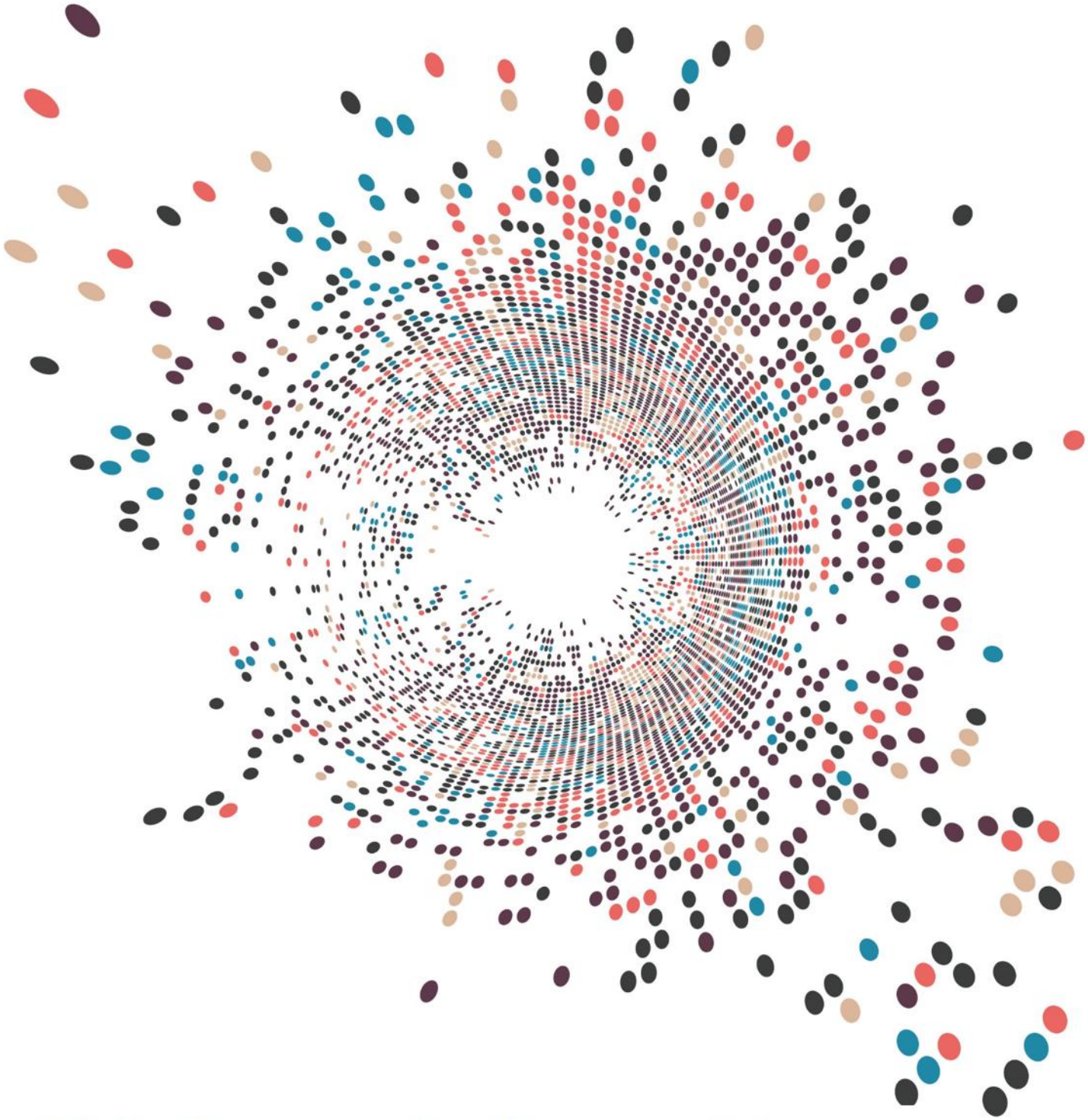


White Paper on the Commercial Application Scenarios of Gigabit Broadband Networks

宽带发展联盟
Broadband Development Alliance

Contents

1 Gigabit Broadband Era

At present, the world economy is going digital. ICT has become a common choice for policy makers to realize sustainable development and enhance national strength.

Technologies enabling ICT investment and deployment include broadband, data center, cloud, big data, Internet of Things (IoT), and artificial intelligence (AI). The amount of digital economy is expected to reach USD 23 trillion in 2025. The blossoming of digital economy makes the support capability of broadband networks increasingly prominent. Broadband has become an indispensable strategic infrastructure for economic and social development.

In recent years, great achievements have been made in the construction of broadband networks in China, and FTTH networks have covered the whole country. By 2019 Q1, the proportion of users with a 100M+ access rate in China reached 73.3%%. The access rate of fixed broadband was estimated at about 120.2 Mbps. Fiber broadband users accounted for 91.6% of all broadband users. With the development of fiber broadband access technologies and the gradual application of bandwidth-hungry services such as HD video, smart home, and cloud VR, Gigabit broadband will become the focus of global broadband development. According to the latest statistics from OVUM, 234 operators in 57 countries have released Gigabit broadband construction plans to facilitate social and economic digital transformation.

Government Policy Promotes Gigabit Broadband Development

Many governments have formulated relevant strategies or policies to encourage the development of Gigabit networks. According to the government work report in 2019, China will launch demo projects to extended 1000M broadband connectivity to urban homes and upgrade networks to support distance education and telemedicine to provide faster and more reliable broadband connections for Internet users. At their executive meeting on May 15, 2019, the State Council expressed their resolve to further accelerate broadband rates and reduce prices. "Accelerating network upgrade and expansion should be a vital focus of investment. The goal is to achieve over 90% FTTH access ports in 2019. In more than 300 cities, Gigabitaccess networks should be deployed to drive fixed and mobile broadband access into the gigabit era."

Mature High-Broadband Services Accelerate the Commercial Use of Gigabit Services

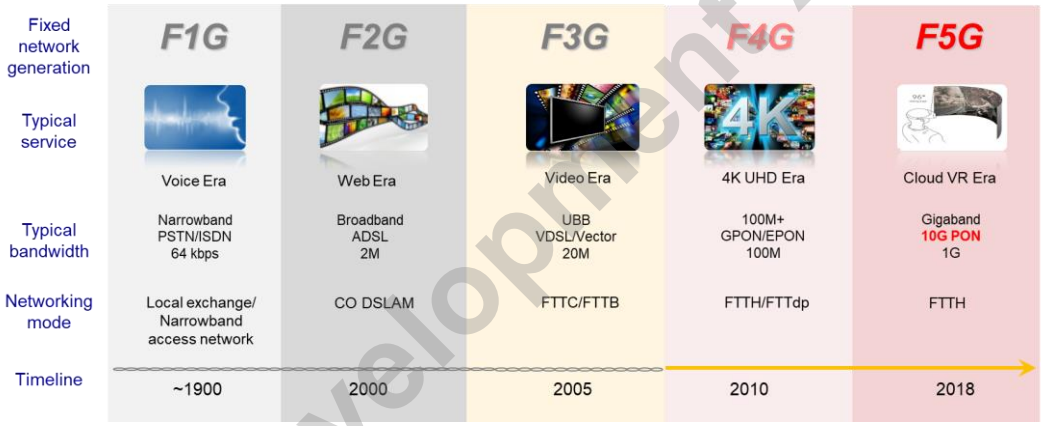
Video content services represented by 4K, 8K, AR, and VR have blossomed. In China, the 4K content duration has exceeded 10,000 hours, and the penetration rate of new 4K TV has exceeded 70%. The number of global mainstream VR platforms applications has exceeded 6000. Cloud VR has a complete E2E ecosystem built in the industry and large-scale deployment conditions are met. The mature application of high-broadband services is driving the commercial use of Gigabit broadband in China.

Since 2018, China's big three telecom operators are proactively promoting gigabit network deployment and exploring gigabit application innovations. By the end of May, 2019, operators in nearly 20 provinces in China released 1000M commercial packages and worked with industry partners to carry out a large number of service innovations based on Gigabit broadband. For example, the smart broadband launched by China Telecom provides products, applications, and services of smart connection, smart TV, smart networking, smart application, and smart service. The intelligent broadband launched by China Unicom provides smart TV, smart home, WO fixed-line phone, and WO home surveillance.

Mature Technology Industry Drives Commercial Applications

Looking back at the development of the fixed communications field in China, the field enters the gigabit access era based on the 10G PON fiber access technology from the voice era based on copper access technology. Driven by the "service innovation + technology development", all things will be sensing, connected, and intelligent.

Figure 1-1 Development history of fixed broadband



The 10G PON access technology and related industries are mature. International standard organizations IEEE and ITU-T take the lead in developing and releasing relevant technical standards. In terms of key components, mainstream vendors' 10G PON core processing chips and optical modules are ready for batch production and large-scale delivery, which meets operator requirements for large-scale deployment, broadband acceleration, and price reduction.

Compared with the previous generations of fixed access technologies, 10G PON gigabit broadband is a great leap forward in terms of bandwidth, user experience, and connection capacity. It delivers symmetric upstream and downstream rates as high as 10 Gbps and a latency as low as 100 us. These changes will drive the fiber network to break through the traditional industrial edge and connect everything including every room in a home, every office building, and every industrial device, and will promote social development in an unprecedented way.

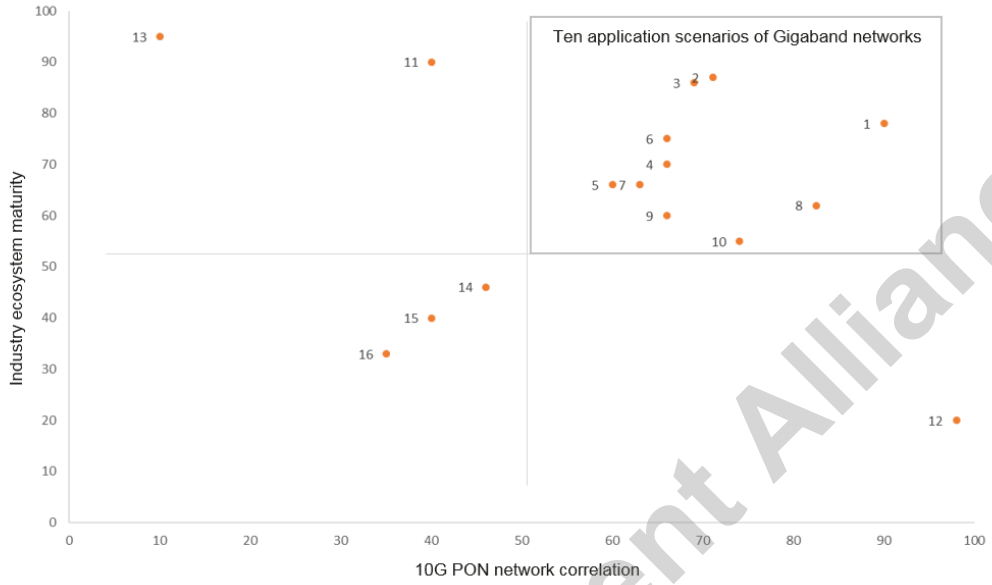
2 Ten Commercial Application Scenarios of Gigabit Broadband Networks

2.1 Overview

The coverage of Gigabit broadband networks pushes the convergence of upstream and downstream industries to release the huge potential of the industries, thus affecting the economic development and changing the way people produce and live. It is believed that as commercial scenarios, industry ecosystems, and Gigabit broadband networks are ready, Gigabit broadband networks will bring about profound changes at the access network level, creating more commercial application scenarios and a new era full of opportunities.

This white paper introduces 10 commercial application scenarios of gigabit fixed broadband networks, including cloud VR, smart home, gaming, social networking, cloud desktop, safe city, enterprise cloudification, online education, telemedicine, and smart manufacturing. These scenarios have high requirements on network bandwidth. Because the industry ecosystems and commercial applications are nearly mature, these scenarios will become key service applications in the Gigabit broadband era and lay a foundation for future service development and commercial application. Based on each typical commercial application scenario of Gigabit broadband networks, this white paper analyzes the market space of service scenarios, summarizes the typical business models of Gigabit broadband network providers, provides specific commercial cases, and puts forward network requirements that support the implementation of commercial scenarios.

