频-云游戏标准体系(2021 版)
[6]	<a href="https://www.omg.org/cloud/deliverables/">https://www.omg.org/cloud/deliverables/</a>

## Authors

- Davy Zhang(Y-semi Computing)
- Chendong Li (Tencent)
- Tina Tsou(ARM)
- Ray Taylor (Genmotion)

## Contributors

- Jim Xu(Zenlayer)
- Corey Ji(Y-semi Computing)
- Jack Chen(Y-semi Computing)