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Metaverse report—
Future is here
Global XR indurstry insight

March 2022
Deloitte China

MAKING AN
IMPACT THAT
MATTERS
since 1845

Foreword

Roblox went public in March 2021, with a market value of more than 40 billion U.S. dollars at the time. In a short period, the concept of the metaverse has blossomed and unlocked the imagination of the "metaverse" industry. In the metaverse, users no longer consciously distinguish between what exist physically and virtually. More importantly, the metaverse creates a new environment where users are virtually connected with their family, friends, pets, favorite items and experiences—the metaverse transports users to the next-generation of social interactions.

The concept of metaverse first appeared in the Avalanche, written by American science fiction writer Neo Stevenson in 1992. It describes a cyber world parallel to the real world, the Metaverse, where people in the real world all have a digital avatar; they interact and live with each other through these avatars. The metaverse encompasses 5G, AI, blockchain, content creation and other elements. The core of metaverse is to continually optimize users' digital life experiences through XR (Extended Reality) and continuous iteration of XR technology and equipment. XR-based digital services will gradually penetrate various scenarios and drive breakthroughs in the disruptive immersive digital life experience of the metaverse, helping opening up the era of the metaverse. This is the first report of the metaverse series, with focus on the XR industry trends.

In addition to consumers' ultimate experience of the metaverse, XR is widely applicable to enterprises. XR is an important productivity tool in industrial manufacturing, healthcare, retail and many other scenarios involving remote training, implementation guidance, process management and knowledge precipitation. As it penetrates more scenarios at a rapid pace, it will deeply affect every aspect of people's lives.

The XR industry has been developing slowly over the past few years. The current XR development stage is similar to the inflection point before the launch of the Apple iPhone 4 in the smartphone industry. Global XR shipments are expected to exceed 10 million units in 2021. The industry has, therefore, already reached the industrial inflection point that Zuckerberg believes is an important milestone for making a sustainable ecosystem for VR developers. In addition, as the industrial chain and technology continues to evolve, content application gradually prospers, ecological partners are rapidly engaged, and the entire metaverse ecosystem is continuing to augment – all helping XR terminal shipments to boom.

In August 2021, ByteDance acquired a leading Chinese VR (virtual reality) startup Pico, arousing a heated discussion in the market, marking ByteDance's first foray into the field of the metaverse. More and more technology companies have plans for deployment in the XR field. Apple, Facebook (Meta), Microsoft, Google, Huawei, Tencent, and ByteDance, among others, are all building XR ecosystems, strategically positioning them as "next-generation computing platforms".

The metaverse industry chain is extensive and complicated, with many investment opportunities in the hardware, software, content and application links. In the meantime, more and more industrial capital is flowing in, and a clear industry-exit path has been shown following Roblox's going public. From the perspective of proprietary technology, China, the United States, South Korea and the World Intellectual Property Organization have rich proprietary technology reserves. Those looking to grasp investment opportunities in the metaverse should take a global view, exploit China's advantages, and draw on the successful experiences of others, so as to promote industrial prosperity while incubating unicorn companies.

Metaverse: unlocking imagination and embracing reality

Following the PC-connection desktop Internet era and the smartphone-connection mobile Internet era, the metaverse has unlocked the imagination of the next era of information interconnection, creating an ideal virtual world through the perfect connection of the virtual world with reality. The concept of the metaverse first appeared in the Avalanche written by American science fiction writer Neo Stevenson in 1992. It describes a cyber world parallel to the real world, the Metaverse, where people in the real world all have a digital avatar; they interact and live with each other through these avatars. The sandbox game platform Roblox as the "first listed company under metaverse concept" again proposed the concept of metaverse in its prospectus, which triggered a heated discussion in capital markets and related industries. Then Facebook's changed its name to "Meta", stimulating even more enthusiasm in the market for metaverse. Hence the sci-fi concept of metaverse was brought into the real life.
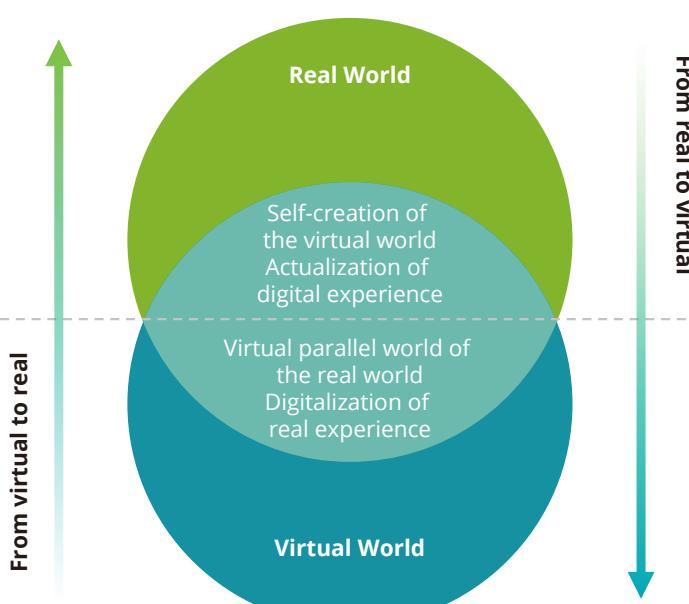
Mutual generation of the virtual and the real is a key feature of the metaverse, which is embodied in six core elements: immersion, virtual identity, digital assets, real experience, virtual-real interconnection and complete social system. In the future, metaverse will develop from real to virtual to realize digitalization of real experience, as well as from virtual to real to realize actualization of digital experience.

Metaverse will show two development directions:
From real to virtual: the virtual world imitates the real world, and the digital experience of real life is enhanced by building immersive digital experiences. It emphasizes realizing **digitalization of real experience.** In the era of mobile Internet, the virtual world is mainly constructed through text, pictures, videos and other 2D forms. In the future metaverse era, the real physical world will be digitally reconstructed in the virtual world to form a completely virtual parallel world.

From virtual to real: here it is no longer about imitation of the real world but self-creation based on the virtual world, which can not only form a value system independent of the real world, but also influence the real world. It emphasize realizing **actualization of digital experience.** For example, the augmented reality (AR) game Pokémon Go helps brands attract more consumers by cooperating with brands to issue limited coupons at specific locations, and in this way the digital experience is driving consumption in the world.

Figure 1: Two Development Paths of Metaverse

Real World

From real to virtual

Self-creation of the virtual world
Actualization of digital experience

Virtual parallel world of the real world
Digitalization of real experience

From virtual to real

Virtual World

Source: Deloitte Research and analysis

Human society evolves around the two complementary axes, material and spiritual civilization. This is what Deloitte believes the core value of the metaverse is rooted in—improving the development efficiency of material civilization and expanding the development space of spiritual civilization. Specifically, the development of metaverse will form a dual-core ecosystem, with the industrial metaverse promoting the production efficiency of the physical world and the consumer metaverse enriching the personal spiritual world.

According to the different service targets, the metaverse will form a dual-core pattern, with the industrial metaverse promoting the production efficiency of the physical world and the consumer metaverse enriching the personal spiritual world. The two development paths integrating the virtual and real world will gradually combine to eventually form a closed-loop ecosystem of the physical and spiritual world.

Developing from real to virtual is the process of improving the experience and efficiency of the real world.
For the industrial metaverse, developing from real to virtual refers to leveraging virtual scenarios during the digital and online deployment process, which improves their actual efficiency in the physical world. For example, vocational education can introduce simulation scenarios to construct virtual digital workshops, to provide students with real technical guidance and efficient practice methods. What's more, 3D simulation models can help accelerate industrial design processes, greatly reducing potential safety hazards in the testing stage as well as resource costs.
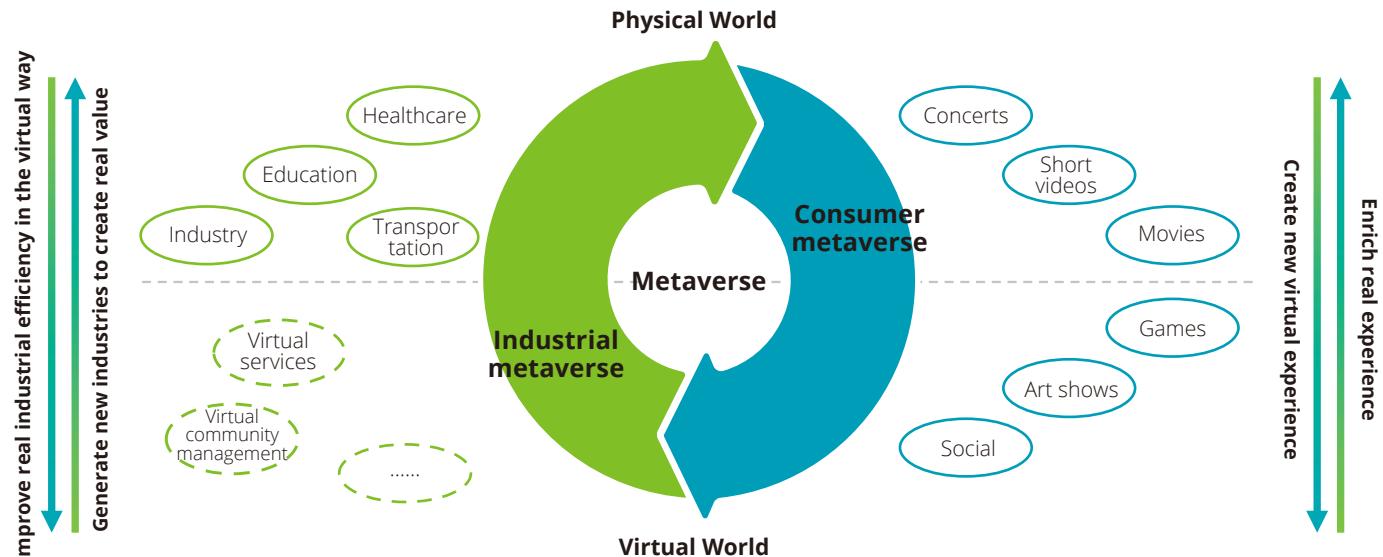
For the consumer metaverse, developing from real to virtual refers to the augmentation of reality through digital virtual experience, so as to enrich the experience of the physical world. For example, in the future, people will be able to see navigation guidance from the screens of their AR glasses as they observe the actual roads. People around the world can attend a meeting in the same virtual office through AR glasses, as seen in the movie Kingsman: The Golden Circle.

Developing from virtual to real is the process of exploring new production and consumption scenarios.
For the industrial meta-universe, developing from the virtual to real means that emerging industries in the virtual world can circulate and be displayed and used in the virtual world, while at the same time also having practical applications in the physical world to influence the physical world and create real economic value. For example, Larva

Figure 2: Ecosystem of the Consumer and Industrial Metaverse

Source: Deloitte Research and analysis

Labs creates "Meebits" and sells them as virtual artworks. The Meebits are 20,000 unique 3D voxel characters, created by a custom generative algorithm, which can be bought and sold on the Ethernet platform. Owners of Meebits are given access to an additional asset pack that include the full 3D model, which can be used to render and animate their Meebits, or the Meebits can be used in animation, movie or other non-virtual scenarios to generate economic value,

thus bringing new value points to the entertainment industry.

For the consumer metaverse, developing from virtual to real means that people's spiritual needs are satisfied in the emerging virtual scenarios through the diverse interactive experiences that bring a sense of reality; in the meantime, people can give full play to their creativity in the virtual world to generate real social and economic value. Virtual idols, for example, are

becoming increasingly popular after several years of development. The Chinese virtual influencer Angie, with vivid skin and facial expressions, has gained nearly 300,000 fans with only 13 videos posted online. Angie's short videos bring a sense of warmth and healing to people, and many fans even confide their troubles to or exchange ideas with her, thus realizing emotional and spiritual interaction.

Multi-system integration is the evolution trend of the metaverse: Due to the diversity and dispersion of industries, Deloitte believes that the metaverse needs to rely on the existing industrial base to develop and integrate from the bottom up, and it is difficult to build a complete system from top to bottom via a unified standard. Therefore, in the early stages of development, various industries are expected to form small decentralized, multi-centered ecosystems of the metaverse; then the small ecosystems will gradually share data and form unified standards, thus achieving integration. In the mature stage of metaverse, we don't know what it will look like, which is still full of all kinds of imaginations.

At Deloitte we see the development of the metaverse through four stages: infancy stage, early stage, mature stage and final stage. Currently, a variety of digital and intelligent concepts have appeared in the industry, which can be regarded as the infancy of metaverse. The next 5-10 years are expected to witness the early development of the metaverse as the relevant technologies mature and the concept of the metaverse strengthens.
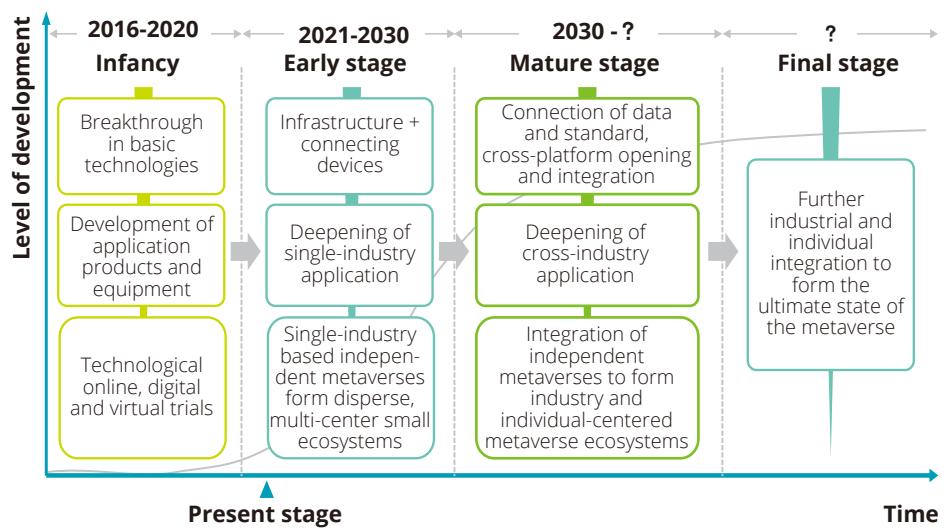
The infancy stage is from 2016 to 2020. Although the concept of metaverse did not appear, different industries were carrying out technological single-point trials for digitalization or virtualisation. This was the embryo of metaverse:

- In the industrial metaverse, applications were mainly building digital, online and simulation

scenarios. For example, Osso VR, a Boston-based doctor training company, has developed software that can create virtual operating rooms to allow doctors to receive more training on complex

operations; RaLC, an assembly line simulation software developed by a Japanese AI company, uses 3D animation as the carrier to build simulation verification models for multiple logistics system elements;

Figure 3: Development Stages of Metaverse

Source: Deloitte Research and analysis

• In the consumer metaverse, applications were mainly to facilitate virtual experiences using 2D forms. For example, in the mobile game "Pokémon GO", jointly developed by Nintendo, The Pokémon Company and Niantic Labs, AR technology is equipped to mobile phones for players to find and capture virtual Pokémon in the physical world; the New York-based health technology company Peloton integrates AR technology with cycling to provide fitness courses on electronic screens, achieving virtual-real integration of 2D imaging and improving users' immersive experience.

The early development stage is from 2021 to 2030. This stage involves further online, digital and virtual applications and technological advancements in different industries, eventually forming a single-scenario based on independent metaverses and small decentralized, single-industry, multi-centered ecosystems of the metaverse. Technological patterns, platform infrastructure and key connecting devices, such as XR devices, will be primarily developed in this stage. Looking at application developments, the focus will be on the applications in hot industries.