Figure 2-1 Commercial application scenarios of Gigabit broadband networks



Legend:

1. Cloud VR
2. Smart home
3. Gaming
4. Social networking
5. Cloud desktop
6. Safe city
7. Enterprise cloudification
8. Online education
9. Telemedicine
10. Smart manufacturing
11. SD video
12. Holographic video
13. Internet access
14. Refined cultivation
15. Intelligent transportation
16. Intelligent power distribution

2.2 Cloud VR

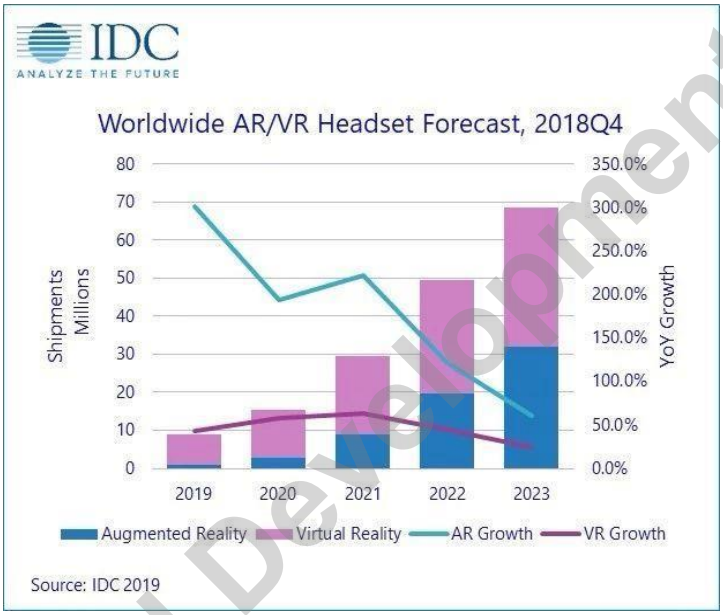
Cloud VR leverages high-speed and stable networks and sends encoded and compressed display output and sound output on the cloud to user devices. It delivers a 360-degree view and immersive experience to users, and has been put into commercial use in fields such as movies and games. The cloud VR service application is based on the interaction of a large

amount of information between user devices and the cloud server. Therefore, it has high requirements on network bandwidth and latency, and is a typical commercial application scenario of Gigabit broadband networks.

2.2.1 Market Space

The "perception" of the physical world and the "interpretation" of the digital world tend to be converged. HD videos such as 4K, 8K, and 32K videos will multiply the depth and sharpness of individual digital interpretation. The development of AR/VR applications will add dimensions for interpretation. As estimated in Huawei's global industry vision (GIV) reports, global VR users will reach 440 million in 2025, and the output value will reach USD 292 billion. According to IDC predictions, the output volume of VR headsets will grow at a high speed with a compound annual growth rate of 66.7%.

Figure 2-2 VR headset market prediction

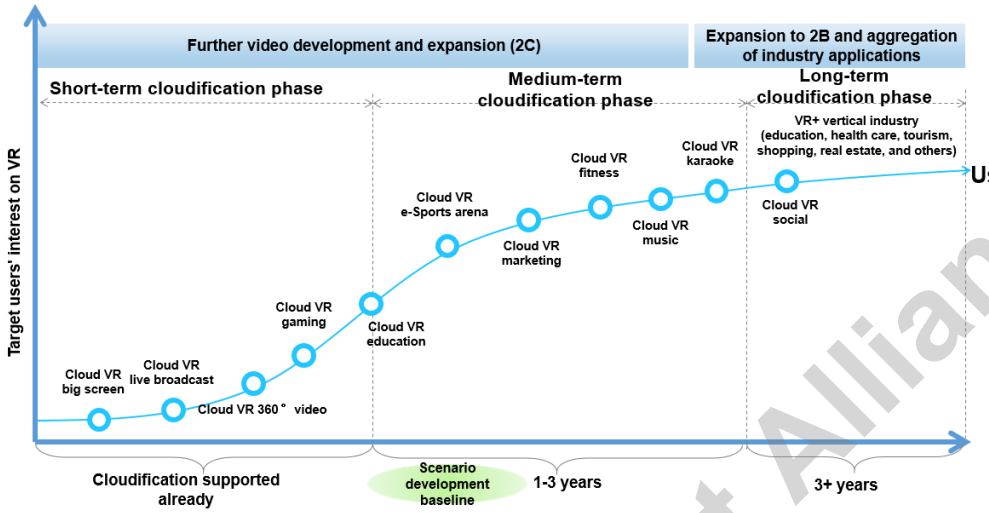


Data source: *Worldwide Quarterly Augmented and Virtual Reality Headset Tracker* from IDC

2.2.2 Business Model and Practice

The development of the cloud VR service requires a gradual process. From the perspectives of content maturity, user experience, and industry maturity, the development can be divided into three phases: short-term cloudification, medium-term cloudification, and long-term cloudification.

Figure 2-3 Three phases of the cloud VR service development

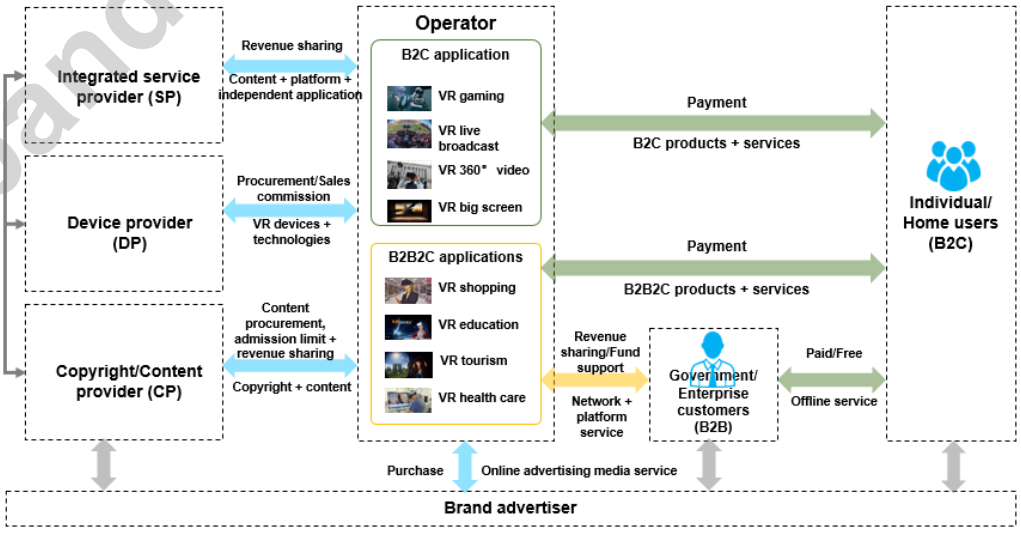


Data source: Huawei iLab

The following provides the details of the phases:

- In the basic service phase of cloud VR, scenarios that already support cloudification such as cloud VR video and cloud VR gaming, are developed first to seize market opportunities, establish a service basis, and cultivate user habits.
- In the basic service phase, users, content aggregation experience, and business model experience have been accumulated. Medium-term cloudification scenarios will be promoted quickly once the industry technologies are mature.
- After 2C users are developed, services can expand to the 2B field to aggregate more industry applications and build a cloud VR service ecosystem.

Figure 2-4 Business model of the cloud VR service



Success stories:

- **Cloud VR provided by China Mobile Fujian**: On July 18, 2018, the company officially released the world's first cloud VR service, which was initially implemented through the 500M broadband access service. VR live TV, VR VOD, VR IMAX, VR education, and VR gaming are provided for users.

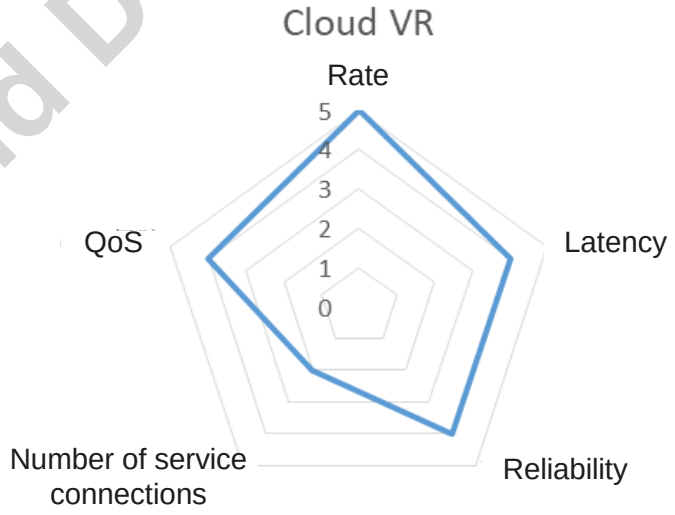
2.2.3 Network Requirement

Different VR service experiences have different network requirements. For Highly-Interactive Cloud VR service, latency and bandwidth are key indicators. Comfortable Cloud VR service requires 130 Mbps bandwidth and 20 ms latency. In the future, bandwidth will need to be at least 540 Mbps to 1.5 Gbps and latency no more than 8-10 ms.

Table 2-1 Cloud VR service requirements on network capabilities

Service Type		Comfortable VR (8K)	Advanced VR (12K)	Perfect VR (≥ 24K)
Barely-Interactive Cloud VR Service	Required bandwidth	120Mbps	420Mbps	1.14Gbps
	Latency	20ms	20ms	10ms
Highly-Interactive Cloud VR Service	Required bandwidth	130Mbps	540Mbps	1.5Gbps
	Latency	20ms	10ms	8ms

Figure 2-5 Analysis of the correlation between the cloud VR service and 10G PON networks



2.3 Smart Home

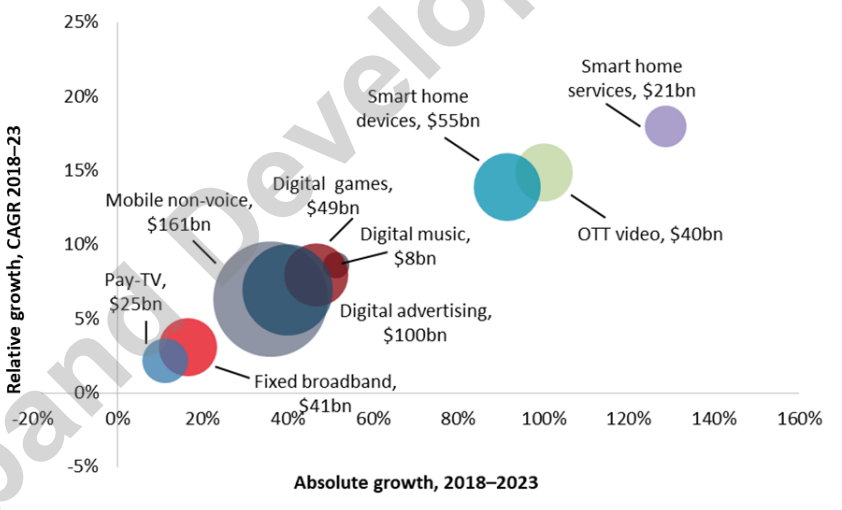
The smart home service uses the broadband network, Internet of Things (IoT), cloud computing, and other technologies to effectively integrate 4K/8K HD video entertainment, smart control over home appliances, information exchange, and consumer services to create a healthy, secure, comfortable, energy-saving, and convenient personalized home life. Smart home devices are connected through Wi-Fi, ZigBee, and Bluetooth. Because smart home devices are connected to the smart home cloud server and the Internet, the network capability of transmitting a large amount of data and the broadband and stability of the connection to external networks will be the key. Therefore, Gigabit broadband networks will become the major bearer networks of smart home in the future.

2.3.1 Market Space

Smart home integrates technologies such as Internet, computing and processing, network communication, and sensing and control, and is regarded as the next blue ocean market. It is estimated that each individual will have 5 smart devices in 2025, and 20% individuals will have more than 10 smart devices. Nearly 20 billion real-time online smart home devices will become a natural extension of individual and family perception.

According to the latest OVUM report, the smart home industry is expected to grow by 129% in five years, which will be one of the fastest growing consumer markets. In 2023, the total smart home market will reach USD 154 billion, including equipment sales.

Figure 2-6 Prediction about the market space of smart home



Data source: *Smart Home Services Forecast Report: 2018–23* from Ovum

Therefore, related industry chain parties including telecom operators, device manufacturers, and content providers are actively advancing into the smart home field. For example, China Telecom launched smart broadband, China Unicom launches smart WO home, and China Mobile also launched their smart home products and services. Operators outside China such as AT&T and Verizon have also announced their advance into the smart home field.

2.3.2 Business Model and Practice

Compared with smart home manufacturers who sales single devices, telecom operators have a mature home network, a large number of users, and good service reputation. Therefore, telecom operators can provide E2E smart home services for home users by binding broadband packages. This is an important business model that telecom operators can consider.

Telecom operators can provide a series of products and services such as home devices, networks, back-end platforms, applications, and after-sales services. Telecom operators can explore innovative business models based on the advantages of service chain integration and information sources, and control costs by taking advantage of the large number to increase benefits, improve user experience, and seize the high ground in the field.

Success stories:

Korean telecom operators have promoted the Gigabit broadband service since 2014 and launched the symmetric 1 Gbps broadband package. One of the major service application scenarios is the smart home control service, which develops rapidly. By 2018, their smart home users have reached 4.45 million, and home video surveillance users have reached 1.13 million. In addition, they provide flexible tariff solutions for gigabit smart home services, effectively promoting the rapid development of services. Telecom operator LG U+ builds IoT experience in all scenarios based on energy saving, security, and convenience services and products. Customers sign a three-year contract with LG U+ to obtain any three home IoT devices at a monthly fee of USD 10. Telecom operator SKT provides a win-win cooperation ecosystem through partners. SKT provides a platform and device authentication services, and users purchase IoT devices authenticated by SKT. Users sign a three-year contract and can connect devices at a monthly fee of USD 9. The number of connected devices is not limited. Telecom operator KT develops home safety, temperature control, and entertainment services on their GiGA platform. Users sign a three-year contract and pay a monthly rental to obtain the smart device. The monthly charge is USD 12 for a secure door lock, USD 4.9 for a gas safety valve, and USD 3 for a smart switch. A home golf push pole is charged USD 352 at a time.

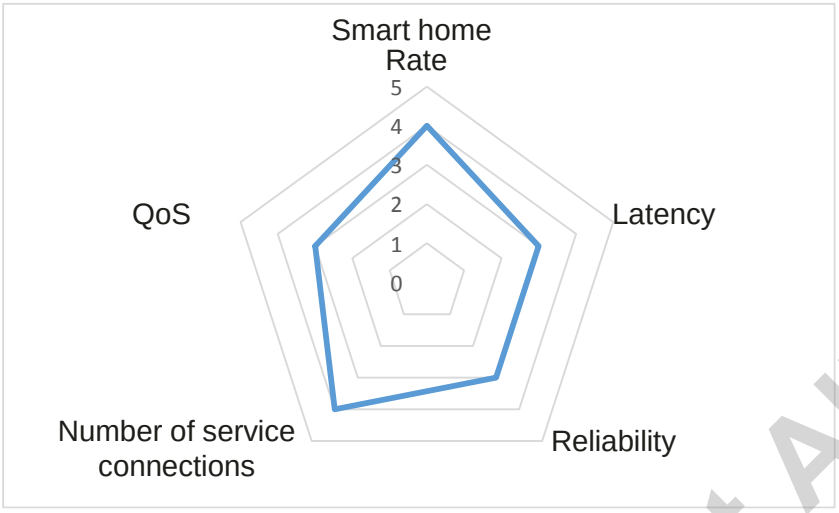
2.3.3 Network Requirement

Smart home services include 4K HD video, home Wi-Fi networking, home storage, sensors, and household appliance control. For example, if five services are provisioned in a home, at least 370 Mbps bandwidth is required, and the access latency must be within 20–40 ms.

Table 2-2 Network capabilities requirements of smart home services

Type	4K Video	Smart Networking	Home Storage	Security Alarming	Appliance Control	Total
Downstream bandwidth	100 Mbps	100 Mbps	60 Mbps	100 Mbps	10 Mbps	370 Mbps
Upstream bandwidth	25 Mbps	100 Mbps	30 Mbps	10 Mbps	2 Mbps	167 Mbps
Latency	20 ms	40 ms	40 ms	20 ms	20 ms	N/A

Figure 2-7 Analysis of the correlation between the smart home service and 10G PON networks



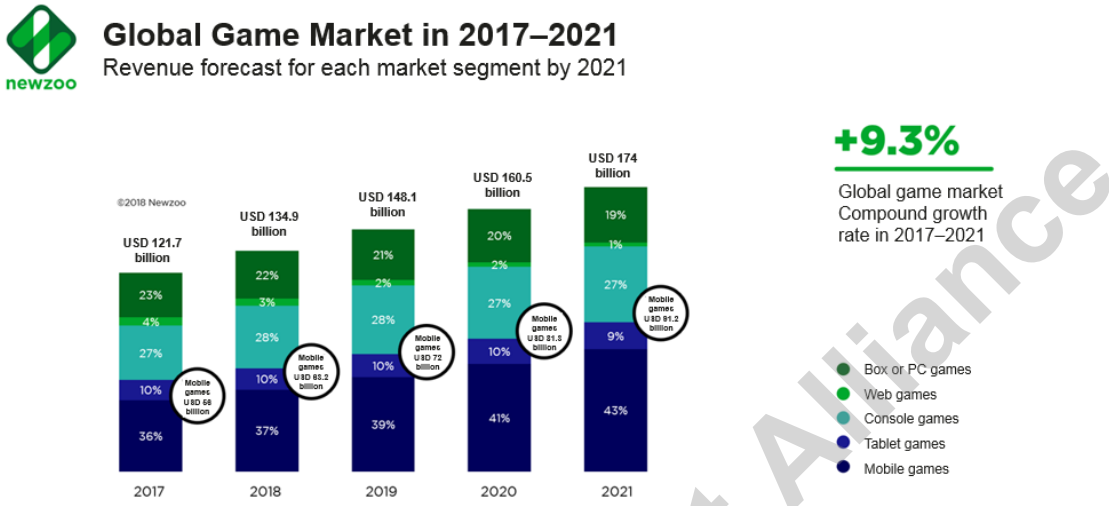
2.4 Gaming

Network games, cloud PC games, and mobile games have become good ways to entertain and socialize because of their strong interaction, high immersion, and interestingness. To achieve better e-sports user experience, large games have high requirements on response latency. A large transmission latency hinders the player status information synchronization on a server, greatly affecting user experience. Therefore, high-bandwidth access services are indispensable to ensure smooth user experience during the commercial application of games. Gaming becomes a typical commercial application of Gigabit broadband networks.

2.4.1 Market Space

According to data from market research institutions, the globalization of the game market is accelerating, and consumers are willing to spend more time on games. According to Newzoo (a game market research and analysis company), there are globally 2.2 billion game players, among which 47% (1 billion) players are willing to spend money when they play games. The compound annual growth rate of the game market from 2017 to 2021 will reach 9.3%.

Figure 2-8 Prediction about the market space of the game industry



Data source: Newzoo

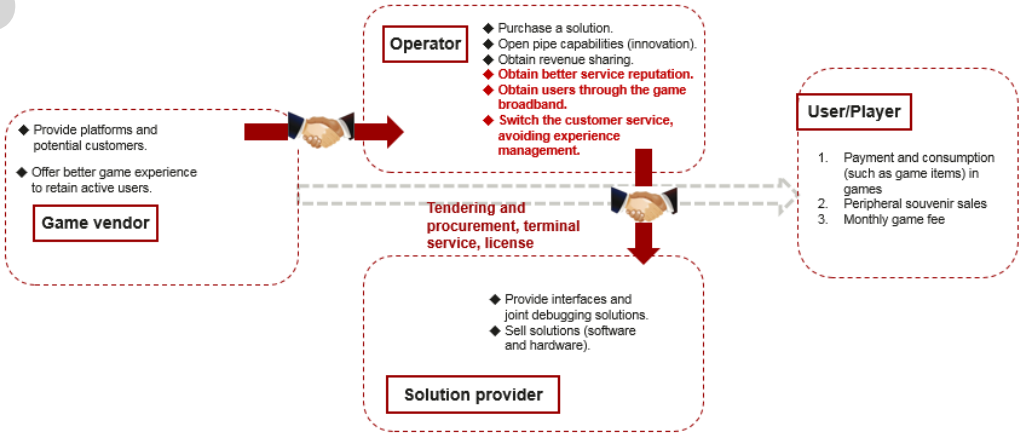
According to data on the global game market in 2018, game markets in the US, Asia Pacific, and China account for 49% of the global game market. It is estimated that the global game market will reach USD 151.9 billion in 2019, and immersive VR and e-sports mobile games will blossom in 2019.

2.4.2 Business Model and Practice

In the business model of traditional game developers and content providers, users buy game products or equipment. For telecom operators, there are two common business models for them to participate in game services as network providers.

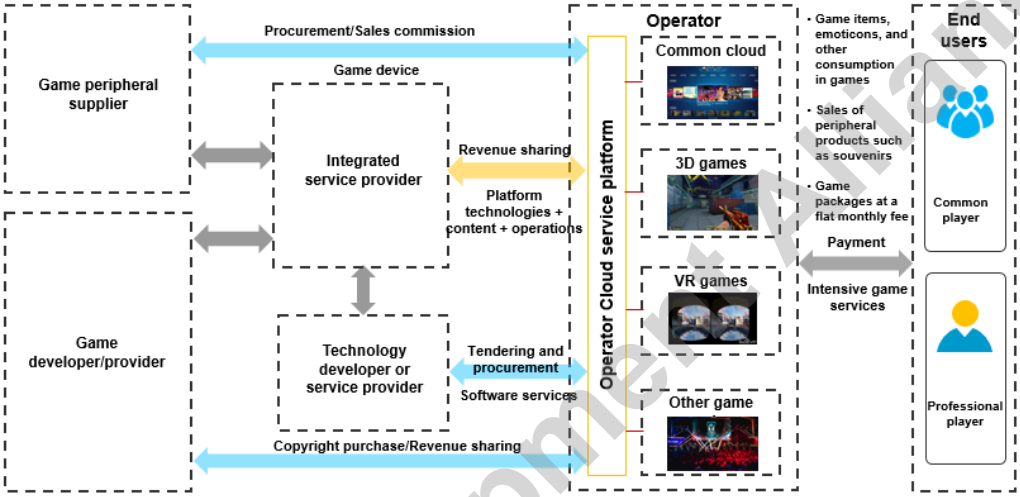
Business model 1: Monetize broadband pipes by launching commercial broadband access service packages dedicated to games. Operators provide game broadband packages and guarantee E2E connection experience to obtain the bandwidth premium.

Figure 2-9 Business model 1 (pipe monetization) of the game industry



Business model 2: revenue sharing mode. Games are one of the most extensive entertainment requirements and a type of service that attracts users and increases user loyalty. Telecom operators attract game content vendors based on the cloud platform to invest continuously. In this mode, telecom operators share revenues with game content providers.

Figure 2-10 Business model 2 (revenue sharing) of the game industry



Success stories:

Exclusive game broadband service: In 2019, China Telecom Guangdong comprehensively upgrades their game broadband. They provide a downstream bandwidth of 200 Mbps and an upstream bandwidth of 100 Mbps, and introduce acceleration technologies at the network layer. After the broadband upgrade, a VIP channel can be provided, line stability and real-time acceleration are guaranteed in games, and intelligent scheduling and optimization in peak hours are supported. Game players enjoy thousands of global games. In the future, with the continuous increase of user experience requirements, large games have continuously increased definition and real-time requirements, and Gigabit broadband will become a necessary network capability to address game experience requirements.