• In the industrial metaverse, the focus will be on the application of basic technologies, which are expected to be expanded to entire-industrial chain and whole-industry virtual applications. For example, NVIDIA actively deploys basic technologies such as virtual

3D simulation and rendering, and applies them to industrial design. At present, the virtual collaboration platforms that can be built through Universal Scene Description technology are mainly applied to digital collaboration and real-time simulation scenarios, creating the technological foundation for the future expansion of metaverse in the industrial design field.

• In the consumer metaverse, the virtual experiences of various independent IPs will deepen. Hardware devices connecting the physical and virtual worlds are continually being developed and optimized. Virtual experiences are improving to provide a greater sense of reality, and a virtual social system is gradually being built. For example, in Roblox, players can exchange game currency with real currency to realize actual economic exchange between virtual and physical worlds. It also provides multiple forms of social interaction to allow users to have a better immersive experience and stimulate their innovative thinking via long online social interactions.

The mature stage starts from 2031, during which the independent metaverses of different industries gradually share data and form unified standards, and achieve integration. Deloitte believes that in this stage, there will be cross-platform and cross-industry ecological connection and integration—the small decentralized, multi-center ecosystems will integrate to

gradually form two metaverse ecosystems respectively centering on industries and individuals. Deloitte believes that unified data standards, payment systems and identity authentication are the key to achieving cross-platform development and integration at this stage.

• In the industrial metaverse, the independent metaverses of similar industries are expected to gradually share data and industry standards will trend towards multi-industry interactions and integration. For example, the industrial Internet in different industrial fields might gradually develop unified data standards and combine to form an industrial metaverse; smart communities, smart buildings and smart transportation may gradually develop unified data standards and join together to form a smart city metaverse.

• In the consumer metaverse, the virtual experience of independent IPs will no longer be separate. The multiple scenarios and virtual elements in individuals' virtual lives are connected to build comprehensive virtual life scenarios and content. Thus the virtual assets and information on various platforms are distributed and shared. For example, Marvel heroes, such as Sun Wukong, and virtual concerts by K-pop groups could appear in the same virtual space.

XR is the entrance for exploring the metaverse: XR devices are the key equipment connecting the virtual and real worlds. At the early development stage, the priority is to construct and develop infrastructure and equipment. Currently, we need to develop the key products, i.e. XR devices, and apply their basic functions.

According to Jon Radoff, who proposed seven layers of the metaverse, the realization of the metaverse consists of seven layers of development and implementation. The infrastructure and human interface layers are mainly for deployment of hardware, software and **other infrastructure and equipment.** The decentralization and spatial computing layers are for the deployment of **development tools.** The creator economy, discovery, and experience layers are for the deployment of **application products and operational ecosystems.**

Based on the four development stages of the metaverse, the focus in the early development stage will be put **on infrastructure and equipment** as well as **development tools.** The **infrastructure and equipment,** in particular, constitute the basic technical framework and key equipment for the construction of metaverse ecosystems.

The development level of XR equipment-related technologies is expected to meet the current development needs of the metaverse

According to Gartner's 2021 ICT graphs, the "six core technologies of the metaverse" explained in the Metaverse Token published by China Translation & Publishing House, and the four development stages of the metaverse identified as above, the development level of the relevant XR technological reserve satisfies the application and product needs of the early development stage of the metaverse.
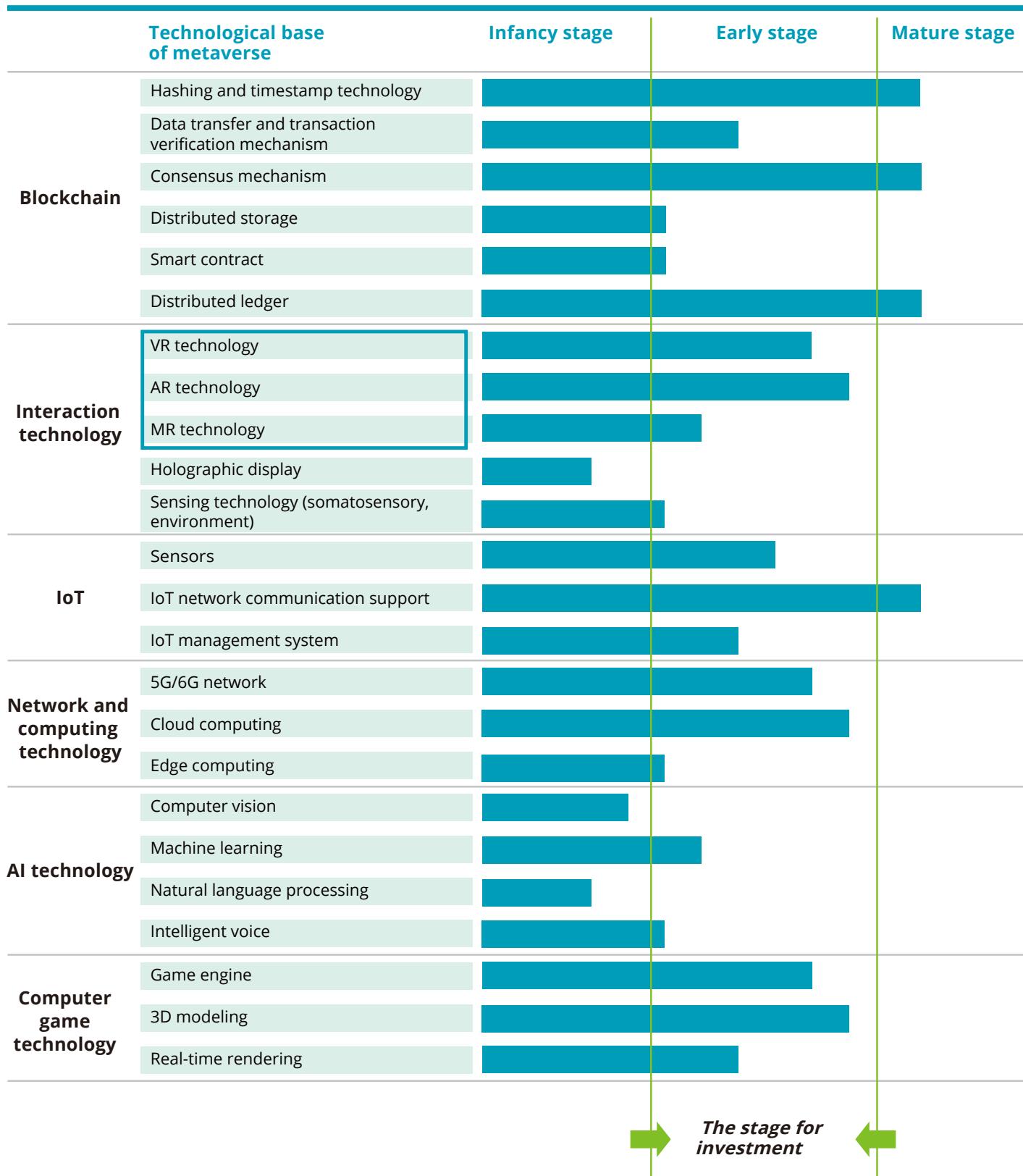
XR devices are the **key connecting devices** of the metaverse ecosystems. They have different characteristics than the mobile Internet, such as three-dimensionality, natural interaction and spatial computing. At present, the metaverse is still confined to two-dimension worlds, with a large gap compared to real three-dimensional immersive experience. XR devices will facilitate the virtual-physical connection necessary for realizing the metaverse, and will be the key to engaging users. This report focuses on the development of the XR equipment industry.

Figure 4: The Seven Layers of the Metaverse

Layer		
EXPERIENCE	Games, Social, Esports, Theater, Shopping	Application Products & Operation Ecosystems
DISCOVERY	AD Networks, Social curation, Ratings, Stores	
CREATOR ECONOMY	Design Tools, Asset Markets, Workflow, Commerce	
SPATIAL COMPUTING	3D Engines, XR, Multitasking, Geospatial Mapping	Development Tools
DECENTRALIZATION	Edge Computing, AI Agents, Microservices, Blockchain	
HUMAN INTERFACE	Wearables, Haptic Gestures	Infrastructure & Equipment
INFRASTRUCTURE	5G, WIFI 6, Cloud, chip technology, GPUs	

Source: Jon Radoff; Deloitte Research and analysis

Figure 5: Development Stage of Various Technologies

Technological base of metaverse	Infancy stage	Early stage	Mature stage
Blockchain			
Hashing and timestamp technology			
Data transfer and transaction verification mechanism			
Consensus mechanism			
Distributed storage			
Smart contract			
Distributed ledger			
Interaction technology			
VR technology			
AR technology			
MR technology			
Holographic display			
Sensing technology (somatosensory, environment)			
IoT			
Sensors			
IoT network communication support			
IoT management system			
Network and computing technology			
5G/6G network			
Cloud computing			
Edge computing			
AI technology			
Computer vision			
Machine learning			
Natural language processing			
Intelligent voice			
Computer game technology			
Game engine			
3D modeling			
Real-time rendering			

The stage for investment

Source: Gartner; Metaverse Token; Deloitte Research and analysis

XR: linking the virtual and the real

XR refers to creating a virtual man-machine interaction environment by combining the real and the virtual through a computer. XR is a general term for VR (Virtual Reality), AR (Augmented Reality), MR (Mixed Reality) and other technologies.

VR and AR are the main components of the XR concept, and both bring virtual world experience. But they vary greatly in terms of the technologies they adopt to achieve a virtual experience: VR simulates a virtual world through equipment and uses computers to generate a simulated environment, which emphasizes real-time interaction of users with the virtual world and creates a closed-loop, immersive virtual world experience; AR uses computer graphics technology and visualization technology to produce virtual objects that do not exist in the real world, and accurately "place" the virtual objects in the real world, putting users in a intertwined real-virtual world.

In general, AR technology lags behind VR. Similar to VR, AR faces the development difficulties in creating a sense of reality, virtual scenario rendering, and the performance of sensing and interaction devices, among other issues. In addition, AR needs to accurately "place" the virtual objects in the real environment, and have display devices that integrate the virtual scenes with the real environment. At present, there are a number of VR HMDs and glasses devices in the market that have been recognized by consumers. However, AR glasses still face many technical obstacles.

At present, VR devices account for nearly half of the market share, AR for about a third, and MR for the rest.

As the development of 5G technology and network empowers more application scenarios, combined with the integration of AI technology with computational vision and the innovative functions of hardware, VR and AR technologies and applications will become more integrated and interoperable>. It is here that the MR and XR concepts emerge. From the perspective of end users, VR and AR both provide and improve the virtual experience of users. This report explores the investment potential and opportunities in the XR market from the perspective of market demand and development.

VR, AR and MR are represented by the general term XR.
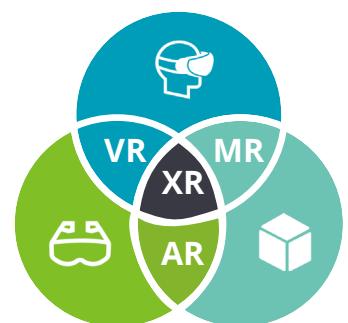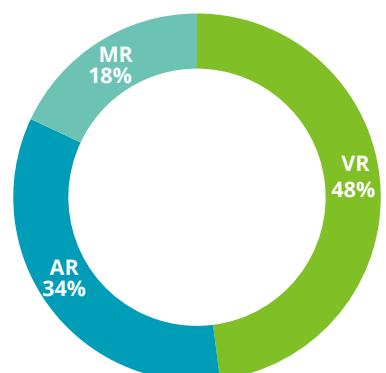
## Figure 7: XR Market Size by Technology Application (2020)

Figure 6: Difference between VR and AR

	VR	AR
Technical principle	Leverage real life data, electronic signals generated through computer technology and various output devices to generate phenomena that people can feel	Virtual image rendering by computers based on the real world—emphasizing interaction with the real world
Terminal device	Head-mounted display (HMD), positioning devices, motion capture devices, interaction devices, etc.	Use cameras or imaging devices to interact with the real world, e.g. AR glasses
Experience	Closed-loop, immersive experience—users interact in real-time with the virtual world	Augmented real experience—users in a real-virtual intertwined world

Source: Deloitte Research and analysis

Imagination of XR applications
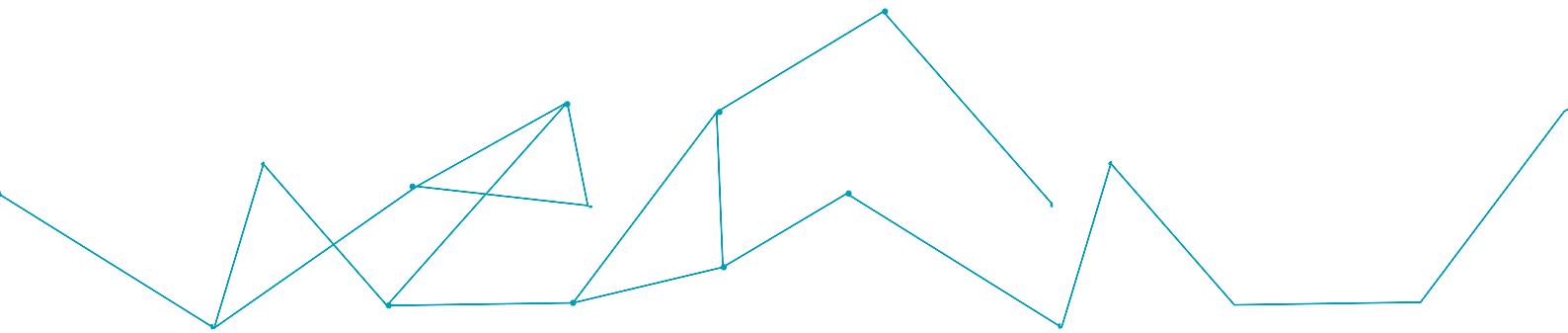
"The full potential of human-oriented computing will only be realized when rather than interacting with the virtual world through flat portals, we live in a world that intertwines virtual and real however we want, and that is what AR and VR are all about. This is the second great wave, and unless it proves to be literally impossible to create good enough virtual experiences, augmented and virtual reality are the future, as surely as personal computers…"

——Inventing the Future by Michael Abrash, Chief Scientist of Oculus

A few decades ago, we could not image that we would carry a computing device with us almost 24 hours, just like we wear clothes, to use it for social interaction, entertainment, work and other activities simply by tapping it or giving voice commands at any time and or any place. We all know this computing tool as the integrator of the mobile Internet era: the smartphone. We can interact with the virtual world anytime anywhere through our smartphones—albeit a 2D world.

Now, we can imagine a future in which we carry an even more powerful computing tool all day. That tool might be nothing like the hardware we see today, but it will bring a new world where the virtual and the real are completely integrated and interchangeable—we can interact and give instructions in a more naturally way, such as by waving our hand, snapping our fingers or simply turning our head, and the information we need to make a decision could appear any direction we look at. Through

EMG and brain-computer interaction, it might know what you are thinking about and intend to do. It might not even need specific instructions, but actively filter the information and help you make a decision through perception of the surroundings and sophisticated AI algorithms. This is the whole new world with new experience that XR will bring.

XR will create a world where the virtual and the real are completely intertwined. It will be a completely human-centered world, where you need not to choose between the real and the digital world, rather, you can freely switch over between the real and the virtual. It will allow you to transcend space and summon objects and devices at will, and will greatly magnify your perception, memory and cognition. It will completely disrupt the way we understand man-machine interactions, achieving completely natural and scenario-based interactions anytime, anywhere.

60 years ago, psychologist J. C. R. Licklider proposed a vision of computers: humans would be able to interact directly with computers to enhance their capabilities. Over the past 60 years, we have enjoyed the Ethernet, Internet, personal computers, and smartphones, realizing free interaction with the virtual world in a 2D mode. Looking into the future, XR will bring a world where the virtual and the real are fully integrated, and where human-centered interaction will push the boundary of human capabilities and create new experience.