2.4.3 Network Requirement

Console games and multiplayer online battle arena (MOBA) games use synchronization algorithms such as frame synchronization. Players compete with each other in the games, requiring a latency less than 50 ms. When the network latency between a client and the server exceeds 100 ms, frame freezing occurs. When the latency exceeds 250 ms, player operations are severely affected and the game cannot be played fairly.

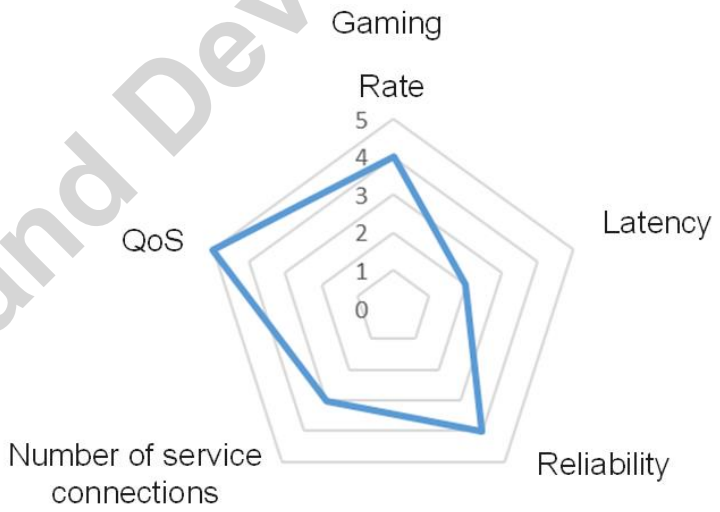
Most massively multiplayer online (MMO) games use the status synchronization algorithm. They focus on attribute development and equipment acquisition. Players also complete with each other in the games, and the latency requirement is lower than that of MOBA games.

Cloud games such as Google Stadia (a cloud gaming service) that deliver 1080P 60 frames per second (FPS) experience require 200 Mbps bandwidth, and games that deliver 4K 60FPS experience require 300+ Mbps bandwidth.

Table 2-3 Network capability requirements of gaming services

Game Type	Typical Game	Service Characteristics
MOBA	Arena of Valor	• The required network latency is less than 50 ms. • Multiple users are online at the same time. The server must be stable and support high-speed read/write.
MMO	Warcraft	• The required network latency is less than 100 ms. • Multiple users are online at the same time. The server must be stable and support high-speed read/write.
First person shooting (FPS)	Counter Strike	• During a real-time First Personal Shooting Game (FPS), clients interact with the server frequently, and the latency needs to be less than 100 ms. • The game status changes frequently, and multiple users are online at the same time. The server must be stable and support high-speed read/write.
Cloud gaming	Google Stadia	• The required E2E latency is 50–100 ms. • 4K 60FPS experience requires 300 Mbps bandwidth, and 1080P 60FPS experience requires 200 Mbps bandwidth.

Figure 2-11 Analysis of the correlation between the gaming service and 10G PON networks



2.5 Social Networking

On social networks, users share their ideas, pictures, articles, activities, and events. For example, online video communication and interaction of popular Internet hosts and real-time

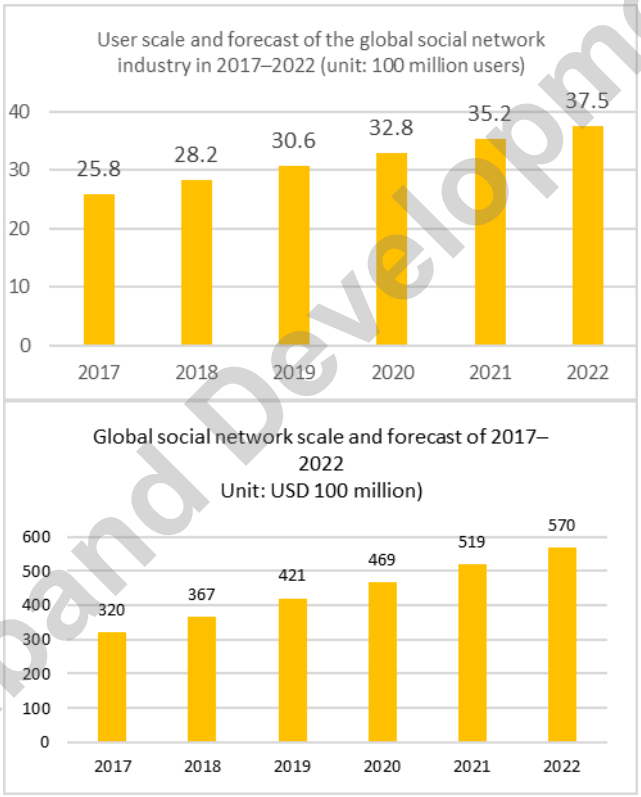
sharing of shopping and life experience have become major social networking scenarios. The video-based online social networks require high bandwidth, low latency, and stable support for user interaction. Gigabit broadband networks are the inevitable choice to deliver ultimate experience of social networks.

2.5.1 Market Space

Global social network users and market size grow rapidly. According to statistics, the number of global social users in 2018 reached 2.8 billion, and the market scale reached USD 36.7 billion. It is estimated that by 2022, the number of global social users will increase from 2.8 billion to 3.75 billion and the social network scale will reach USD 57 billion.

The development of communications technologies drives continuous network rate increases, so that streaming media and video live broadcast are gradually becoming mainstream development trends of social networks. It indicates that users are increasingly accepting shared content (including live videos). In the next few years, UHD and immersive video live broadcast will be widely used by popular e-commerce, extreme sports players, fashion bloggers, and trendsetters.

Figure 2-12 User scale and market space forecast of the social network industry



Data source: a social network industry report from Forward Business and Intelligence (an industry research institute)

2.5.2 Business Model and Practice

According to the forty-second China Internet Network Development Statistics Report released by Internet Network Information Center (CNNIC) in February 2019, the business models of

social applications are nearly mature. Among them, popular e-commerce is the fastest growing and key monetization mode. In 2018, the revenue of popular e-commerce reached CNY 25.4 billion, with a year-on-year increase of 36%.

In the next few years, with the acceleration of VR social cloudification, application scenarios of immersive video live broadcast will be enriched, which will further improve the monetization capability of social networks. For telecom operators, mainstream business models of video live broadcast are similar to those of games and are implemented by providing broadband service pipes and services. The following table lists the details.

Table 2-4 Business models of social networks

Business Model	**Live broadcast**				**Monetization**	
Mode Segmentation	HD video live broadcast	Immersive video live broadcast			Direct monetization	No direct monetization: ecosystem construction
Application Scenario	Popular Internet hosts	VR live video	VR get-together and VR conferencing	Original VR content sharing	Social advertisements	Value-added applications
Typical Application	Hosts on live broadcast platforms such as Douyu TV, Inke, and Momo in China	VR live broadcast platform of Facebook	Facebook Spaces, AltspaceVR, BeanVR	Sansar, High Fidelity, and VRChat	TikTok short-video advertisements	Immediate purchase function during the live broadcast of Alibaba's fashion show
Operator Opportunity	Gigabit pipes, connection monetization				Business cooperation and profit sharing	

Success stories:

Professional host broadband: Online video communication with popular Internet hosts and real-time sharing of shopping and life experience have become popular social network scenarios. Gigabit broadband provides high downstream bandwidth and upstream bandwidth, allowing fans and idols to interact with each other in real time as if face to face. On the World Information Society Day of 2019, China Telecom Guangdong launched the telecom smart broadband to achieve full coverage of gigabit fiber broadband and build 3000 gigabit demo communities. The dedicated host broadband service was launched, providing network live broadcast users with low-latency, high-upstream-bandwidth, and HD video upload experience.

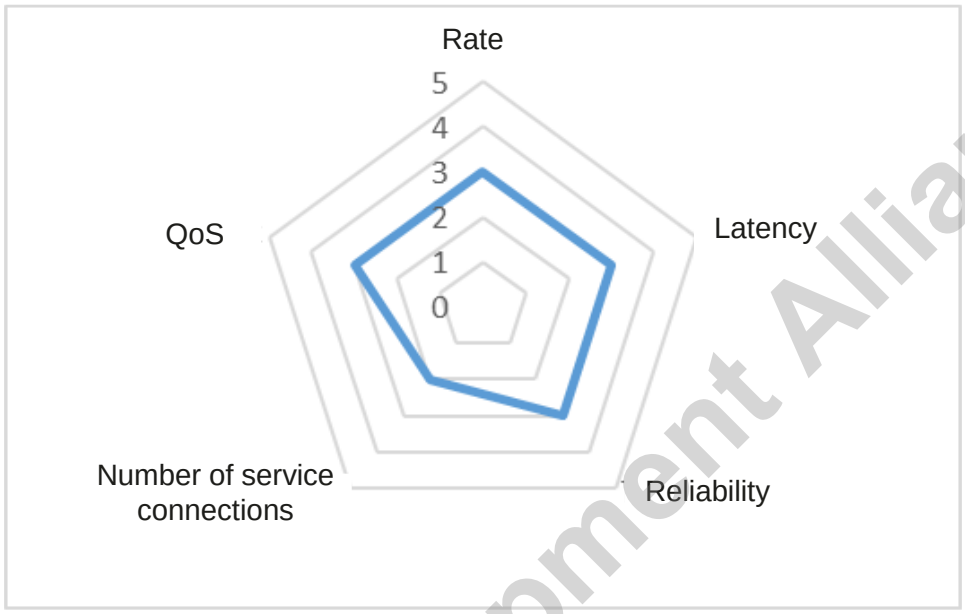
2.5.3 Network Requirement

The video live broadcast technology transforms real-time videos from one-to-one communication to one-to-many interaction. Video recording devices are developed from mobile phone cameras to the 360 °panorama cameras, and the resolution is increased from 480P to 4K/8K (VR). These changes pose high requirements on the bandwidth, latency, QoS, multi-user support, and reliability of networks.

- HD video live broadcast: The minimum network bandwidth is 50 Mbps. When multiple video streams are on live broadcast at the same time, the required downstream bandwidth may exceed 200 Mbps.
- Immersive video live broadcast: Comfortable experience (no dizziness) of VR video live broadcast requires a minimum network bandwidth of 200 Mbps and a latency of less

than 20 ms. In the case of multi-channel live broadcast, the required network bandwidth may exceed 500 Mbps. VR experience sharing requires at least 200 Mbps upstream bandwidth.

Figure 2-13 Analysis of the correlation between social networking and 10G PON networks



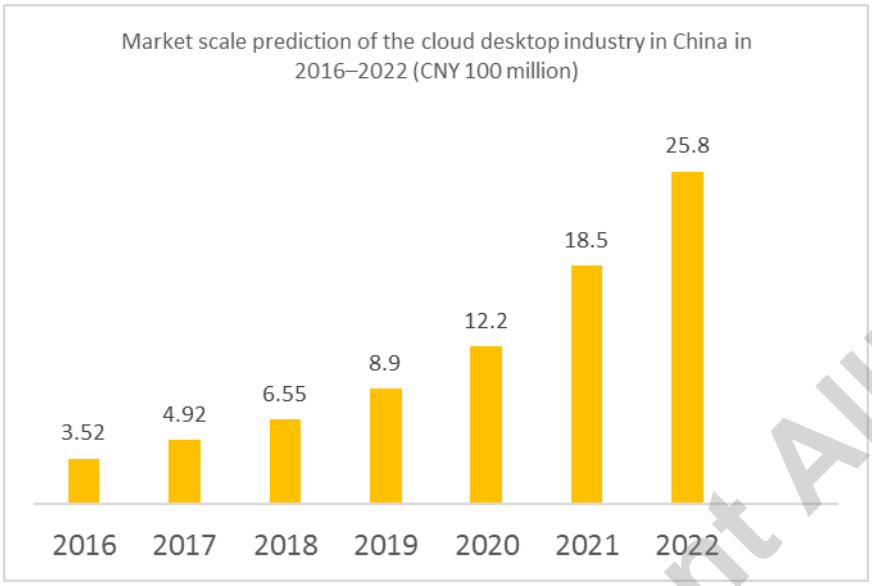
2.6 Cloud Desktop

The cloud desktop service connects a client to a virtual PC on the cloud. It offers remote office anytime and anywhere and the same operation experience as that on a real PC. The cloud desktop application reduces the burden of carrying laptops on business trips and ensures the security of enterprise information assets. The cloud desktop service applies to high-speed and stable interconnection and information transmission between users and cloud servers. It is a typical commercial application of Gigabit broadband networks.

2.6.1 Market Space

The shipment of traditional PCs decreases year by year. It is a trend that cloud desktops replace traditional PCs. According to a market research, the compound growth rate of the cloud desktop market scale in 2016–2022 will reach 39.4%. It is estimated that by 2022, the cloud desktop market in China will reach CNY 2.58 billion.

Figure 2-14 Prediction about the market space of the cloud desktop industry in China

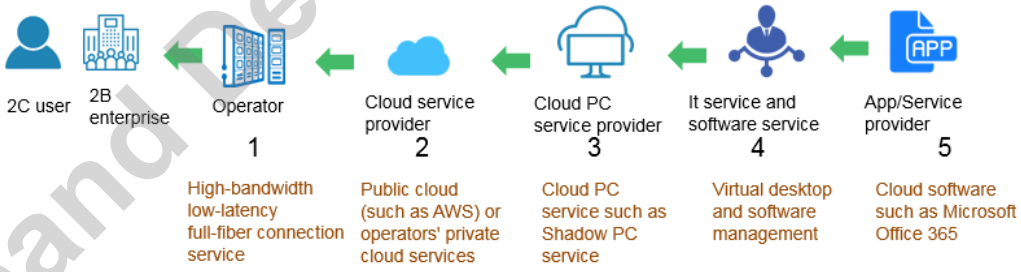


Data source: China desktop cloud market survey for 2017–2023 and market operation trend report from Zhiyan Research (a market research company in China)

2.6.2 Business Model and Practice

Figure 2-15 shows the business model of the cloud desktop service.

Figure 2-15 Cloud desktop business model



The cloud desktop service is provided with a complete ecosystem. Telecom operators can take their network advantages and integrate upstream software and services based on the cloud PC service. Through their network connections, telecom operators provide the cloud desktop service for users. Compared with other cloud desktop service providers, telecom operators have obvious differentiated advantages.

Table 2-5 lists the cooperation models in the ecosystem.

Table 2-5 Cloud desktop business models

Business Model	Involved Node	Business Model Description
Model 1	Node 1 in the preceding figure	High-speed connection pipe services are provided.
Model 2	Nodes 1 and 3	The cloud PC service and connection service packages are provided.
Model 3	Nodes 1 and 2	Connectivity and cloud service platforms are provided for cloud PC service providers.
Model 4	Nodes 1, 2, 3, 4, and 5	Self-operated cloud PC services are provided based on self-operated telecom clouds.

Success stories: As a typical application of cloud computing, the cloud desktop service has been provided by many telecom operators. The monthly charging mode or hourly charging mode is provided according to the usage mode and resource configuration required by users.

Table 2-6 describes the typical tariff for the cloud desktop service.

Table 2-6 Typical tariff of the cloud desktop service

	Basic Application	Business Office	Remote Desktop Games
Resource configuration	2-core CPU, 4G memory 10G hard disk	4-core CPU, 8G memory 20G hard disk	4-core CPU, 8G memory + GPU 100G hard disk
Network configuration	High-speed broadband access	High-speed broadband access	High-speed broadband access
Monthly flat fee	CNY 29.8	CNY 59.8	CNY 119.8

2.6.3 Network Requirement

User experience of cloud desktop applications must be the same as that on local PCs. Specifically, high definition, smooth desktop display, and low latency are required.

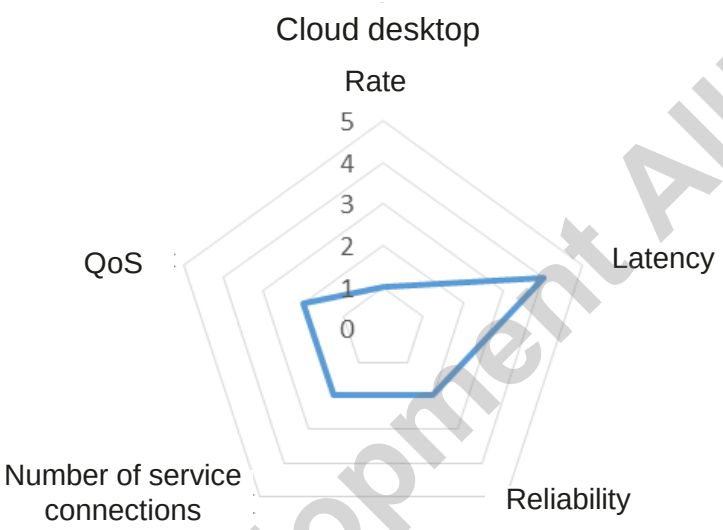
Different cloud desktop applications have different network requirements. For example, the latency directly affects user experience of business office or remote desktop games, and the bandwidth affects the smoothness of desktop display.

Table 2-7 Network capability requirements of the cloud desktop service

	Basic application	Business office	Remote desktop games
Display Requirement	1080P @ 30FPS	2K @ 30FPS	2K @ 60FPS

Bandwidth	20–50 Mbps	100+ Mbps	100+ Mbps
Latency	RTT < 30 ms	RTT < 20 ms	RTT < 10 ms

Figure 2-16 Analysis of the correlation between the cloud desktop service and 10G PON networks



2.7 Safe City

The safe city service (video surveillance service) is related to the life and property security of the country and people in China. The video surveillance system requires clear and smooth images, stable transmission quality, and a short construction period. This poses new requirements on bearer network construction. With the evolution of video surveillance to UHD and intelligent video surveillance, access networks must be continuously upgraded. Therefore, Gigabit broadband networks will become main support networks in the future.

2.7.1 Market Space

The safe city project is driven by video networking and intelligent upgrade. The investment is still heavy. According to IHS (an information provider), by the end of 2022, the global professional video surveillance market (excluding consumer applications) will reach USD 24.1 billion, and China will become the largest video surveillance market.

Figure 2-17 Prediction about the market space of video surveillance

Data source: *video-surveillance-intelligence-market-insight-premium-july-2018* from HIS

2.7.2 Business Model and Practice

The safe city system is a multi-service multimedia convergence platform with video surveillance as the core. It supports multiple departments to coordinate and implement city governance. Because of the advantages of terminals, networks, and platforms, the general contractor of the services can be a telecom operator, responsible for E2E delivery of the system or focusing on the delivery of ICT network facilities. The system provides stable and reliable real-time video backhaul services by using fiber infrastructure with full coverage, and provides intelligent analysis functions such as AI facial recognition and intelligent video retrieval based on cloud service capabilities. Table 2-8 describes the typical business model.

Table 2-8 Typical business model of the safe city service

Model	Description	Application Scenario
Substituting leasing for buying	Governments and enterprises propose construction requirements, operators implements construction and O&M on existing networks, and users only need to pay usage fees based on an agreement. Therefore, no construction costs are required for the video surveillance system.	Public security surveillance, traffic surveillance, and enterprise campus surveillance

Success stories:

China Mobile Hefei deployed Gigabit broadband network with 20 km coverage as the real-time video backhaul network of safe city. With an AI analysis system, the Gigabit broadband network guarantees stability for the safe city service. Based on the video backhaul solution, China Mobile Hefei is also considering developing video surveillance services such as safe campus and smart store for enterprise customers.

2.7.3 Network Requirement

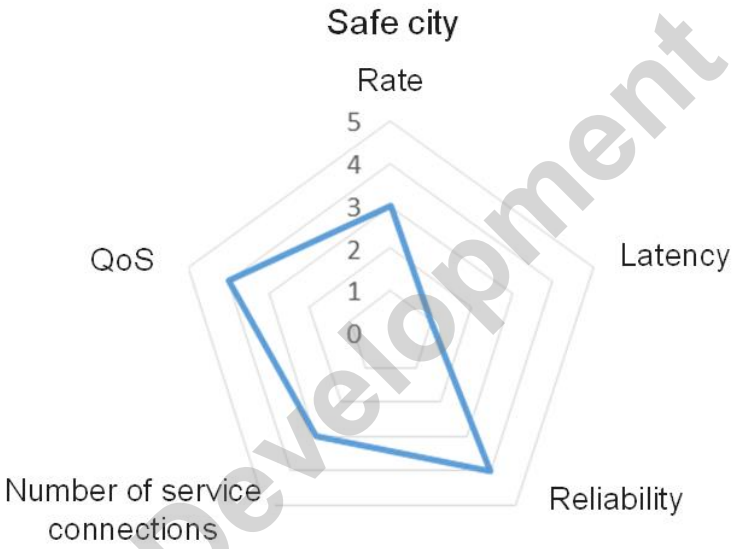
The 4K video surveillance service implements wide-angle surveillance and facilitates intelligent video analysis in high definition resolution scenarios such as facial recognition and vehicle recognition. It requires a bandwidth of 25 Mbps and no bandwidth convergence for 25FPS. If multiple cameras are used at the same time, a high-bandwidth network is needed.

With the deployment of a cloud and edge computing, the network infrastructure needs to support more AI-based surveillance applications and ensure that cameras collect videos on a 24/7 (24 hours a day, 7 days a week) basis.

Table 2-9 Network capability requirements of the safe city service

AI-based Surveillance Camera	Bandwidth	Resolution
Single camera	25 Mbps	4K
AI-based multiple cameras	200 Mbps	360 °4K+

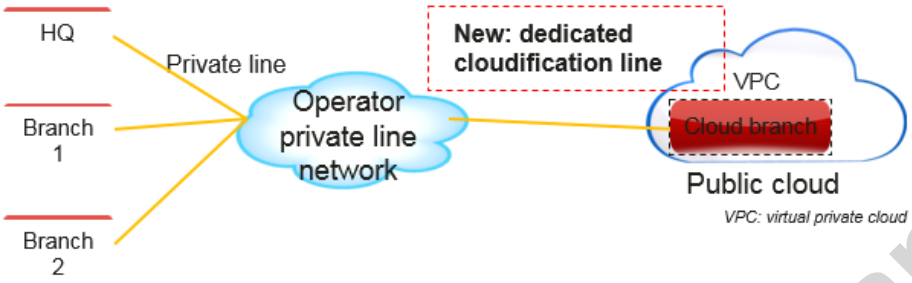
Figure 2-18 Analysis of the correlation between the safe city service and 10G PON networks



2.8 Enterprise Cloudification

Currently, the digital transformation of enterprises is being accelerated, and it is increasingly demanded that core services such as daily office, ERP, and CRM are deployed on the cloud. It is estimated that all enterprises will connect to the cloud by 2025 and 85% applications will be deployed on the cloud. A large amount of data is exchanged between devices and the cloud, posing high requirements on network bandwidth and stability. Gigabit broadband networks will become one of the most important bearer networks in the commercial scenarios of enterprise cloudification.

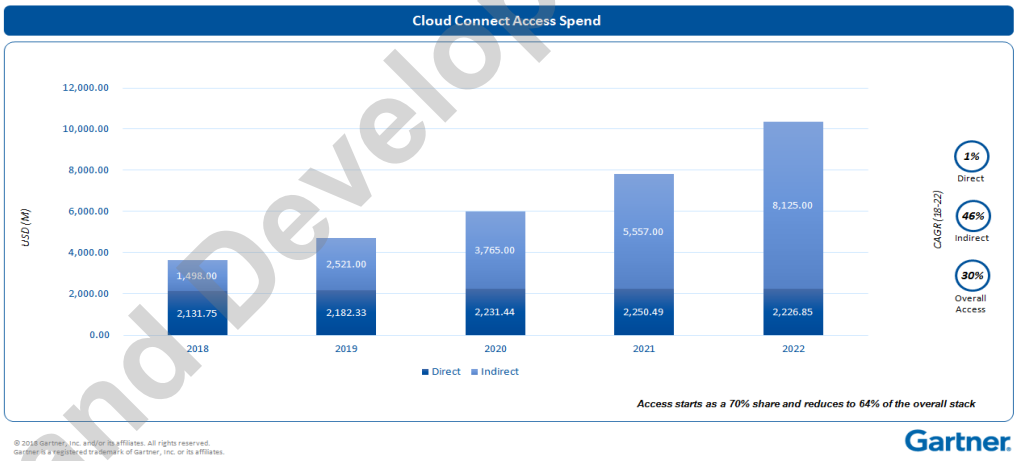
Figure 2-19 Dedicated enterprise cloudification line



2.8.1 Market Space

There are more than 40 million small and medium-sized enterprises (SMEs) in Europe and America and 50 million SMEs in China. As predicted by Huawei Market Insight (MI), 85% enterprise applications will be deployed on the cloud in 2025. This will substantially increase the bandwidth requirement. Enterprise data traffic passing through the WAN will account for 80% of the total enterprise traffic. According to Gartner, the growth rate of investments on dedicated enterprise cloudification lines will exceed 30% by 2022.