Mark Zuckerberg sees XR as the next generation of computing platforms, and has decided to make continuous investment in XR the crux of Facebook's strategy for the next 10 years. XR is called the next generation of computing platforms not only because it can bring about a new world, but also because it is a synthesis of key technologies of the computing era. It not only uses current key technology capabilities such as AI, blockchain and big data, but also has higher requirements for

computing power, algorithms and data. In addition, it requires higher precision and higher experience standards for optical, chip, sensing, perception and interaction technology, operating system, and other hardware and software capabilities. XR devices, as the hardware used in daily life, have high requirements for stability, accuracy, real-time performance, user friendliness, and lower cost of each technical capability.

An important step of VR is importing the real world into the virtual world. VR HMDs can be installed with sensors to recreate real-world models in real time, and then embellish, modify, augment and share the models. Virtual images can be intertwined with the real world to augment the real world, while avatars reflecting the appearance, movement and unique characteristics of real people can share this space. In contrast, AR integrates the virtual into the real world to create unique experiences. For instance, AR devices can clearly display the surrounding shopping centers and restaurants, and provide real-time navigation. In a supermarket, the AR devices will show you the detailed introductions, production process, ingredients, source, and even uses of any item you pick up, greatly enhancing the efficiency of information acquisition. With AR devices, objects in real environment will no longer need to be recognizable: building walls could be blank, roads need no signs, markings or traffic lights, and goods need no labels, advertising or identifiers—the world will be reshaped by AR, and everything will be vivid, active, and updated in real time.

AR and VR together form a broad platform that affects every aspect of life in the form of XR. There is no fixed concept yet as to what the XR's final user interfaces will be like, but there are various discussions about future interaction with XR. In VR scenarios, user interaction contributes to users' immersion and experience, while in AR scenarios, users can interact with the real world anytime, anywhere completely hands free. Gesture control, eye movement tracking and immersive sound fields (which are still in the course of research) have their respective advantages, but none of them can meet all the requirements. The main challenge is to develop a solution that allows seamless switching between various scenarios, integrates multiple modes, and enables users to switch freely. Neural perception and brain-computer interaction may be the ultimate solution in XR scenarios. Although the technology is not mature, what is happening proves that we are approaching what is expected.
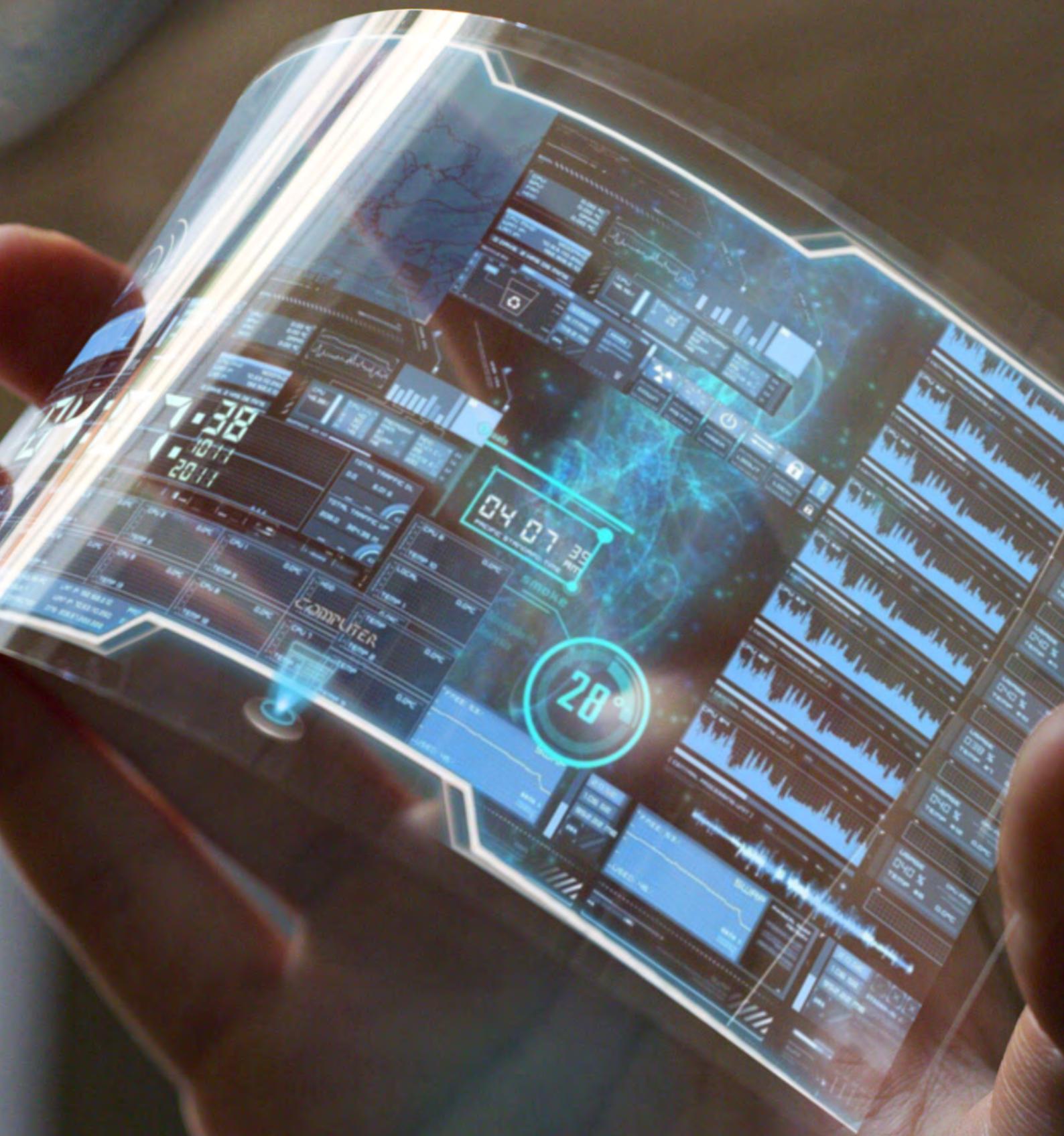
Imagination of application—XR devices will build a whole new world

Work scenarios: With a HMD, you no longer need a physical office, because all work can be done in a virtual environment. In the virtual world, we have offices that feel realistic and high-end, with diversified display equipment, and a highly customized work environment.
All meetings can be held online, doing away with time-consuming commuting—you only need to send a meeting invitation, then enjoy an immersive "face-to-face" experience of meeting with customers and colleagues.

Education scenarios: We will learn in a new way. Online education resources will allow all students to enjoy the best resources, and teaching styles will be diversified in the virtual world. For example, students can closely observe the chemical reactions in chemical experiments through AR glasses, talk "face-to-face" with native speakers to learn a foreign language, and experience through digital reconstruction what is narrated by the text of the writing. Education can become more engaging, efficient, interactive and personalized.

Life scenarios: VR will change how we use our spare time. The social environment built in the virtual world will allow people to hold parties with friends anytime and anywhere, and have close conversations, play games and watch movies with relatives far away. The future depicted in the 2018 hit movie Ready Player One is becoming a reality. In the future, XR will integrate all information, social, news and entertainment resources, doing away with a need for TV sets, game consoles, desktop computers, e-books and other equipment. In the world built by XR, we can easily access anything we need, greatly reducing the costs on equipment purchases and replacement—we only need to pay for software to get a virtual big-screen TV, rather than an expensive physical machine installed in the living room.

Health care scenarios: XR will be applied more extensively in the medical field: future surgeries will rely more heavily on AR equipment and technology. Virtual images and real surgery scenarios will be combined to provide the best solution and operation support for real-time diagnosis and treatment, significantly reducing the diagnosis time and improving the treatment outcomes. In the future, AR holograms could play a leading role in medical training, which will greatly improve communication efficiency between doctors and effectively replicate medical resources.

Future is here

XR: from incubation to rapid development
While the future is promising, XR has gone through ups and downs during the development process. The development of XR can be divided into four stages: technological development, capital rush, trough, and recovery.

Technological development
The concept of virtual reality was born in the last century. From 1920s to the first decade of the 21st century, we have made continuous attempts to develop and apply VR technology, but with limited success due to immature technology. The emergence of Oculus Rift in 2012 enabled the public to experience VR scenarios for the first time, and the release of Google Glass in the same year fueled a massive wave in the AR field. These two landmark events drove the industry into the next stage of development.
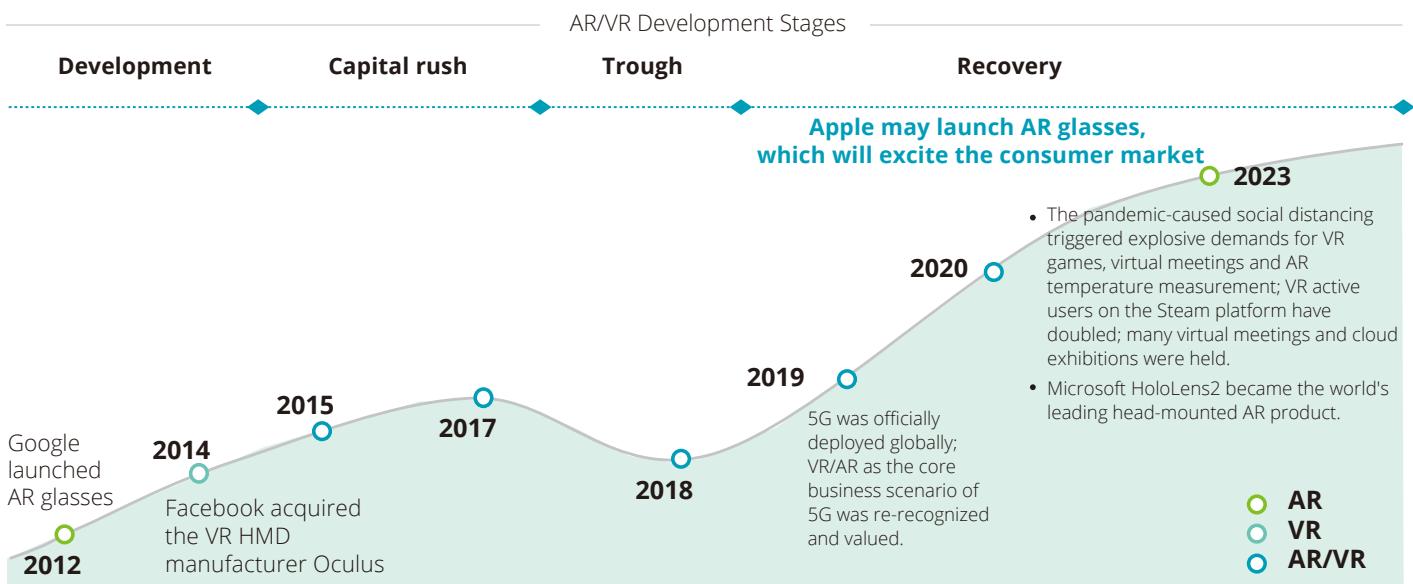
Capital rush
Facebook's $3 billion Oculus acquisition in 2014 aroused heated discussions in the industry and attracted the attention of many companies. Smart device manufacturers, such as Facebook, Google, Sony, HTC and Samsung, successively increased their XR investment. XR was booming as a new form of entertainment devices in the consumer electronics market. According to IDC, global XR shipments climbed 383% year-on-year to 9.04 million units in 2016, and VR shipments in China reached 204,000 units in Q3 2016, up 367.9% from previous quarter. Global capital quickly rushed to the XR market. In 2015, there were 152 XR financing cases globally, and 64 XR-related financing activities in the Chinese mainland.

Figure 8: XR Development Stages

Source: Deloitte Research and analysis

Trough

At the beginning of 2017, there were signs of overheated investment in the industry. From 2016 to 2017 alone, more than 3,000 start-up teams emerged in China, and the number of VR-related applications increased tenfold. However, the technology and ecosystem at that time could not accommodate the rapid growth of the market. Due to the limitations in hardware, software and network environment, XR devices launched in the market underperformed, due to poor user experiences. In 2018, global shipments of VR HMDs declined to 3.5 million units, from 3.75 million units the prior year, while AR glasses shipments dropped from 450,000 units to 260,000 units. The XR market suffered a downturn.

Recovery

In the following two years, a large number of players withdrew from the XR market, and the remaining manufacturers worked on hardware iteration and content development, gradually overcoming weaknesses. The industry has shown signs of recovery. Since 2019, the deployment of 5G high-speed network has effectively reduced dizziness issues caused by latency. Image quality has improved by using Fresnel lenses, Fast LCDs, and VR-dedicated chips. Software developers have developed user-centered XR applications. XR product experience has continually advanced. In addition, the spread of COVID-19 since the beginning of 2020 prolonged the amount of time consumers' spend at home, generating greater demand for entertainment and telecommuting. The rise of the metaverse concept in 2021 again promoted the XR industry to the forefront. We expect that the XR industry will see rapid development in the next 5 years.
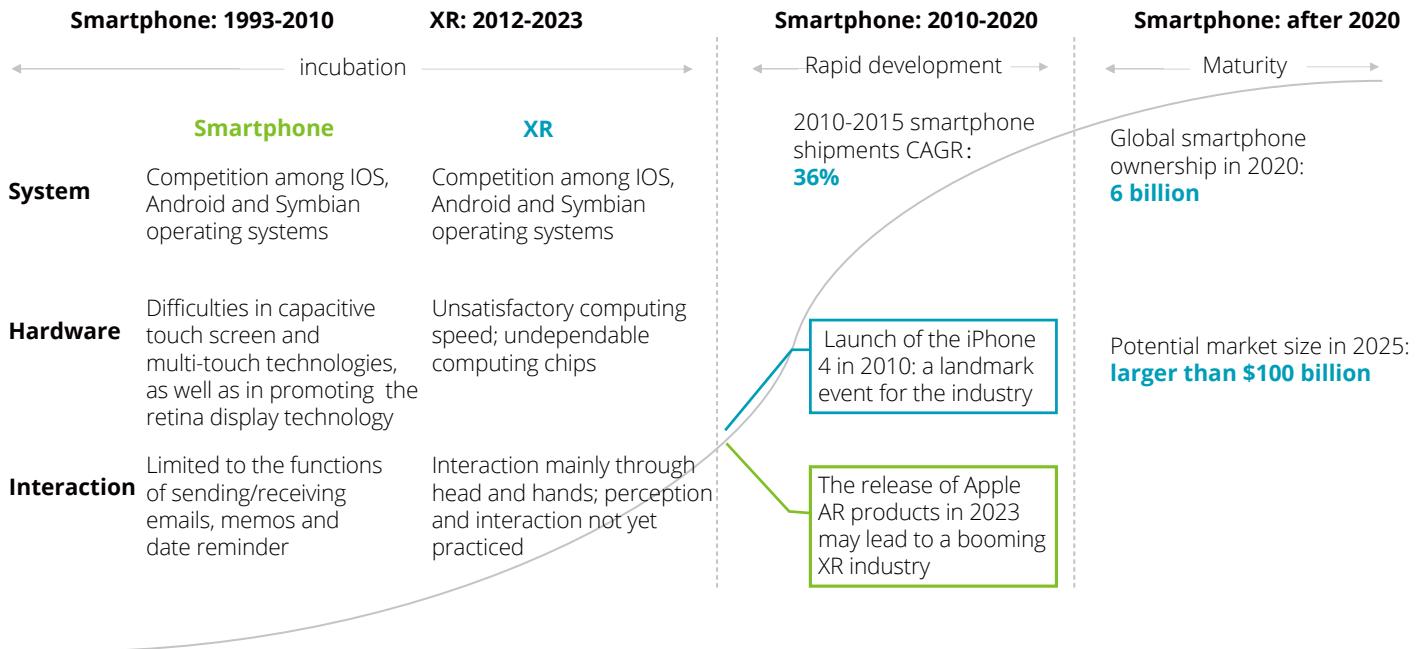
Moreover, it is widely speculated that Apple will launch AR glasses around 2023, which may take the consumer market by storm in the XR era, just like the smartphone in the era of mobile Internet.