Figure 2-20 Prediction about the market space of dedicated enterprise cloudification lines



Data source: Gartner

There are two modes for enterprise cloudification:

- Indirect mode: The cloud service provider provides cloud services and cloud private line services in a unified manner.
- Direct mode: The cloud service provider provides cloud private line connection services.

2.8.2 Business Model and Practice

Enterprises of different sizes and service types have different requirements on cloudification. There are two typical business models for developing the dedicated cloudification line service: network + self-owned cloud and network + third-party cloud.

Table 2-10 Business models of enterprise cloudification

	Mode 1 (Network + Self-Owned Cloud)	Mode 2 (Network + Third-Party Cloud)
Network connection	Private cloudification line + self-owned cloud	Private cloudification line + third-party clouds (multiple clouds)
Operator advantages	SMEs' one-stop ICT service requirements are met.	Multiple third-party clouds are aggregated.
Typical product	"Cloud-based network connection" by China Telecom	NetBond (cloud aggregation) by AT&T

Success stories:

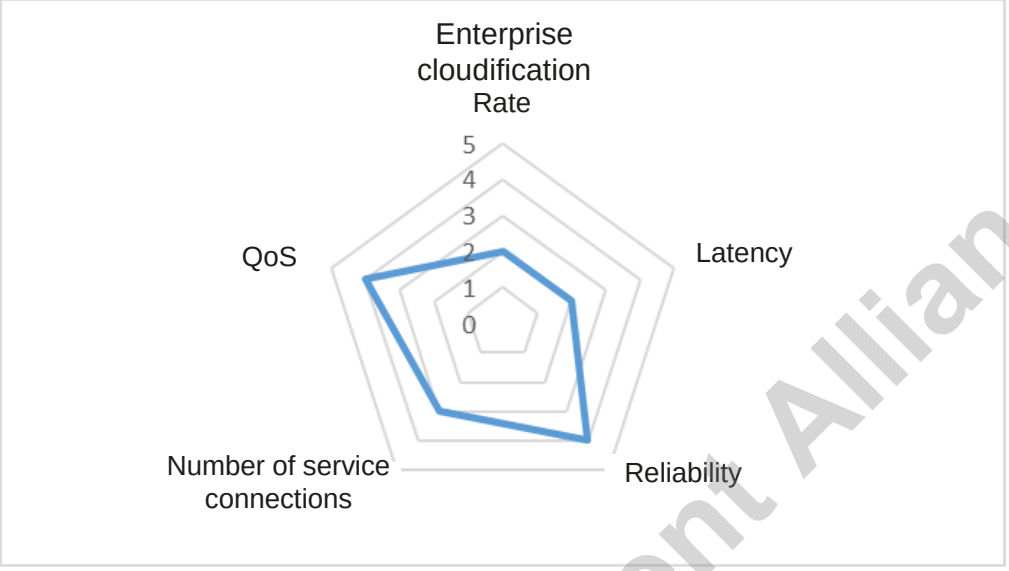
In China, the number of enterprises connected to the cloud exceeds 3 million and is increasing every day. Service providers released enterprise cloud services such as Alibaba Cloud. With high-quality network connections, these cloud services demonstrate their advantages of one-click cloud access and globally shared clouds. With the products, a multi-region global network can be established in minutes and integrate with hybrid clouds to build an intelligent cloud-based network with enterprise-class scale and communication capabilities. These high-quality enterprise cloud services and basic support networks are evolving to Gigabit broadband networks to meet the ever-increasing and changing user requirements.

2.8.3 Network Requirement

Due to the differences in services deployed on the cloud, enterprises have different requirements on the dedicated cloudification line service. Small and micro enterprises require cost-effective and agile private line connections. Medium- and large-sized enterprises require high-reliability elastic-bandwidth private line connections.

Telecom operators can use existing wide-coverage PON networks to quickly provision dedicated cloudification lines and provide stable and reliable last-mile connections. The full fiber network based on 10G PON supports the upstream and downstream symmetric bandwidth of 100 Mbps to 10 Gbps required for enterprise cloudification, and provides guaranteed low network latency and zero packet loss. In addition, node-level protection and link-level protection are configured on the PON and metropolitan area network (MAN) network in E2E mode to provide full path redundancy. When a line fault occurs, a fast switchover can be performed within 50 ms to ensure high reliability of the dedicated cloudification line service.

Figure 2-21 Analysis of the correlation between the enterprise cloudification service and 10G PON networks



2.9 Online Education

Online education provides a way of learning anytime and anywhere. Unlike traditional education, online education can be implemented outside the classroom. In the age of information and knowledge explosion, online education has attracted more and more attention as a flexible, all-weather, and sustainable education mode.

Countries around the world have started large-scale education informatization construction, such as Digital Education Revolution (or DER, an educational reform program) in Australia, "Promotion Strategy for Smart Education" in Korea, ICT Masterplan for Education in Singapore, a promotional project of future campuses in Japan, and Education Informatization 2.0 Action Plan in China. To ensure high quality and stability of online education, more and more commercial organizations choose to use Gigabit broadband networks to ensure service experience.

2.9.1 Market Space

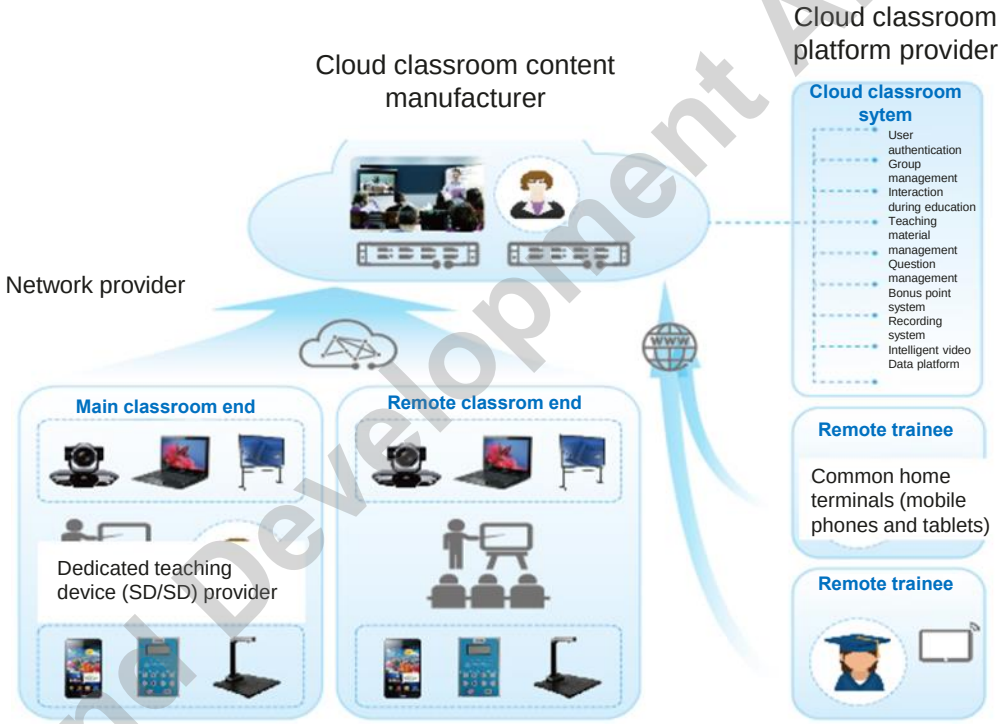
The global is aware of the importance for online education, and the global online education market is developing steadily. According to *TE-Learning Industry Overview - Market Growth, Trends And Forecast* from Technavio (a leading market research company), the global online education market is expected to grow from USD 176.12 billion in 2017 to USD 398.15 billion in 2026, with a compound annual growth rate of 9.5%. The European online education market will increase by USD 36 billion in 2018–2023, with a compound annual growth rate of 15%.

2.9.2 Business Model and Practice

Internet education is directly related to user ages, Internet usage habits of users, and requirement scenarios.

The online interactive class is a mainstream application solution. It is applicable to various scenarios such as higher education, K–12 education, and vocational education. It consists of an online classroom system, the teacher end, and the student end. It is established jointly by platform providers, course content producers, network providers, terminal providers, device providers, and other industry partners. Bearer networks are used to transmit voice, images, and videos between multiple users in real time to implement teaching, learning, practice, tests, and evaluation.

Figure 2-22 Business model of the online education industry



2.9.3 Network Requirement

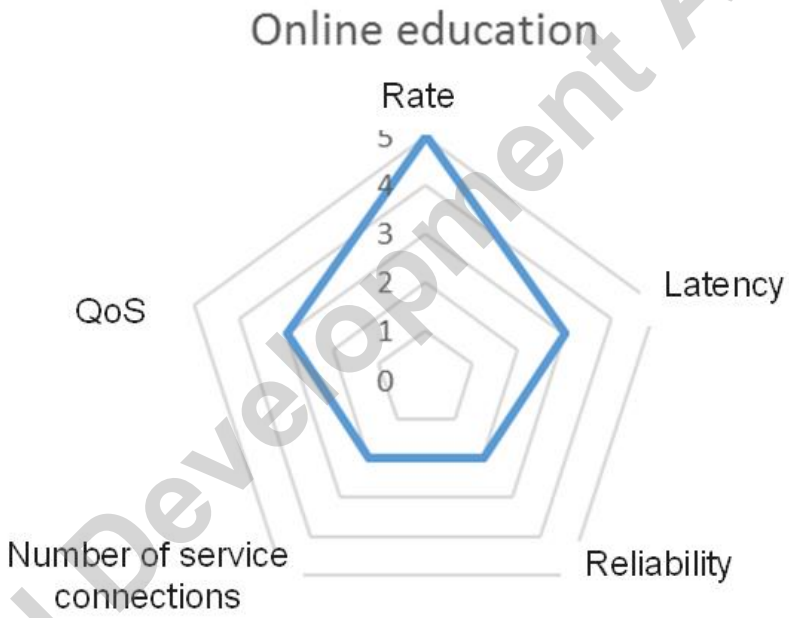
Table 2-11 describes the requirements on the bearer network of online interactive classes.

Table 2-11 Network capability requirements of online interactive classes

Service Type	UEs	Access Bandwidth	Access-Side Latency	Packet Loss Rate
Live video classroom		**750 Mbps to 1.5 Gbps**	**20 ms**	**0.5%**
4K video device access	3–4 UEs per classroom	50 Mbps per device	20 ms	0.5%

SD video device access	30–50 UEs per classroom	20 Mbps per device	100 ms	0.5%
VR classroom		**1–10 Gbps**	**8 ms**	**10^{-6}**
Internet device access (such as mobile phones and tablets)	30–50 UEs per classroom	20 Mbps per device	20ms	0.5%
Cloud VR device access	30–50 UEs per classroom	300 Mbps to 1 Gbps per device	8 ms	10^{-6}

Figure 2-23 Analysis of the correlation between online education and 10G PON networks



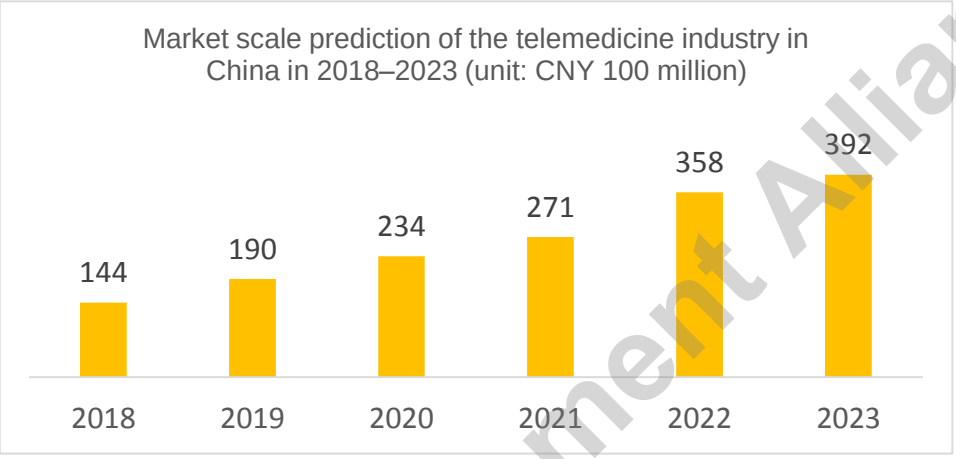
2.10 Telemedicine

Telemedicine uses computer technologies, remote sensing, telemetry, and remote control technologies. It takes full advantage of medical technologies and medical devices in large hospitals or specialized medical centers, and performs long-distance diagnosis, treatment, and consultation for patients with poor medical conditions or in remote areas. Telemedicine technologies have developed from TV monitoring and remote telephone diagnosis to real-time voice and HD image communication, and remote surgery has been gradually applied, providing a broader development space for modern medical applications. The use of Gigabit broadband networks to ensure the precision and reliability of the treatment process has become an important node in the development of telemedicine.

2.10.1 Market Space

According to BCC Research (a market research company), the overall scale of the telemedicine market in 2019 will reach USD 43.4 billion. In the next 3 years, the market value of global telemedicine is expected to exceed USD 66 billion. The telemedicine market in China will reach CNY 39.2 billion in 2023, keeping an annual growth rate of 22%.

Figure 2-24 Prediction about the market space of the telemedicine industry in China



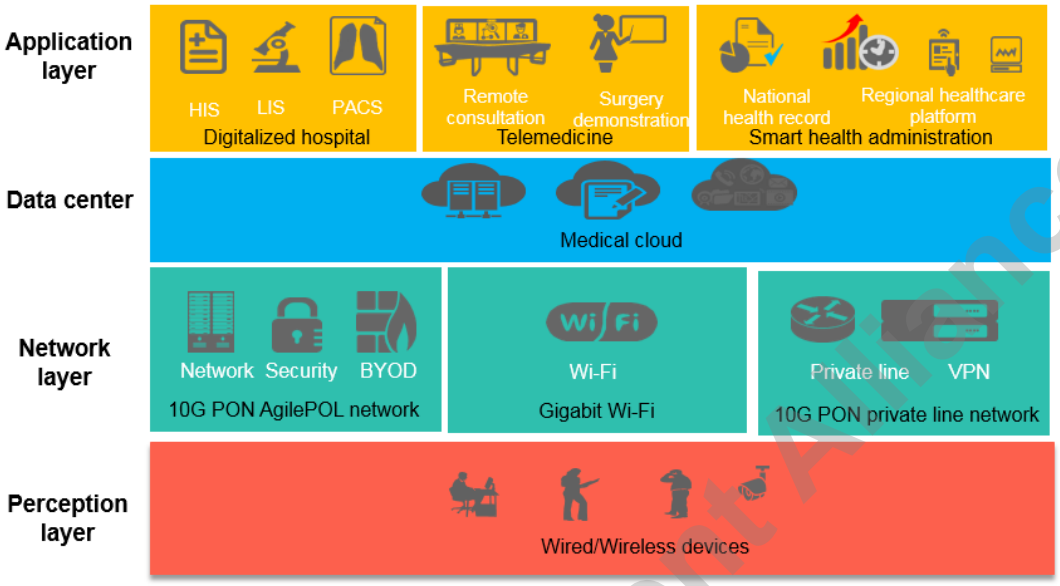
Data source: Forward Business and Intelligence

2.10.2 Business Model and Practice

Thanks to the popularity of the Internet, information about medical resources can be available from the Internet. Telemedicine can alleviate the uneven distribution of medical resources, shorten the patient consultation time, break the distance limit, and improve the utilization of doctor resources.

Telemedicine needs to be conducted based on hospital informatization networks. It provides online consultation services and makes profits through patient charging, medicine guidance, and big data mining. As an important participant in the telemedicine industry, telecom operators are a key part of the value chain. They provide high-speed, reliable, and low-latency informatization networks for hospitals, improving remote diagnosis and treatment experience and achieving pipe monetization. In addition, the application of big data can also help hospitals increase the efficiency of new medicine R&D and improve clinical treatment.

Figure 2-25 Telemedicine business model



Operators can participate in the three network scenarios:

1. Medical cloud. Operators can build a medical cloud to meet service cloudification requirements.
2. Gigabit access private line network. It implements various Internet private line connections for hospitals.
3. Gigabit broadband AgilePOL network (including gigabit Wi-Fi). It implements the hospital network reconstruction and sets up ubiquitous gigabit connections.

Success stories:

Some hospitals and medical colleges with sufficient resources in China have already carried out telemedicine. Some medical institutions use the bidirectional symmetric gigabit access rate provided by 10G PON networks to build a Gigabit broadband smart medical center. The networks offer high-speed network coverage services to hospitals' campus surveillance system, hospital information system (HIS), clinical information system, and regional medical imaging centers. These services guarantee diagnosis and treatment data for doctors and patients and real-time interaction through HD videos, improving diagnosis efficiency and accuracy.

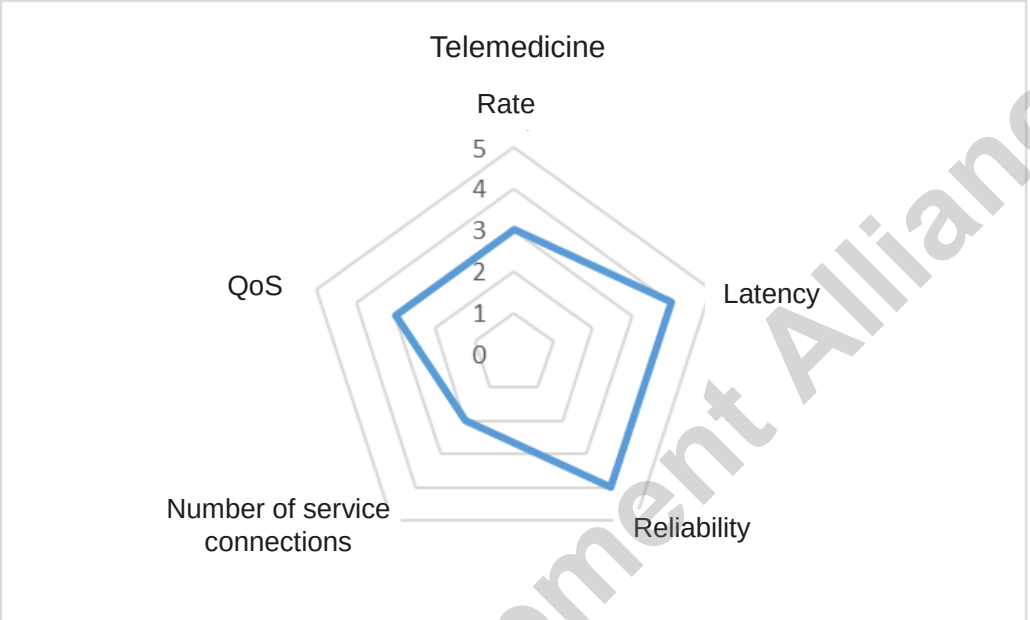
2.10.3 Network Requirement

A telemedicine system provides two service modes: real-time (online) and non-real-time (offline). The real-time mode applies to emergency scenarios and scenarios when conditions permit. In this mode, patients can obtain timely assistance, but the cost is high and the operation is difficult. In non-real-time mode, information about the medical service requesting party is sent to the service provider for processing. Experts in large hospitals can make diagnosis according to documents provided by users. The non-real-time mode applies to medical consultation, training, and education scenarios.

- Real-time HD audio and video backhaul requires at least 200 Mbps upstream and downstream network rates. Emerging real-time diagnosis and treatment methods such as remote endoscopy and remote ultrasound require an E2E network latency of less than 10 ms.

- A comfortable experience of cloud VR medical training requires a network rate of greater than 200 Mbps.

Figure 2-26 Analysis of the correlation between telemedicine and 10G PON networks



2.11 Smart Manufacturing

In Germany's "Industry 4.0" strategy, smart manufacturing and smart factory are important topics.

The construction of the smart factory involves interconnection and integration of smart devices, smart control systems, and Industrial Internet at various layers. The importance of automatic integration service providers is becoming increasingly important. The Industrial Internet that realizes device data collection and device interconnection is the important foundation of smart manufacturing. From the perspective of the network, device interconnection and information exchange in the factory within and outside the smart factory are important application scenarios of Gigabit broadband.

2.11.1 Market Space

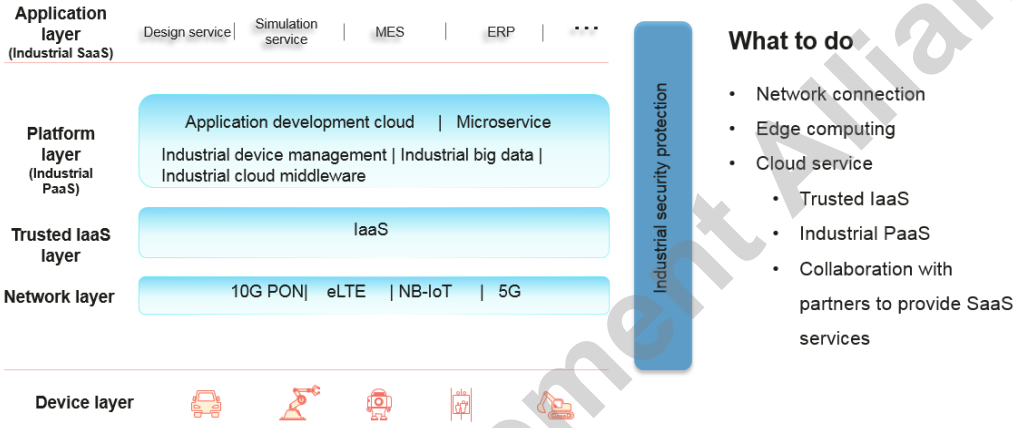
The Industrial Internet that supports the smart factory is the product of integration between a new generation of information technology and the manufacturing industry. On the Industrial Internet, running of physical devices and exchange of a large amount of data are performed. It is a bridge between physical manufacturing and digital manufacturing and the basis for achieving a "digital twin" of production lines and factories.

As estimated in Huawei's global industry vision (GIV) reports, 30 billion devices will be interconnected worldwide by 2025. Industrial Internet technologies such as Time-Sensitive Networking (TSN) and IPv6 will be widely deployed in industrial enterprises.

2.11.2 Business Model and Practice

The core of the Industrial Internet is to rely on connections and big data analysis to create new industrial values. Operators have the opportunity to proactively participate in this process. With their own complete infrastructure, reliable security quality, and ubiquitous cloud services, operators can help manufacturing enterprises and logistics enterprises upgrade and reconstruct smart manufacturing.

Figure 2-27 Business model of smart manufacturing



Data source: Huawei MI

It is a global consensus and trend to improve the intelligent level of industrial manufacturing through informatization reconstruction. The application and deployment of the Industrial Internet are still in the experimental stage. The US released the *National Artificial Intelligence Research and Development Strategic Plan* and *Strategy for American Leadership in Advanced Manufacturing* in October 2016 and October 2018 respectively, highlighting the full life cycle optimization of products, advanced robot development, big data mining, and manufacturing system network security. The EU released their digitalized industry strategy in May 2016, focusing on the R&D of advanced robots and industrial autonomous systems.