XR is entering a rapid development stage similar to the smartphone

The development courses of XR and smartphone bear many similarities. The rudiments of the smartphone first appeared in 1993. In 2007, Apple released the first generation iPhone, providing a unified standard for smartphones, and then the industry experienced a period of technological breakthroughs. In 2010, Apple launched the iPhone 4, marking the inflection point of the smartphone industry into the rapid development stage. Smartphone shipments saw explosive growth, and the market in China was gradually dominated by giants such as Apple, Huawei, Xiaomi, Oppo and Vivo. At present, the smartphone industry is at a mature and stable development stage, and smartphone manufacturers are actively exploring new hardware.

The current development of XR as carriers of next generation hardware is similar to when smartphones entered the inflection point of high-speed development. As the metaverse concept goes viral, relevant buzzy applications, such as the game Half-Life: Alyx, and great hardware products have been launched. The market is approaching a turning point of rapid development. This development course can be analysed by looking at operating systems, hardware and interaction mode.

Figure 9: Development Course of Smartphones and XR

	Smartphone: 1993-2010	**XR: 2012-2023**	**Smartphone: 2010-2020**	**Smartphone: after 2020**
	incubation		Rapid development	Maturity
	Smartphone	**XR**	2010-2015 smartphone shipments CAGR: **36%**	Global smartphone ownership in 2020: **6 billion**
System	Competition among IOS, Android and Symbian operating systems	Competition among IOS, Android and Symbian operating systems		
Hardware	Difficulties in capacitive touch screen and multi-touch technologies, as well as in promoting the retina display technology	Unsatisfactory computing speed; undependable computing chips	Launch of the iPhone 4 in 2010: a landmark event for the industry	Potential market size in 2025: **larger than $100 billion**
Interaction	Limited to the functions of sending/receiving emails, memos and date reminder	Interaction mainly through head and hands; perception and interaction not yet practiced	The release of Apple AR products in 2023 may lead to a booming XR industry	

Source: public information; Deloitte Research and analysis

Operating systems: In the early stage of smartphones various smartphone operating systems were competing in the market. During this period, iOS and Android did not have a duopoly in the market, with Symbian, Microsoft Widows Mobile, Nokia and Intel's Meego, and Blackberry BB OS vying for market share. Nokia' s Symbian accounted for 63.5% of the global smartphone operating system market share in 2007. But then Google's Android, an open source system, attracted many mobile phone brands and seized a large portion of market share thanks to the rise of Samsung smartphones. Apple, taking the dominant position in the smartphone market, released the iOS in 2007 and has occupied increasingly more market share since the launch of the first generation iPhone. In the XR market, Android still dominates, and the remaining market share is occupied by Microsoft WMR, Sony PS and a few other platforms. As the hardware market is not yet well developed, who will be the mainstream operating system platform is not yet determined.

Hardware: Initially smartphone manufacturers also faced many technological difficulties. First, big screens came with difficulties in capacitive touch and multi-touch technologies, and it was hard to promote the retina display technology. As a result, smartphones initially had a small screen, low resolution (800*400px), and limited storage capacity. In addition, high-performance chips were not applied to small devices. Secondly, 3G penetration rate was low in China before 2010; there were no extensive mobile communication base stations or end-user equipment, and the data transmission rate of 3G network could only support basic pictures, voice and Internet access, rather than high-quality videos and images. Although the XR industry has seen technological breakthroughs, it still lags behind the standard of a good immersive experience. Taking VR as an example, it still needs the PC, smartphone or all-in-one VR headset as a carrier. However, the current computing speed is still inadequate, a completely virtual environment that feels real enough to trick the brain cannot yet be created, and the computing chips are not mature. In addition, the limitations in mobile devices' storage, transmission speed, battery technology, and heat dissipation have prevented VR from being more widely applied.

Interaction mode: Today, smartphones are used in every aspect of life, but in the early days, they were limited by hardware, applications, infrastructure and other factors. As a result they only had basic interactive functions. Initially smartphones only offered traditional business functions, such as sending/receiving emails, memos and date reminders, as well as simple entertainment functions. Due to their siloed systems and the difficulty of interacting with third-party scenarios, smartphones could then only be regarded as the advanced version of traditional mobile phones, and they were far from disruptive. XR is now facing a similar situation. Take VR as an example, at present, the mainstream solution to interaction is moving one's head (inside-out six degrees of freedom [6DOF]) and gamepads (6DOF). But bulky HMDs and simple gamepad operation cannot bring users a truly "immersive" experience. Many companies are concentrating on research in cutting-edge technologies, such as spatial scanning and modelling, spatial positioning and tracking, full body motion capture, eye movement tracking, hand tracking and facial tracking, but there is no fully mature solution yet.

During the development course of smartphones, the release of iPhone 4 was an epoch-making event. It triggered trends in large, multi-touch screens and app stores, enriching the app ecosystem and promoting the next iteration of human-machine interaction. The iPhone 4 had a front camera and a 5-megapixel camera. Since its launch, smartphones' camera functions have becomes one of the most important hardware considerations for consumers. The use of the high-resolution Retina screen on the iPhone 4 triggered consumers' demand for a new mobile phone with "large screen + multi-touch". The rise of app stores expanded the ecological boundaries of mobile phones. Many content providers rushed to add their apps; the various applications provided rich software functions, and mobile phones changed from a means of communication to an omnipotent tool for diverse scenarios. With GPS, gyroscope, compass, NFC and other sensors, mobile phones can provide various information about people' s food, clothing, shelter, transportation, health care, exercise, transactions, just to name a few.

The success of the iPhone 4 led smartphones into a period of explosive growth. Annual shipments of smartphones saw many new highs after 2010, with over 1.5 billion units in 2017. Apple also started early deployment in XR hardware, software, and content ecosystems, and is expanding the XR ecosystem using the mobile phone ecosystem as a basis. Apple's AR HMD, which is speculated to be launched in 2023, may be a disruptive enough product to replace the iPhone. If this holds true, XR is expected to enter a similar explosive growth period as the smartphone.

Tech giants are expanding deployment in the XR industry as they aim for the next generation of computing platforms

In August 2021, ByteDance made its first foray into VR through the acquisition of the start-up Pico. Before that ByteDance had been investing in VR/AR research for a long time, developing many technological advances in interaction systems and gaining a greater understanding of the environment. The deal sparked much discussion, demonstrating ByteDance determination to expand businesses in the XR field and encouraging more tech companies to make strategic moves into the XR industry. Apple, Facebook (Meta), Microsoft, Google, Huawei, Tencent, and ByteDance are all building XR ecosystems and aiming strategically to becomes key players in the "next generation computing platform." Looking at the XR environment, different tech giants have entered the market via varied development directions and paths, based on their comparative advantages, resulting in differentiated XR ecosystems.

Apple: aiming build complete XR ecosystem based on its mobile phone ecosystem; its AR hardware may be a sensation in the consumer market

Apple has launched a number of disruptive PC and smartphone products in its history. As a result, if, as expected, Apple launches AR glasses around 2023, they are expected to disrupt and boost the XR industry. In fact, Apple has already deployed an XR ecosystem and is gradually promoting AR experiences and services to consumers through its mobile phones.

In 2010, Apple purchased a number of facial recognition, indoor positioning, motion capture, MicroLED display and other relevant technologies. Since 2015, Apple has comprehensively accelerated technological deployment in the XR field, and acquired a large number of AR and AI software and hardware companies. Recently, it started to acquire content companies, too.
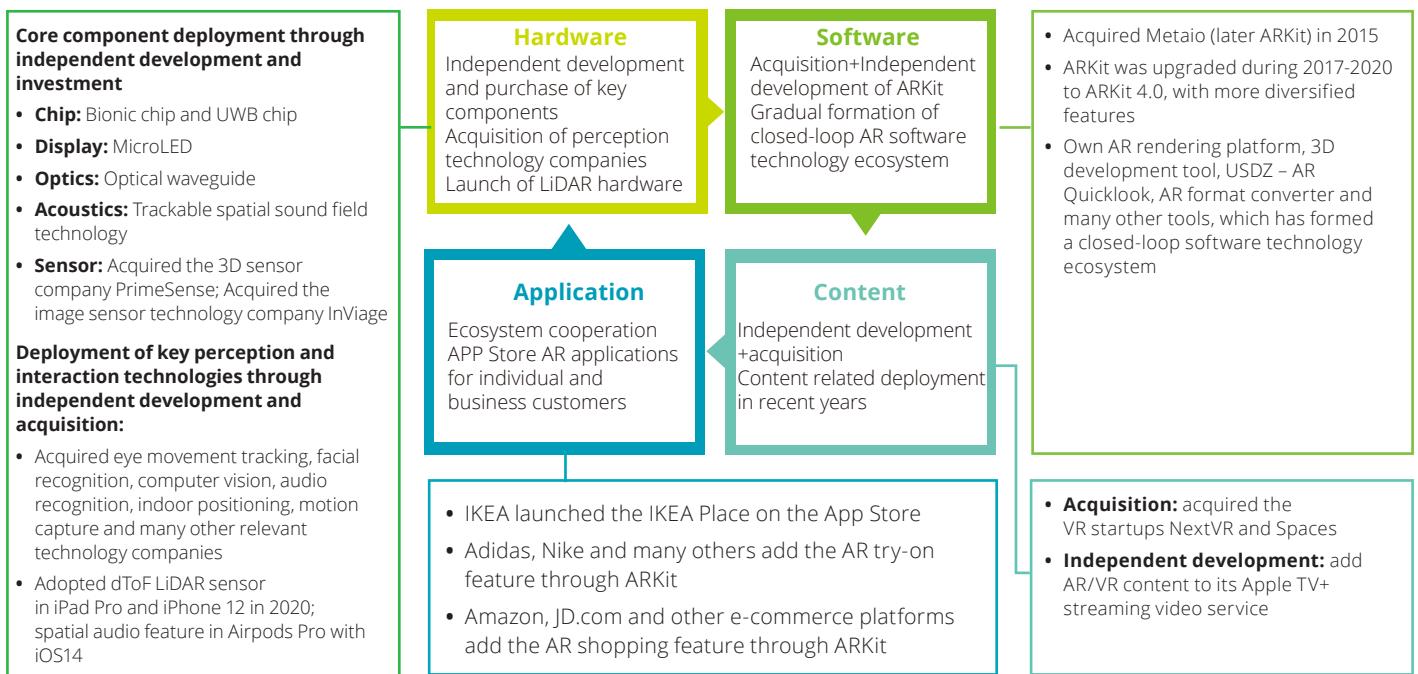
Through independent development and acquisition, Apple has built a moat of core technology patents, which is an important guarantee for Apple to enter the XR industry. In January 2020, Apple obtained 59 patents for AR and 3D reconstruction technologies. Apple has so far over 330 key XR patents.

In addition, Apple is also expanding its AR ecosystem partners. It actively cooperates with various partners to develop new tools and technologies to create better application experience for users while enhancing relationships with the developers to build a closed-loop ecosystem.

So far, Apple boasts an operating system with over 1 billion active users worldwide, the industry-leading AR Kit software platform and a comprehensive hardware and software ecosystem. This puts Apple in a good place to launch another disruptive product that stimulates the AR/VR consumer market.

Figure 10: Apple's Deployment in the XR field

Core component deployment through independent development and investment
- **Chip:** Bionic chip and UWB chip
- **Display:** MicroLED
- **Optics:** Optical waveguide
- **Acoustics:** Trackable spatial sound field technology
- **Sensor:** Acquired the 3D sensor company PrimeSense; Acquired the image sensor technology company InViage

Deployment of key perception and interaction technologies through independent development and acquisition:
- Acquired eye movement tracking, facial recognition, computer vision, audio recognition, indoor positioning, motion capture and many other relevant technology companies
- Adopted dToF LiDAR sensor in iPad Pro and iPhone 12 in 2020; spatial audio feature in Airpods Pro with iOS14

Hardware
Independent development and purchase of key components
Acquisition of perception technology companies
Launch of LiDAR hardware

Software
Acquisition+Independent development of ARKit
Gradual formation of closed-loop AR software technology ecosystem

- Acquired Metaio (later ARKit) in 2015
- ARKit was upgraded during 2017-2020 to ARKit 4.0, with more diversified features
- Own AR rendering platform, 3D development tool, USDZ – AR Quicklook, AR format converter and many other tools, which has formed a closed-loop software technology ecosystem

Application
Ecosystem cooperation
APP Store AR applications for individual and business customers

Content
Independent development +acquisition
Content related deployment in recent years

- IKEA launched the IKEA Place on the App Store
- Adidas, Nike and many others add the AR try-on feature through ARKit
- Amazon, JD.com and other e-commerce platforms add the AR shopping feature through ARKit

- **Acquisition:** acquired the VR startups NextVR and Spaces
- **Independent development:** add AR/VR content to its Apple TV+ streaming video service

Source: public information; Deloitte Research and analysis

Facebook (Meta): An important evangelist for the XR industry; retaining the social platform throne in the XR era

Starting from social media, Facebook is an important evangelist in the XR field—Facebook believes that XR is the "next generation computing platform", and XR represents the "second great wave of human-oriented computing". Since its acquisition of Oculus in 2014, Facebook has been vigorously expanding its XR ecosystem to cover hardware, software, content, and applications. Today, Oculus VR headsets have become the best-selling headsets on the market, laying a solid foundation for Facebook's future deployment in the XR field. In addition, five years after the Oculus acquisition, Facebook unveiled its VR social platform Facebook Horizon at the Oculus Connect 6 conference in 2019, and officially launched it in 2020—a major step into the metaverse field. In the Horizon, users can create characters, play with friends, and build unique content, creating a huge imaginary space for Facebook to become the next generation social platform.

Chinese tech companies: Build differentiated XR application ecosystems by leveraging their individual advantages

Huawei: XR, as a cross-domain and highly integrated technology application scenario, is a major technology in Huawei's strategic plans. The first VR glasses "HUAWEI VR"

were released in 2016, and HUAWEI VR2, a VR headset supporting mobile phones, computers and Cloud VR, was launched in 2017. In 2020, Huawei unveiled the VR Glass 6DOF Game Set. In addition, HiSilicon released the XR chip that supports 8K decoding and packs a high-performing GPU and NPU, and the AR glasses Rokid Vision. In terms of software, Huawei released the universal Huawei AR Engine at the Huawei Developer Conference 2018, and launched the new AR content development tool Reality Studio. Looking at ecosystem construction, Huawei held global 5G+AR summit online and offline with a view to jointly promote the development of 5G+AR through cooperating with global operators and partners and leveraging third-party application ecosystems.

Tencent: Tencent's 2020 publication World Values Life puts forward the concept of the "Complete Reality of Internet (CRI)". Tencent strives to support an underlying platform for developers and connect hardware, software, content and other key links. In February 2020, Tencent participated in the $150 million series G funding of Roblox, and became the exclusive agent for Roblox's product release in China. In April 2021, Epic, a game company with 48.4% of its shares held by Tencent, obtained a new round of $1 billion in funding for metaverse development. In June, a Tencent subsidiary planned to invest £35 million into Ultraleap, a British

XR haptic simulation technology company. All these moves by Tencent indicate that the era of mobile Internet will end, and the next generation Internet will be a virtual world closely linked to the "metaverse".

In addition, Alibaba and Baidu are implementing plans for building XR ecosystems. At present, Alibaba focuses more on future XR shopping. From its "Buy+" plan announced in 2020, to the "Maker" plan, its investment in Magic Leap, and the upcoming VR payment, Alibaba has set up a number of early application scenarios for XR. Baidu has restructured its VR browser, first launched in 2018, under the comprehensive "Baidu VR" brand, with additional technological open platforms, VR advertising platforms, and VR industry solutions, expanding from a single application to an eco-base gathering together Baidu's various VR projects.

Moreover, many hardware manufacturers are strengthening their efforts in the hardware development and content space. HTC launched the VR content store Viveport, the world's first subscription-based VR app store service, several years ago. This disrupted the VR content platform business model and has since gradually incorporated more types of high-quality content to meet the needs of end consumers. HTC announced its new VIVE Business platform in May 2021, providing

enterprises with hardware, software and integrated service solutions, facilitating innovative VR business models. Based on its industrial chain advantages, Xiaomi has launched cost-effective VR all-in-one equipment. Combined with its built-in app store ecosystem and AI system, XR is seen as an important link in Xiaomi's eco-chain. Xiaomi, Oppo and Vivo all have invested heavily into R&D of VR chips. These brands have all made remarkable achievements in the smartphone field; it is expected that further positive developments will occur in the XR era, where domestic Chinese brands will grow, strengthened by competition.

The XR industry ecosystem is getting richer

Continuous breakthroughs in technology will help improve the hardware experience and ecosystem

As the integrator of many cutting-edge technologies, the current industry development of XR is limited and is hampered by technological limitations. The XR industry includes five key technologies: near-eye display technology, perceptual interaction technology, network transmission technology, rendering and computing technology, and cloud content production and distribution. Each type of technology is the integration of multiple technologies or has multiple technology paths, which need to meet the demand of various application scenarios, especially B2C consumer experience demand.

Figure 11: Five Key Technologies of XR

	Key technology	Key subdivision technology and maturity		
			Mature / Developing / Starting	
End (terminal)	Near-eye display technology	Free form surface, new transflective, ultrathin VR, OLEDos, LCOS, Rapid response liquid crystal	Optical waveguide, Micro LED, LBS laser display	Holographic display
End (terminal)	Perceptual interaction technology	Inside-Out, Outside-In	Virtual movement, immersive audio, gesture tracking, odor simulation, tactile feedback, speech recognition, eye tracking, 3D reconstruction, environment understanding, cloud AR	Electromyographic sensing Brain-computer interface
Channel (5G)	Network transmission technology	Access network, bearer network, pre-processing, data center, monitoring and maintenance		
Cloud (application)	Rendering and computing technology	Multi-resolution rendering, asynchronous timewarp, asynchronous spacewarp, distortion compensation rendering, MultiView	Deep learning rendering, fixation point optics, foveated rendering	Hybrid cloud rendering, real-time path tracking, light field rendering
Cloud (application)	Cloud content production and distribution	Normalized VR live streaming	Support technology, avatar (upper body), personalized video, 6DOF videos	Full body avatar

Source: public information; Deloitte Research and analysis

The five key technologies of XR can be grouped into cloud, channel and end architecture. The "end" mainly includes near-eye display technology and perceptual interaction technology. The optimization of near-eye displays and perceptual interaction technologies for end-user hardware can effectively solve major experience pain points, such as the low image definition, limited visual field of view, and a sense of dizziness. Together they can bring a better end-user immersion experience.

The development of near-eye display technology is mainly being driven by improvements in optical systems and display devices. In terms of optical systems, optical waveguide is viewed as a key technological solution. Although currently mass production faces certain difficulties, numerous domestic Chinese and foreign companies are presently engaged in research and development, and the technology is expected to mature in 2-3 years. Considering display screens, Micro LED technology can help overcome the disadvantages of low brightness optical waveguide displays. The technology is currently on the eve of a breakthrough in mass production. Together MicroLED + optical waveguide are viewed as a highly promising combination.

The current major focuses of near-eye display technology includes optical systems that maximize the field of view of user devices, and display screens with improved resolution and refresh rate and reduced power consumption. Optical waveguide has optimal performance, but faces difficulty economizing mass production. What's more, the current manufacturing costs of MicroLED is relatively high. Upstream semiconductor manufacturers and the downstream equipment manufacturers need to further cooperate in the future to utilize upstream and downstream supply chains to enhance R&D efficiency and drive down costs.

XR has been called the next-gen computing platform, improving dimensionality and perception compared to the current computing environment. To facilitate this XR devices must have integration capabilities in spatial scanning modeling, spatial positioning tracking, whole body motion capture, eye tracking, hand tracking, facial tracking and other cutting-edge technologies. Optimization of the perceptual interaction system can effectively relieve "dizziness" and alleviate vergence-accommodation and multisensory conflict. Eye tracking and related derivative technologies are the current development hotspots.

Table 1: Types and Development Stages of Perceptual Interaction Technologies

Perceptual interaction technology	Development stages
Tracking and positioning	Manufacturers are actively investing in the basic capabilities of perceptual interaction; the technology is becoming more and more mature
Immersive audio	Sound positioning, reverberation, synaesthesia, etc. have become the development focus, areas in which manufacturers such as Facebook, Microsoft, Nvidia, Dolby, Google, and Qualcomm are actively investing
Gesture tracking	The technology is preliminarily mature, and will become the new mode of ARVR input interaction
Eye tracking	Eye tracking is the new standard configuration for AR/VR devices. The grouping of eye tracking + multi-focus display + foveated rendering is expected to become a key technical combination to enhancing virtual reality immersion
Environment understanding and 3D reconstruction	This area will become one of the core technologies in the field of ARVR perceptual interaction
Electromyographic sensing EMG	In a R&D stage; Facebook is developing EMG to accelerate the combination of wristband neural interfaces and ARVR
Brain-computer interface	Facebook, Valve, and Neuralink have all made moves into this space. It will play a key part in the long-term future of interaction

Perceptual interaction emphasizes technical collaboration with key areas such as near-eye displays, rendering computing, content production and network transmission. It involves the integration of sophisticated technical capabilities, such as optical display, sensing, image recognition and algorithms. Consequently, there are high technological barriers to thriving in this area. Apple has developed a comprehensive foundation in perceptual interaction technology through self-research and acquisition, including eye tracking technology, facial recognition, gesture interaction, motion capture, etc.
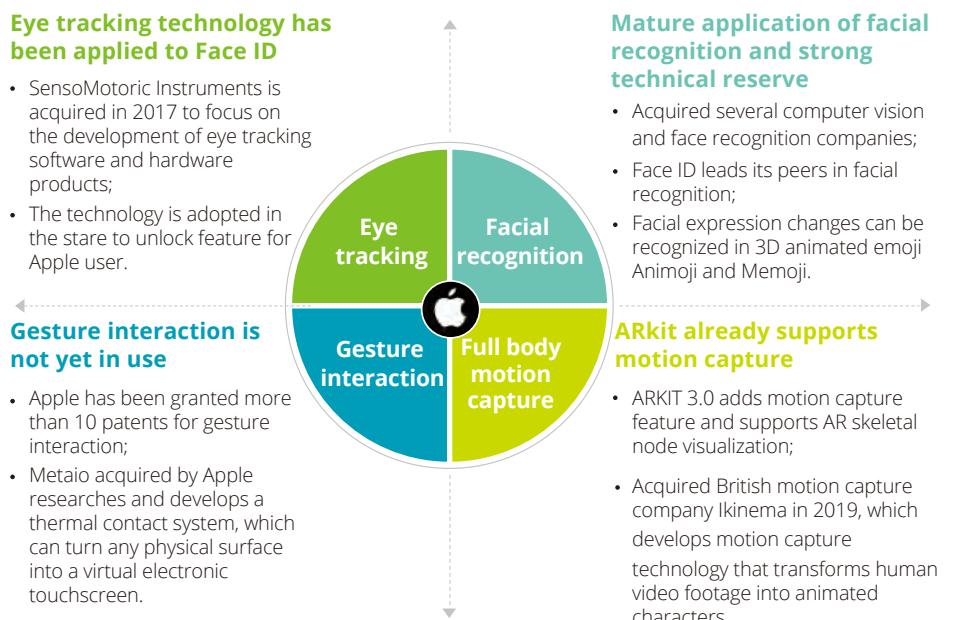
Among the perceptual interaction technologies, solutions to the vergence-accommodation conflict are still immature and will be the focus of future development. The combination of eye tracking + multi-focus display + foveated rendering is expected to become a key technical combination to enhance the virtual reality immersion.

The "channel" mainly refers to the network transmission technology, which empowers cloud edge computing and processing of content and applications that can be realized with the high speed, low latency and large bandwidth of a 5G network. 5G network features combined with edge computing, AI and other technologies will greatly promote the implementation of AR/VR applications.

The "cloud" mainly includes rendering computing and production and distribution of cloud content.

- With 5G technology the cloud can focus on rendering and processing massive amounts of data in real-time. This will allow for lighter, more comfortable end-user hardware, intensive processing tasks will not need to be performed locally in the device. Cloud technology can also improve the quality and efficiency of rendering using AI technology.

- Content development is limited by the penetration of downstream applications and end-user devices, rather than the maturity

Figure 12: Example: Apple's Technology Layout in the Field of Perceptual Interaction

Eye tracking technology has been applied to Face ID

- SensoMotoric Instruments is acquired in 2017 to focus on the development of eye tracking software and hardware products;
- The technology is adopted in the stare to unlock feature for Apple user.

Mature application of facial recognition and strong technical reserve

- Acquired several computer vision and face recognition companies;
- Face ID leads its peers in facial recognition;
- Facial expression changes can be recognized in 3D animated emoji Animoji and Memoji.

Gesture interaction is not yet in use

- Apple has been granted more than 10 patents for gesture interaction;
- Metaio acquired by Apple researches and develops a thermal contact system, which can turn any physical surface into a virtual electronic touchscreen.

ARkit already supports motion capture

- ARKIT 3.0 adds motion capture feature and supports AR skeletal node visualization;
- Acquired British motion capture company Ikinema in 2019, which develops motion capture technology that transforms human video footage into animated characters.

Source: Public market information; Deloitte Research and analysis

of the technology. As near-eye and perceptual interaction technologies continue to mature and hardware shipments increase, the content ecosystem is expected to develop rapidly. Cloud content production and distribution will help further promote the development and prosperity of the content ecosystem.

Downstream application scenarios are increasing

Unlike 5 years ago when VR first emerged, XR now has a wide range of downstream applications that continue to penetrate multiple scenarios. 2020 XR downstream applications with the most expenses are at the B2C consumer level, accounting for more than half global XR downstream application expenses, including VR/AR games, film and television, entertainment, education, etc. B2B level applications are mainly for industrial manufacturing, medical and retail.
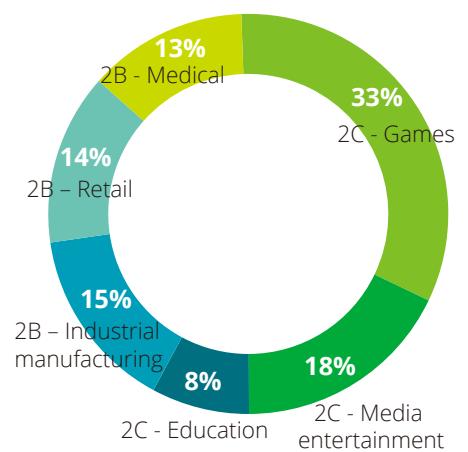
There is a huge space for imagination in the B2C market. Facebook's investments in the XR field and the idea of creating a virtual world social ecosystem has triggered the industry's imagination when it comes to XR's B2C application. In addition, the high level of immersion, privacy and customizable personal experiences possible in XR make it naturally suitable for B2C applications, such as games, social networking and video entertainment. The concept of the "metaverse" has successfully penetrated into public consciousness, and the video entertainment field

has successfully launched a number of applications. XR enterprises in the industry are providing customized recommendations based on the latest games and films, stimulating user purchases and user stickiness, and creating viral content that directs users to the right portal. In the near future we will see livestreaming, shopping, travel and other consumer scenarios.

On the other hand, B2B users are concerned about how to achieve cost reduction and efficiency increase through XR, and are seeking
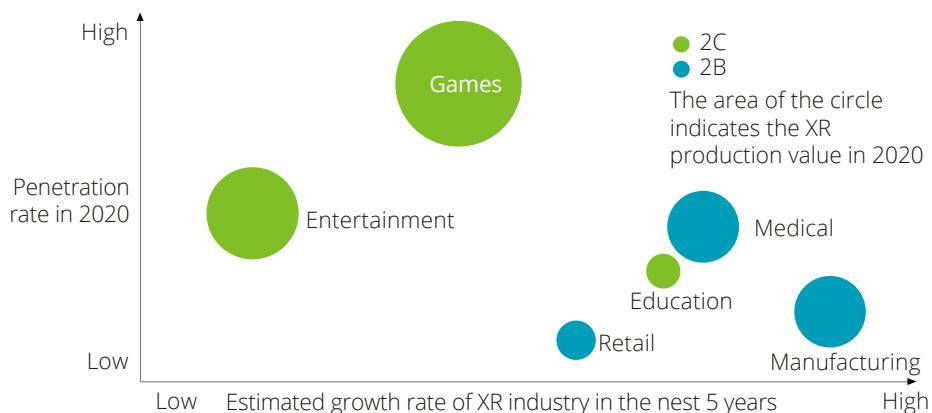
customized and specialized solutions. As a result B2B application scenarios are scattered and widely different. According to market penetration rates, future XR industry growth rates and existing XR production value, XR has considerable development potential in the medical, industrial manufacturing and retail industries, in scenarios such as remote training, implementation guidance, process management and knowledge accumulation. XR can be an important productivity tool and will continue to penetration into more scenarios.

According to a 2020 Capgemini study on enterprise-level XR applications, 40% of total 709 business user respondents said their companies were actively engaged in activities through XR, with 57% responded that XR applications have improved business efficiency and 53% reported it has improved business security. According to Microsoft Hololens data, B2B applications of HoloLens can result in a 30% improvement in assembly time consumption, 50% store space spared, 80% design verification time saved, 85% overall training time saved, 90% higher accuracy in service repair, and 97% information delivery time saved; the vast majority of Fortune 500 companies have now purchased Hololens AR products.