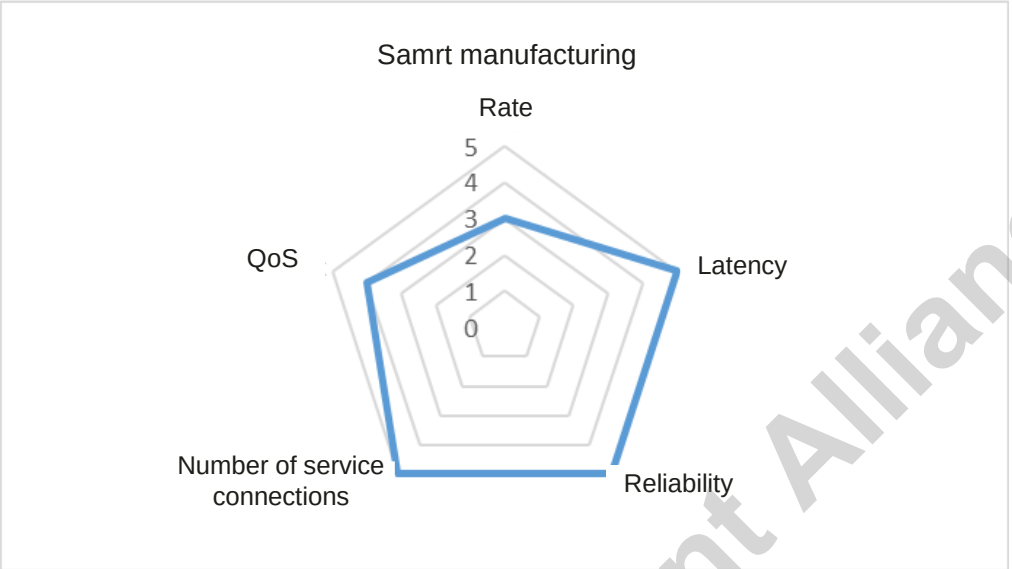
Success stories:

With the help of applications such as industrial PON, industrial cloud, and digital work stations, operators can help high-end parts manufacturing enterprises to implement Industrial Internet reconstruction, introduces Gigabit broadband networks into the construction of the Industrial Internet, and promotes the efficient transmission and interconnection of information.

2.11.3 Network Requirement

Synchronous real-time control machines require a microsecond-level network latency. The wired connection mode of industrial communications accounts for 94% of the total market share. In the industrial manufacturing field, 10G PON is used to on gigabit fiber networks, which can be free from electromagnetic interference and deliver high reliability. Compared with other transport technologies, optical fiber networks support ultra-large bandwidth and ultra-low latency and therefore better meet the requirements of sophisticated precision manufacturing.

Figure 2-28 Analysis of the correlation between smart manufacturing and 10G PON networks



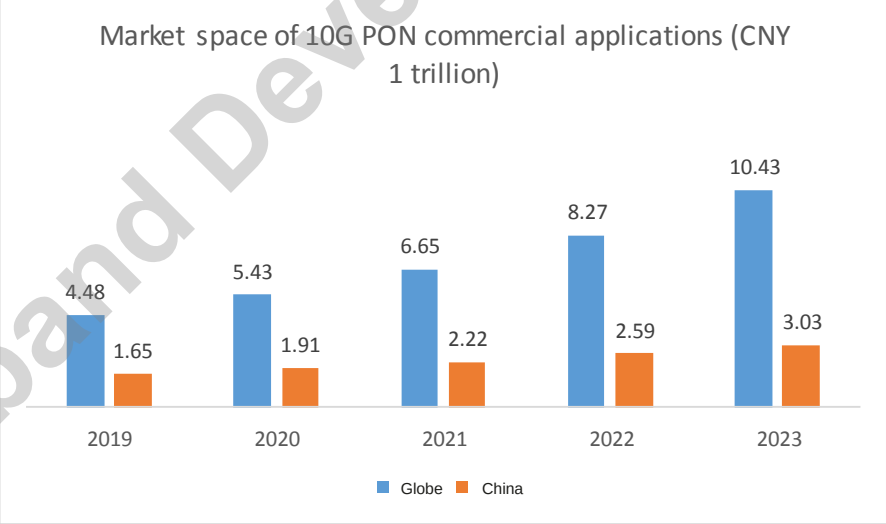
3 Conclusion and Outlook

3.1 Promotion in Economic and Social Development

10G PON Gigabit broadband networks deliver full-fiber connections, ultra-high bandwidth, and ultimate experience, and will be deployed in the preceding 10 commercial scenarios. It is estimated that by 2023, the direct output driven by 10G PON will exceed CNY 10 trillion in the global market and more than CNY 3 trillion in the China market.

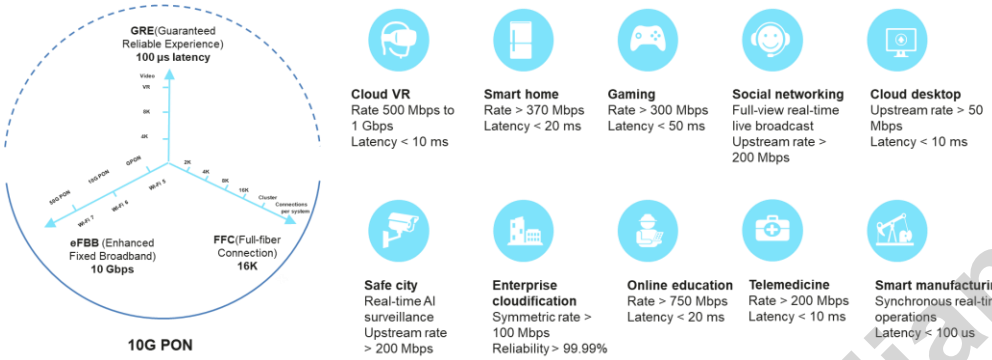
The commercial use of Gigabit broadband networks will trigger a new wave of investment, promote digital economy development with assistance of new industry applications, and further promote information consumption.

Figure 3-1 Prediction about the market space of 10G PON commercial applications



Gigabit broadband networks can be deployed in a large scale in 10 commercial scenarios from the perspectives of rate, latency, reliability, number of service connections, and QoS.

Figure 3-2 Requirements on the KPI of 10G PON networks in 10 commercial scenarios



According to an analysis of 10 commercial application scenarios, different service experiences have different network requirements. The white paper evaluates the rate, latency, reliability, number of service connections, and QoS as shown in the following table. In the table, a larger score indicates a stronger correlation.

Table 3-1 Scoring rules for Correlation between 10 commercial scenarios and 10G PON networks

Score	Rate	Latency	Reliability	Number of Service Connections	Guaranteed QoS
5	800 Mbps to 1 Gbps+	≤ 1 ms	Excellent	A large number	Excellent
4	600–800 Mbps	≤ 10 ms	Good	Many	Good
3	400–600 Mbps	≤ 20 ms	Average	Average	Average
2	200–400 Mbps	≤ 50 ms	Fair	A small number	Fair
1	< 200 Mbps	≤ 100 ms	Poor	Few	Poor

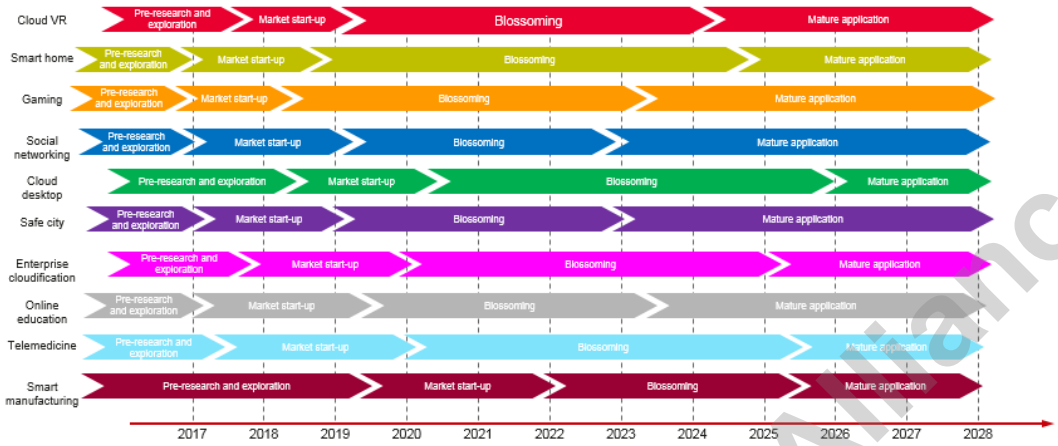
Figure 3-3 Analysis of the correlation between 10 commercial scenarios and 10G PON networks (a larger score indicates a stronger correlation)

3.2 Timeline for the Deployment of 10 Commercial Application Scenarios

The following rules are observed from the perspective of Gigabit broadband networks and the application process of each industry:

1. Bandwidth acceleration in home scenarios starts first. The bandwidth is gradually increased from 100M to 300M, 500M, and 1000M, providing users with higher connection bandwidth.
2. Gigabit broadband gradually penetrate into high-value vertical industries based on home access to increase network efficiency and shorten the investment cycle.
3. From the mature process of application scenarios, home and individual entertainment consumption will blossom first, followed by enterprise cloudification and the education industry. Telemedicine and smart manufacturing involve more precise control and are being explored.
4. Gigabit applications are based on networks and are closely related to national policies and industry digital transformation progress.

Figure 3-4 Timeline for the deployment of 10 commercial scenarios



3.3 Business Model of Gigabit Broadband Networks

1. **Bandwidth-based business model**

   In home scenarios, the bandwidth-based operation model is the main business model of telecom operators. For example, in scenarios such as VR, smart home, gaming, social networking, and cloud desktop, users can enjoy different service experiences with different access bandwidths. Operators can formulate differentiated bandwidth charging modes.

2. **Connection-based business model**

   For large-connection scenarios such as the smart home IoT service and safe city service, different devices, sensors, and applications need to be integrated. In addition to bandwidth services, telecom operators can formulate charging modes based on the number of connected devices for a large number of IoT devices, cameras, and sensors.

3. **Solution-based business model**

   Telecom operators can provide customized services for industry customer application scenarios such as enterprise cloudification, online education, telemedicine, and smart manufacturing. These customized services include software and IT integration service, big data analysis service, and security service. Compared with the previous business models, the solution-based business model has higher added values and poses higher requirements on operators' comprehensive integration capabilities.

3.4 Future Prospect of Gigabit Broadband Networks

Gigabit broadband networks have been widely used in following commercial application scenarios: cloud VR, smart home, gaming, social networking, cloud desktop, safe city, enterprise cloudification, online education, telemedicine, and smart manufacturing. In the future, as the society more and more relies on information and the digital economy is being rapidly developed, there will be increasingly requirements on the network support capabilities. Gigabit broadband networks will gradually become the core technology and mainstream service of broadband access networks in the next few years. They will play an important role in improving the service experience of home users. They will also comprehensively support

industry development and support the development of smart agriculture, smart manufacturing, and Industrial Internet. They will promote the equality of public services and play a bigger role in remote education, telemedicine, and smart elderly care. In addition, Gigabit broadband networks will support the modernization of social public governance systems and are becoming more and more important in transportation and social management.

A Acronyms and Abbreviations

Acronym and Abbreviation	Full Name
AI	Artificial Intelligence
AR	Augmented Reality
ARPU	Average Revenue Per User
BT	Build-Transfer
Cloud VR	Cloud Virtual Reality
FTTH	Fiber to the Home
GIV	Global Industry Vision
HIS	Hospital Information System
ICT	Information and Communications Technology
IEEE	Institute of Electrical and Electronics Engineers
ITU-T	International Telecommunication Union-Telecommunication sector
PC	Personal Computer
PON	Passive Optical Network
PPP	Public-Private Partnership
QoS	Quality of Service
RTT	Round-Trip Time
TSN	Time-Sensitive Networking
VPN	Virtual Private Network
VR	Virtual Reality
Wi-Fi	Wireless Fidelity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