Figure 13: Expense Share of Global XR Downstream Application Industry (2020)
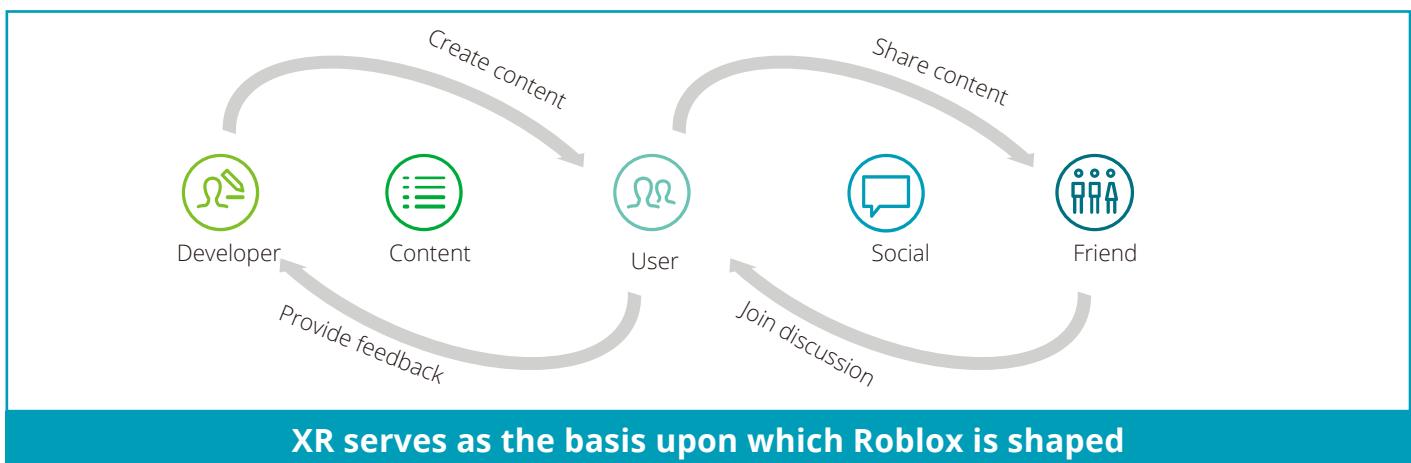
Source: Motor Intelligence; Deloitte Research and analysis

Figure 14: Overview of Downstream Application Scenarios in the XR Industry

Source: BIS Research; Statista; World Bank; Deloitte Research and analysis

Figure 15: Business Model of Roblox

XR serves as the basis upon which Roblox is shaped

Source: Roblox prospectus; Deloitte Research and analysis

B2C application: Metaverse has penetrated public consciousness and XR leads the new trend in game entertainment

On March 10, 2021, Roblox was listed on the New York Stock Exchange, becoming the first metaverse-linked IPO. As one of the world's largest interactive communities and massively multiplayer game creation platforms, Roblox is vigorously developing a space in the VR field, activating its VR functions as early as 2016 and gradually facilitating cross-platform and cross-device adaptations of VR games. Gamers can experience VR games through various user devices such as computers, cell phones, Xbox, Oculus, etc. The business model of Roblox is to create a metaverse world that connects the world through games, enabling anyone to explore tens of millions of immersive 3D games built by a global community of developers. In the future, Internet-embodied immersion is crucial to achieving a truly seamless integration between online and offline, the real world and simulated world, enabling the Metaverse to widely penetrate into daily life. One day there could even be brain-machine interfaces.

There are more and more XR applications in the video entertainment field.

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There are more and more XR applications in the video entertainment field. In April 2020, American hip-op artist Travis Scott hosted an online virtual concert in the popular Battle Royale shooting game Fortnite, using XR technology to present the entire performance, which attracted more than 27.7 million players to watch. As a result of this event, the mobile version of Fortnite drew in $44 million in revenue in April 2020, grew by 6 million installs, and made the top 10 best-selling mobile games on the App Store, with an 89% increase month-on-month.

B2B applications: Deeply applied in industrial field, with huge space for imagination in medical industry

In terms of B2B applications, whether there is application prospect for XR depends on three aspects: 1) can the XR solutions be "scenario-ized", productized and replicated? 2) can it truly solve pain points?; and 3) is the scenario market space large enough to support technology development?

In the industrial field, XR has become one of the core technologies to creating digital twins based on industrial Internet and IoT platform. Taking industrial software giant PTC as an example, PTC has integrated its core advantages in product design and product lifecycle management into its internal XR platform. The digital twin helps PTC build a digital mirror in the virtual space that is completely equivalent to the physical world. By collecting and analyzing data in the dimensions of product development, manufacturing, and business promotion, it lays the foundation for the next key steps of product design, production process and market launch.

XR also brings great value in the medical industry. In surgical operation training, XR technology can immerse training doctors in virtual scenarios through display, haptic, and force feedback devices, allowing them to perform surgical operations and exercises and experience real clinical surgical processes, improving doctors' ability to diagnose conditions and develop treatment plans, while significantly reducing the cost of equipment and resources compared to traditional training. In addition, XR will also play an important role in telemedicine and the improvement of diagnosis and treatment technology, improving the problem of uneven medical resources.

The progress across multiple aspects of XR in the industry has provided industry player with a boost of confident. Although most products still struggle to reach a stable level of profitability, the industry has moved on from being completely dependent on investors and have formed a strong source of financing. In the future, as the number of B2C users continues to increase and the development of B2B applications becomes more diversified, the development of XR in downstream applications will continue to accelerate.

A positive content-hardware-ecosystem cycle has initially formed

With improvements in optical devices and other technologies and systems, a better product experience is being introduced to XR end-user hardware. The emergence of viral content and applications is driving increasing shipments of XR hardware and attracting more content producers and application developers to participate in the ecosystem. Many signs indicate that the XR ecosystem is entering a virtuous cycle.

Viral content apps are boosting device sales significantly

Content is king when it comes to the consumer market. High-quality content has always been an important part of smart ecosystems, and it is no exception in the XR market. Half-Life: Alyx is a VR-exclusive game developed by Valve (a company specializing in video games and also the developer of the Steam platform). Released in March 2020, the game integrates virtual reality, FPS (First-person Shooting), puzzle solving and other game elements with the high-quality graphics and strong physical interaction to create a deep immersive experience.
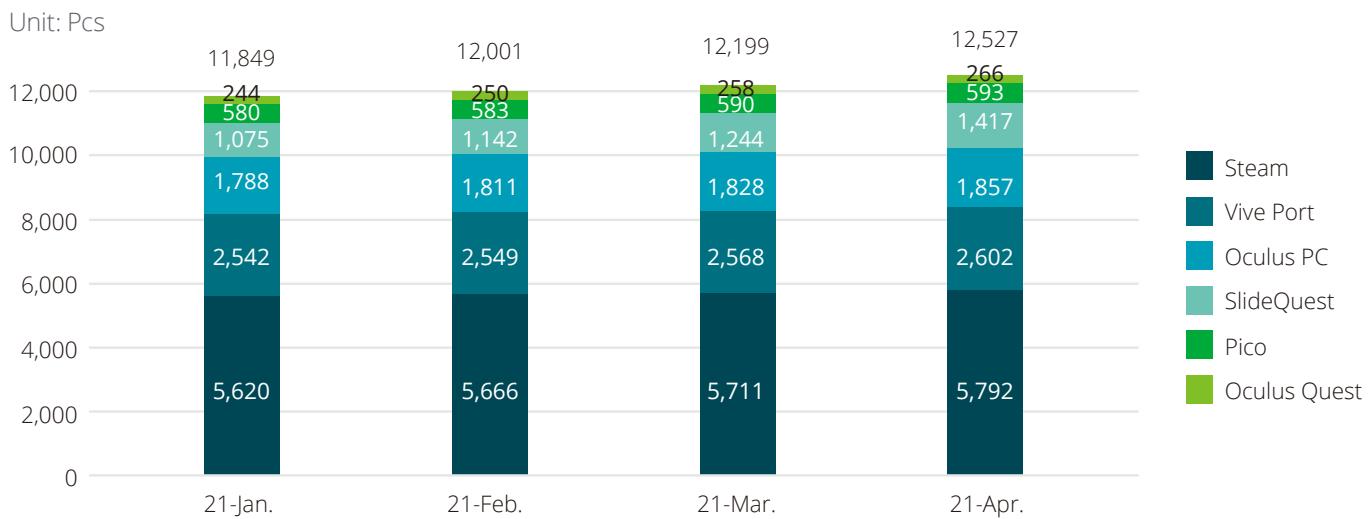
Half-Life: Alyx is exclusive to VR, and Valve bundles the game with the Valve Index. As a result, the game has rapidly driven sales of VR devices.

According to the data published by Nielsen, as Half-Life: Alyx began pre-orders in Q4 2019, Valve IndexVR devices, priced at $999, were sold out in 31 countries by late 2019. Annual sales reached 149,000 copies. On March 24, 2020, Half-Life: Alyx was officially released on Steam and received 10,654 positive reviews in just one day, with a positive rating of over 95%. Driven by Half-Life: Alyx, the number of online VR users on Steam climbed significantly in March 2020, reaching 255,800 and 452,900 VR users in March and April, respectively—a monthly increase of 77%. VR users accounted for 1.91% of the total number of Steam platform users, a much higher figure than the overall VR game user penetration rate.

In 2021, the content on multiple platforms continued to expand. The number of games and applications is growing rapidly on a monthly basis, and a number of blockbuster VR games have, or will soon, enter the market, such as "Resident Evil 4" and "Splinter Cell", which are expected to further promote user growth significantly. In addition to increasing market demand in the short term, more importantly, such viral applications will also provide a solid foundation for market development in the long term. The increase in the number of devices sold will allow a wider range of people to access XR, and the success of the applications will allow more market players to see the opportunities for industry development and thus invest more resources—a positive cycle in the ecosystem will be formed.

Figure 16: Number of Games and Applications on Global VR Content Platforms in 2021 (January-April 2021)

Unit: Pcs

Source: Statista; Deloitte Research and analysis

**Device shipment is taking shape**
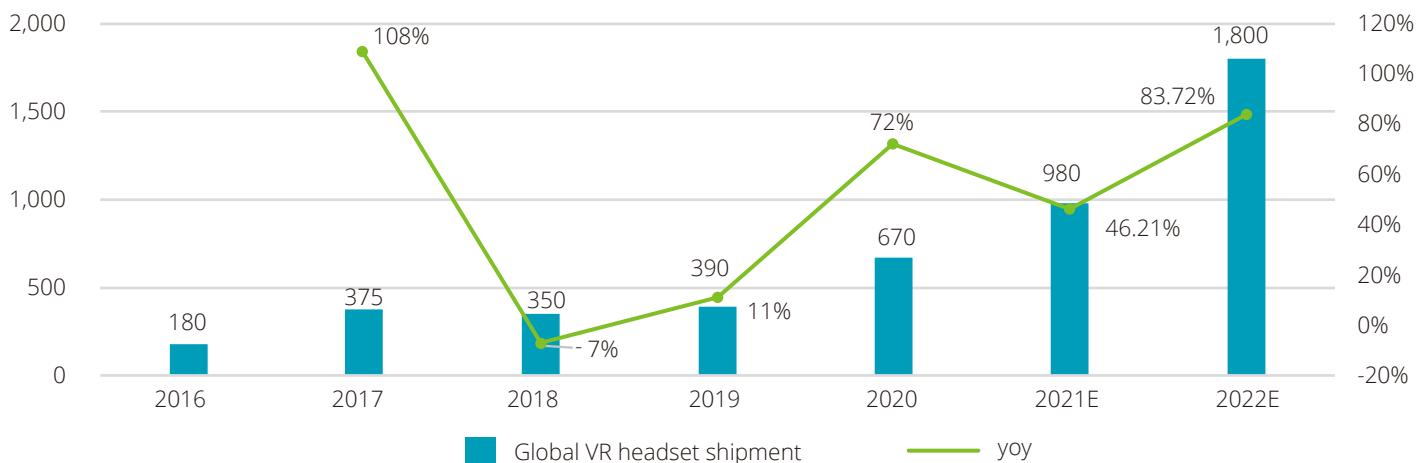
After laying low for more than 10 years, XR device shipments are expected to explode in the near future. In terms of VR devices, according to IDC data, global VR shipments grew 72% year-on-year to 10,000 in 2020—a sign of positivity since the trout in 2017. VR shipment in the U.S. grew 58% year-on-year to 2.84 million, accounting for about 51% of the global share, and leading the global demand recovery in VR. Global AR shipments in 2020 was 287,000, with consumer and commercial AR accounting for 25.2% and 74.8% of shipments, respectively.

Figure 17: Global VR Device Shipment and Forecast (2016-2022E)
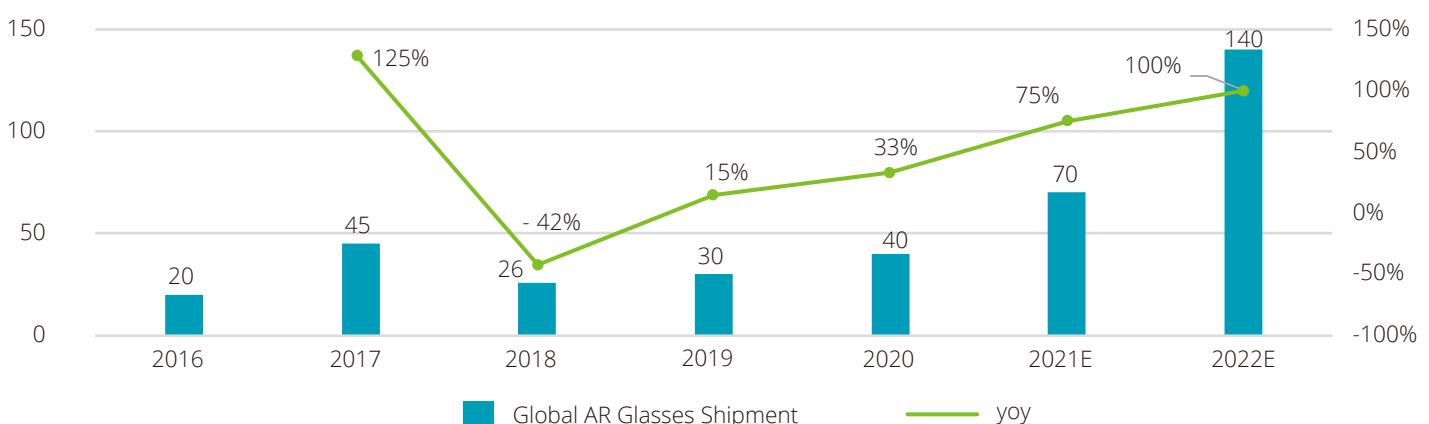
Unit: 10,000 pcs

Source: IDC; Deloitte Research and analysis

Figure 18: Global AR Device Shipment and Forecast (2016-2022E)

Unit: 10,000 pcs

Source: IDC; Deloitte Research and analysis

Looking at the Oculus Quest 2, released by Facebook at the end of October 2020, the sales have reached 3 million after 3 months, and monthly sales have exceeded 10,000. According to a forecast by Yivian, annual sales of Oculus Quest 2 are expected to reach 7 million in 2021. In addition, Apple, Huawei, Sony and other technology giants have announced new product release plans. High-quality content and increasingly mature hardware will continue to bring energy to the market.

Facebook founder Zuckerberg believes that when active users reach 10 million, the VR market will reach a development stage where developers will continue to invest. Based on this standard, the XR industry is expected to reach a tipping point in 2021, when the industry enters a period of prosperity and growth.

XR ecosystem is becoming sound

In the growing market, XR has gradually built a sound ecosystem consisting of multiple players such as computing platforms, hardware suppliers, content application vendors and users, and infrastructure providers such as mobile operators, cloud service providers and network service providers. This provides a basis for the healthy development of the ecosystem.
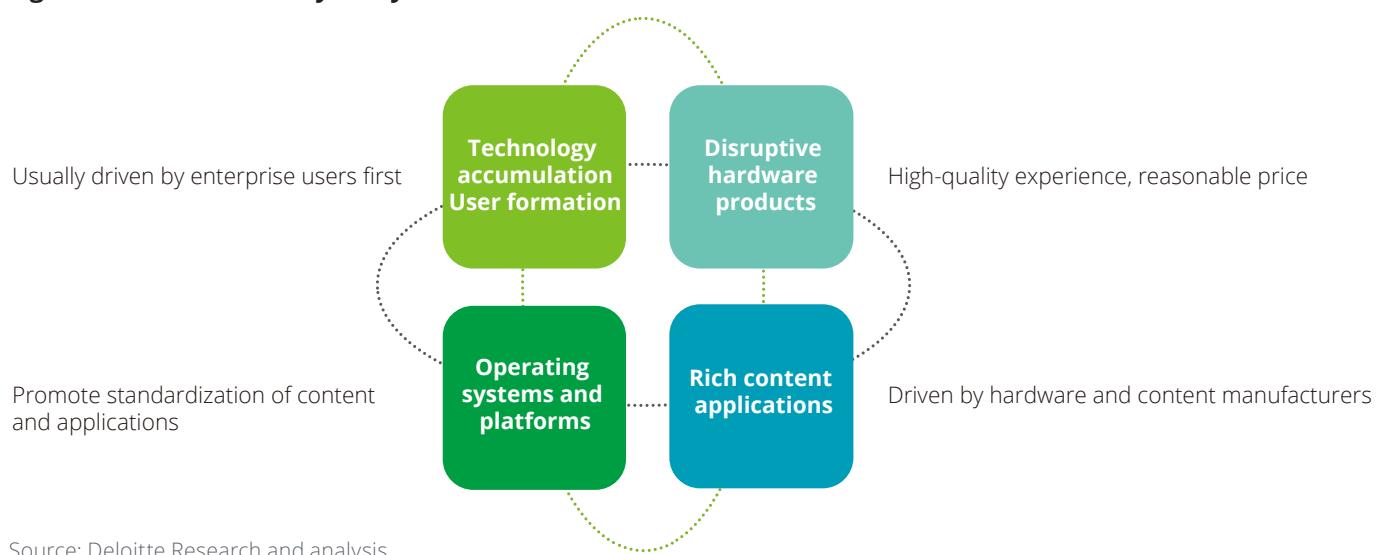
- Computing platforms: this includes giant companies with a notable industrial base such as Apple, Google and Sony;

- Device manufacturers: this mainly includes independent manufacturers and OEMs of core devices such as chips and sensors, perceptual interaction technology, end-user devices and device peripherals;

- Content application manufacturers: major film and television platforms, game companies and social media are focusing on B2C, while B2B applications will target educational institutions, medical institutions, advertising companies, etc.;

- Users: B2C consumers and B2B enterprise-level users who pay for XR devices and content applications;

- Eco-partners: this mainly includes mobile operators providing 5G network products or solutions, cloud vendors providing cloud services, technology companies providing technical support for AI and IoT, etc.

Following the early stages of technology development and breakthrough, capital introduction, lightweight hardware production, and the generation of initial users, the XR industry has now evolved from a few companies, such as hardware manufacturers and application developers working alone, to a multi-party ecosystem cooperation model. All parties involved are working together to build a thriving ecological environment, and all parties in the ecosystem are accelerating integration and innovation.

Figure 19: The XR Industry Ecosystem

Usually driven by enterprise users first

Technology accumulation
User formation

Disruptive hardware products

High-quality experience, reasonable price

Promote standardization of content and applications

Operating systems and platforms

Rich content applications

Driven by hardware and content manufacturers

Source: Deloitte Research and analysis

# It is time to invest in the XR industry

Capital is rebounding, exit channels are gradually clear

After experiencing a trough in 2018, global XR financing has rebounded significantly. According to incomplete statistics, the compound annual growth rate of the global XR financing and M&A deal size from 2018 to 2020 reached 31%, from the industry low point of RMB 14.2 billion in 2018 to RMB 24.4 billion in 2020. The number of financing and M&A deals also increased from 109 in 2018 to 166 in 2020. In 2021, signs of rebound were more obvious, with global financing and M&A amounting to RMB 22.9 billion in the first half of the year, increasing by 108% compared with the first half of 2020.

In terms of regional markets, capital in overseas markets outside of China came first, leading the global rebound trend. From 2018 to 2020, domestic capital was still slightly declining. In 2019, financing deals worth over one hundred million RMB were mainly conducted by HiAR, Sandbox, Digital Domain, iQIYI Smart, providing a boost the market. However, in 2020, only RMB 2.1 billion domestic of financing and M&A occurred, a decrease of 58% year-on-year. Influenced by rebounding global capital sentiment, Chinese XR financing also saw a recovery in 2021. Whether it was the huge financing of hundreds of millions of RMB from iQIYI VR or the A financing of hundreds of millions of RMB from Raypai Tech, both indicate that the industry is heading for recovery.

Figure 20: Global XR Financing and M&A Size (2016-2020)

Unit: RMB 100 million
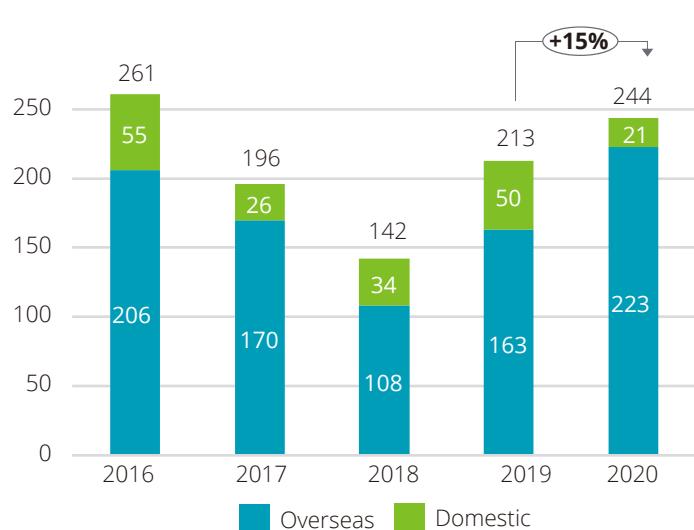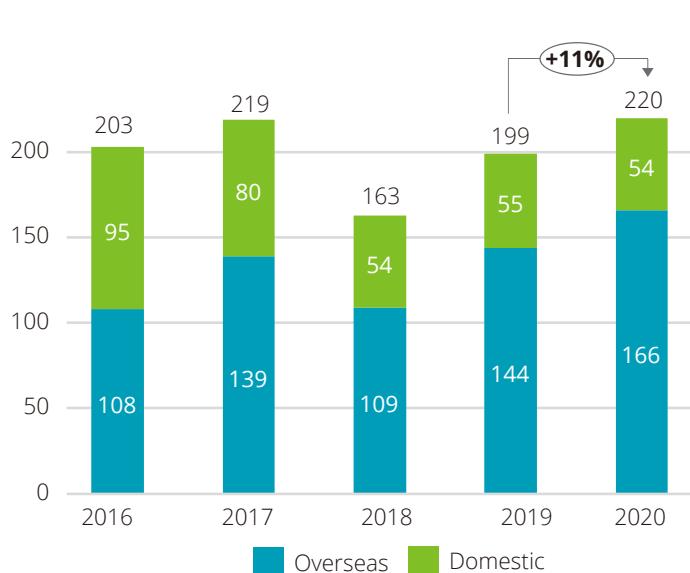
Figure 21: Global XR Financing and M&A Number (2016-2020)

Source: VR Tuoluo; Deloitte Research and analysis

Source: VR Tuoluo; Deloitte Research and analysis

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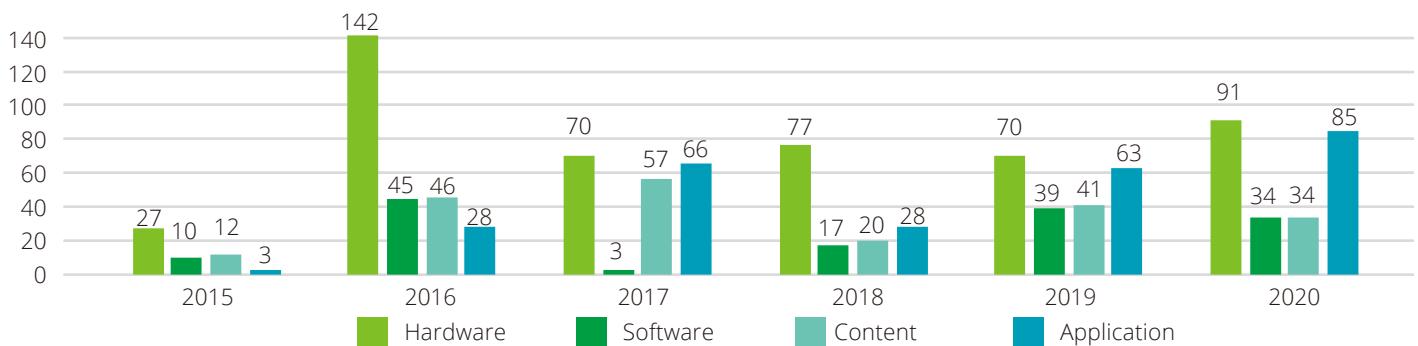
In terms of investment direction, current global capital is concentrated in two industry chain links: hardware and applications. With respect to hardware, capital is focusing more on AR glasses and optical devices; with respect to applications, it is focusing on education and training, medical health and solutions.

Figure 22: Global VR/AR Industry Chain Financing and M&A Amount and Number in Each Link
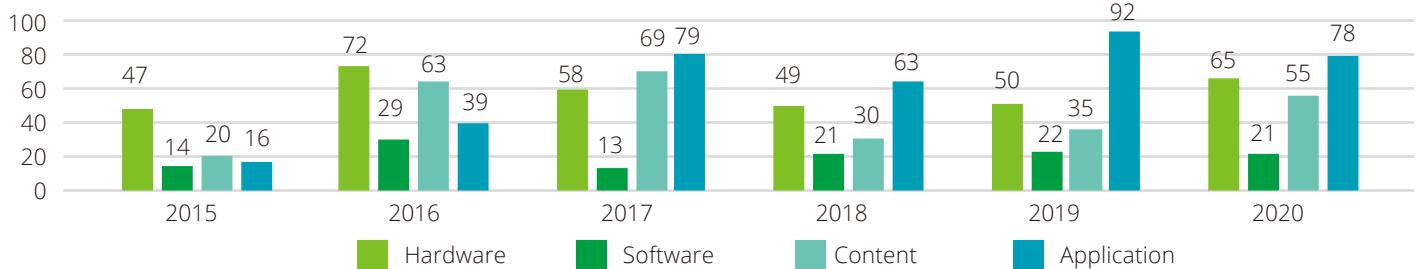
Financing and M&A amount and number of global VR/AR industry chain in each link
Unit: RMB 100 million

Financing and M&A number of global VR/AR industry chain in each link
单位：起

Source: IDC; VR Tuoluo; Deloitte Research and analysis

Financing and M&A of VR/AR hardware in 2020 was dominated by AR glasses and optical devices:

• AR glasses are considered the next-generation general-purpose computing platform, but consumer-level products in the true sense have not yet appeared at this stage, and capital is still concentrating on the sector;

• Optical devices are the key component of AR glasses at the consumer level, and are also attracting capital attention.

In 2020, financing and M&A of VR/AR applications focused on education and training, healthcare, solutions, and other fields
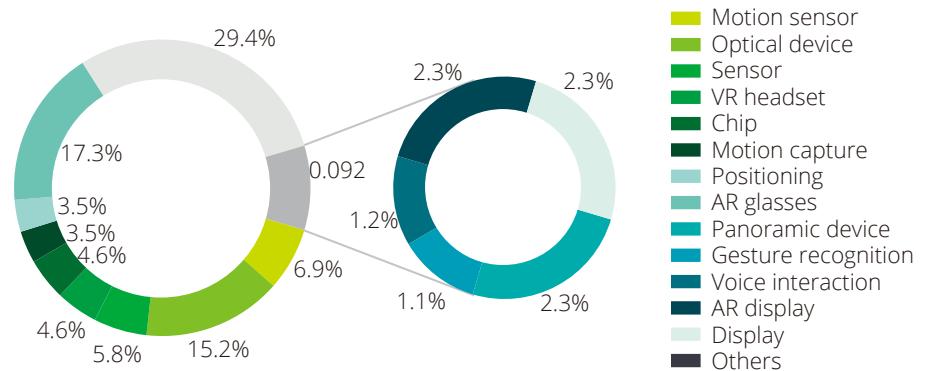
• AR/VR education and training are the most important B2B implementation scenarios at present;

• In the field of healthcare, AR/VR can help doctors better implement triage treatment and help patients recover more effectively.

Exit channels are gradually clearing up: In 2020, in terms of the global financing rounds of XR, besides seed rounds, A rounds and other financial investor-led investments, strategic investment and M&A were the main transaction types in the capital market. 220 financing events occurred in 2020, strategic investment occurred 54 times, and there were 38 M&A deals, reaching 41.8% of the overall financing events. Taking Google as an example, in recent years Google has implemented several M&A investments in the XR field, such as acquiring North, a Canadian AR glasses manufacturer, for $180 million in 2020, investing 5% equity in Hello TeamSolar, an AR startup, to develop augmented reality technology in 2019, and strategically investing $15 million to acquire Micro LED manufacturer Glo's 13% equity at the end of June 2017, in an attempt to open up the underlying technology of the whole industrial chain. In a market environment where the industry chain is trending towards mature and the giants are making more and more moves, startups will get more opportunities to be strategically invested in or acquired by larger companies. In addition, the successful listing of Roblox in 2021 provides a typical case for exit.
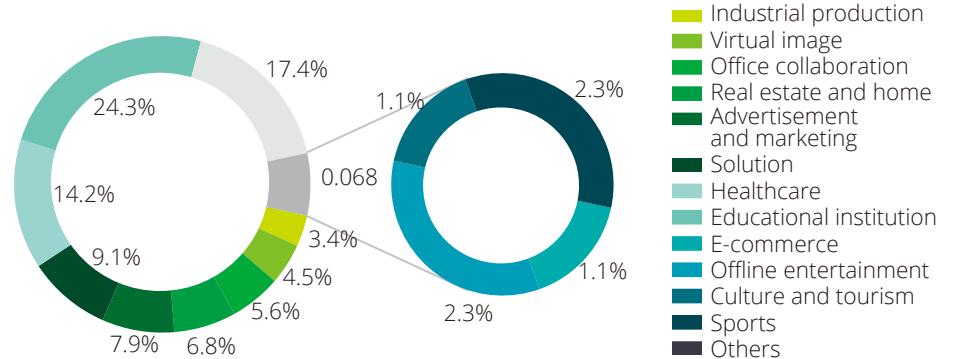
Figure 23: Financing and M&A Distribution in VR/AR Hardware and Application Field in 2020

Financing and M&A distribution in VR/AR hardware field in 2020
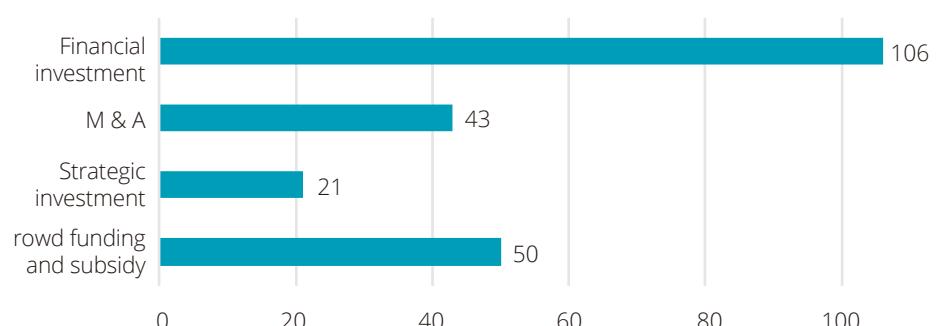
Financing and M&A distribution in VR/AR application field in 2020

Source: IDC; VR Tuoluo; Deloitte Research and analysis

Figure 24: Global Financing Breakdown of XR

Source: VR Tuoluo; Deloitte Research and analysis

Investment opportunities across the entire industrial chain of hardware, software, content and application are emerging
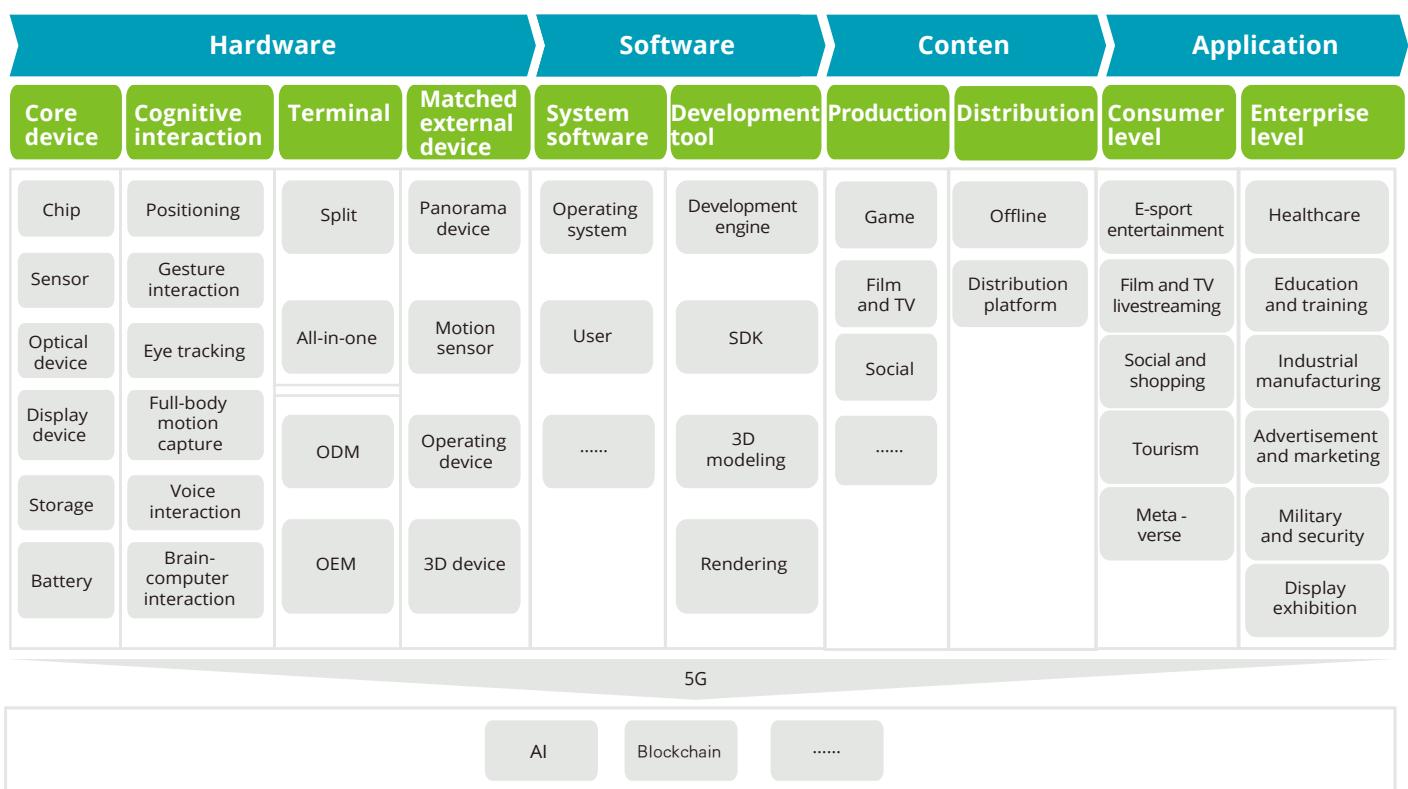
The XR industry consists of four industry chains: hardware, software, content and applications, each of which contains multiple sub-chains. The whole industry chain has numerous links, and each link is intertwined. The overall prosperity of the XR industry requires the collaborative growth of each industry chain link and ecosystem.

In terms of investment, the rise of industrial ecosystems is breeding a plethora of investment and strategic positioning opportunities. The core devices in hardware, for example, include optical devices, screens, processors, storage, cameras, batteries, etc. Breaking down the cost structure of the Oculus VR headset, optical devices and screens account for 40% of the hardware cost, and are the key devices. The chip is also important: the processor and memory account for 30% and 15% of the cost, respectively, and Qualcomm occupies a large share in the field. But the space is becoming competitive, overseas giants, such as Apple, Google, Microsoft, Facebook and Sony, are self-researching related chips, while domestic manufacturers, led by Huawei, are also investing in chip development. These companies are aiming to make XR no longer be subject to third parties, while using XR to form a competitive advantages.

In terms of software, the operating system and development engine are also important considerations, and the ability to help build an efficient developer ecosystem is also of concern to the industry. In terms of content, the ability to lower the creation threshold to improve the efficiency of content production, and the ability to build an active content ecosystem, are also key focuses.

Figure 25: Whole Industry Chain of the XR Industry

Hardware				Software		Conten		Application	
Core device	Cognitive interaction	Terminal	Matched external device	System software	Development tool	Production	Distribution	Consumer level	Enterprise level
Chip	Positioning	Split	Panorama device	Operating system	Development engine	Game	Offline	E-sport entertainment	Healthcare
Sensor	Gesture interaction			User	SDK	Film and TV	Distribution platform	Film and TV livestreaming	Education and training
Optical device	Eye tracking	All-in-one	Motion sensor			Social		Social and shopping	Industrial manufacturing
Display device	Full-body motion capture	ODM	Operating device	......	3D modeling	......		Tourism	Advertisement and marketing
Storage	Voice interaction							Meta - verse	Military and security
Battery	Brain-computer interaction	OEM	3D device		Rendering				Display exhibition

5G

AI Blockchain ......

Source: Deloitte Research and analysis

Table 2: Examples of Leading Companies in XR Segments

Type	Name	Business
Technology	Tobii Technology	Swedish company, leading provider of eye tracking and eye control technology
	CREAL	Swiss company, developer of light field display technology focused on AR/VR
	Ultraleap	Merged by Ultrahaptics and Leap Motion in 2019, focusing on gesture interaction technology development
Hardware	Nreal	Chinese company, developer of MR smart glasses
	Mira	US company, AR glasses manufacturer, supplier of AR glasses for Nintendo AR karting project at Universal Studios Japan
Software	Unity3D	US listed company, game engine developer; Unity3D supports real-time content development platform for mainstream ARVR devices
Application	Vection	Australian company, real-time software company focused on bringing 3D, AR, VR solutions to Industry 4.0
	Librestream	Canadian company, provider of enterprise mobile video collaboration solutions
	Augmedics	US company, developer of AR surgical visualization systems
	Poplar	UK company, AR content maker

Source: Public market information; Deloitte Research and analysis

Global investment in key technologies to fix weak links
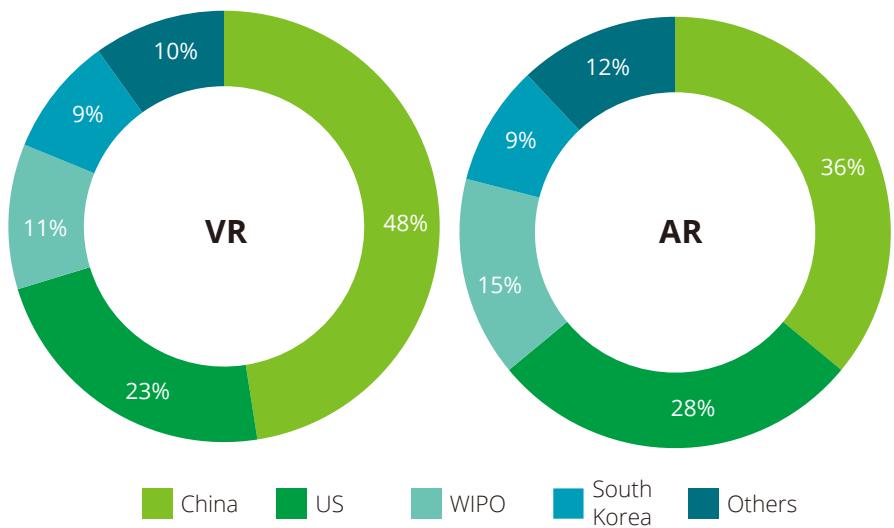
Taking a global view on investment opportunities in XR can be helpful. Taking advantage of China's own strengths while absorbing the strengths of others, will help the industry prosper while winning investment returns.

Although China is leading in global patent applications, it still lags behind the global leaders in forward-looking research, especially in key technology areas, such as perceptual interaction, rendering computing, and content production and distribution.

- In terms of rendering technology and perceptual interaction technology, overseas giants, such as Google, Facebook, Apple and other technology giants, have already advanced through self-research and mergers and acquisitions in the early stage, and quickly widened the gap between themselves and other enterprises after XR crossed the initial threshold of immersive experience.

- In terms of cloud content production and distribution, looking at weak interactive content production with three degrees of freedom, the influence of local panoramic brands, such as the domestic brand Insta360, is increasing. Looking at strong interactive content production with six degrees of freedom, there is still a gap between

Figure 26: Global Distribution of VR and AR-related Patents (total in 2017-2020)
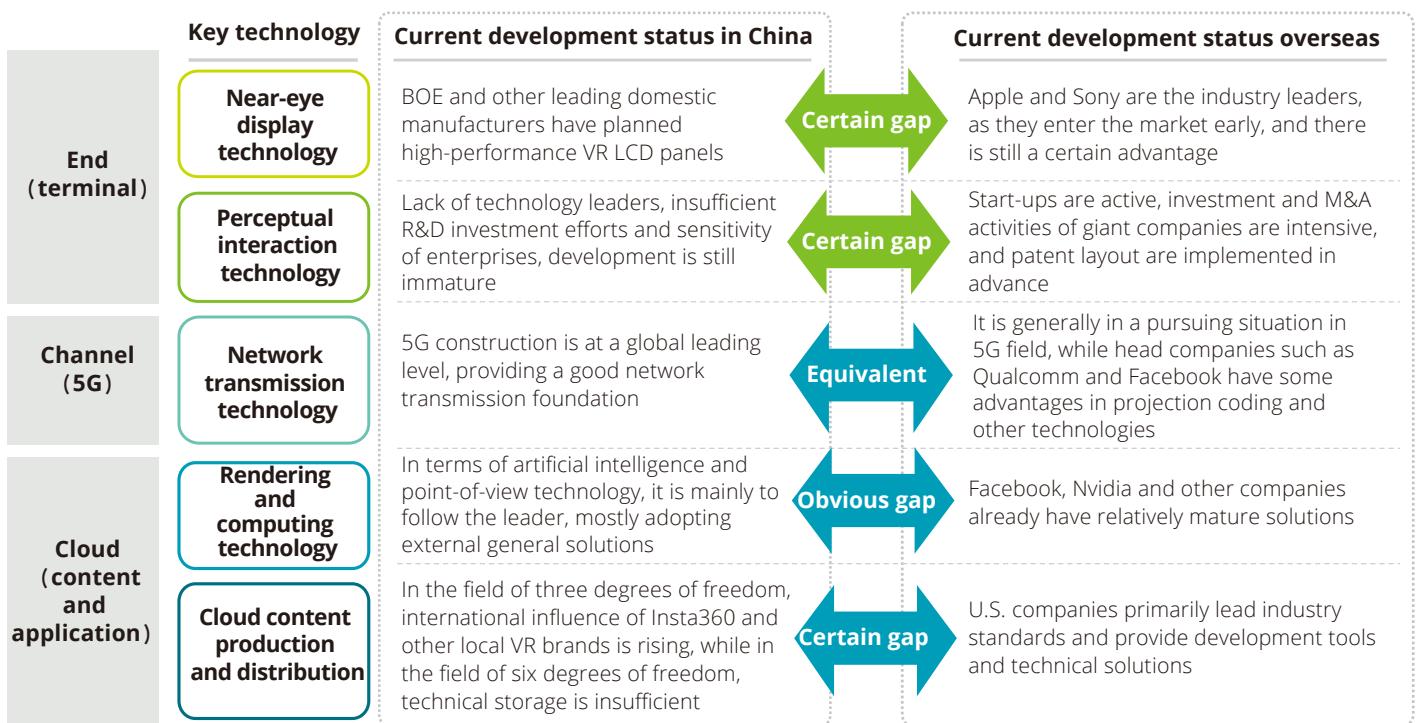
Source: BIS research; Deloitte Research and analysis

domestic Chinese firms and overseas companies; technology realization is mainly based on technical solutions from leading foreign enterprises.

- In terms of near-eye display technology, with the rise of BOE and

other domestic screen enterprises, the overall gap between domestic and top overseas enterprises has been shrinking, but there is still some gaps in technological distribution.

Figure 27: Current Development Status of Key Technologies in XR in China and Overseas

Key technology		Current development status in China		Current development status overseas
End (**terminal**)	**Near-eye display technology**	BOE and other leading domestic manufacturers have planned high-performance VR LCD panels	**Certain gap**	Apple and Sony are the industry leaders, as they enter the market early, and there is still a certain advantage
	Perceptual interaction technology	Lack of technology leaders, insufficient R&D investment efforts and sensitivity of enterprises, development is still immature	**Certain gap**	Start-ups are active, investment and M&A activities of giant companies are intensive, and patent layout are implemented in advance
Channel (**5G**)	**Network transmission technology**	5G construction is at a global leading level, providing a good network transmission foundation	**Equivalent**	It is generally in a pursuing situation in 5G field, while head companies such as Qualcomm and Facebook have some advantages in projection coding and other technologies
Cloud (**content and application**)	**Rendering and computing technology**	In terms of artificial intelligence and point-of-view technology, it is mainly to follow the leader, mostly adopting external general solutions	**Obvious gap**	Facebook, Nvidia and other companies already have relatively mature solutions
	Cloud content production and distribution	In the field of three degrees of freedom, international influence of Insta360 and other local VR brands is rising, while in the field of six degrees of freedom, technical storage is insufficient	**Certain gap**	U.S. companies primarily lead industry standards and provide development tools and technical solutions

Source: Deloitte Research and analysis

[1] WIPO (World Intellectual Property Organization) is a permanent body of the United Nations, headquartered in Geneva, Switzerland.

Deloitte China contacts

Lam, Taylor
Vice Chairman & TMT Industry Leader,
Deloitte China
E-mail: talam@deloitte.com.cn

Lah, Stanley
M&A Services Leader, Deloitte Asia Pacific & China
E-mail: slah@deloitte.com.cn

Pu, Qing Lu
Partner, M&A Services, Deloitte China
E-mail: qlpu@deloitte.com.cn

White Paper Preparation Team

Pu, Qing Lu
Partner, M&A Services, Deloitte China

Pang, Yuping
Manager, M&A Services, Deloitte China

Peng, Bo
Manager, M&A Services, Deloitte China

Hu, Calan Jianan
Manager, M&A Services, Deloitte China

Zhang, Ada Yandi
Senior associate, M&A Services, Deloitte China

Office locations

Beijing
12/F China Life Financial Center
No. 23 Zhenzhi Road
Chaoyang District
Beijing 100026, PRC
Tel: +86 10 8520 7788
Fax: +86 10 6508 8781

Changsha
20/F Tower 3, HC International Plaza
No. 109 Furong Road North
Kaifu District
Changsha 410008, PRC
Tel: +86 731 8522 8790
Fax: +86 731 8522 8230

Chengdu
17/F China Overseas
International Center Block F
No.365 Jiaozi Avenue
Chengdu 610041, PRC
Tel: +86 28 6789 8188
Fax: +86 28 6317 3500

Chongqing
43/F World Financial Center
188 Minzu Road
Yuzhong District
Chongqing 400010, PRC
Tel: +86 23 8823 1888
Fax: +86 23 8857 0978

Dalian
15/F Shenmao Building
147 Zhongshan Road
Dalian 116011, PRC
Tel: +86 411 8371 2888
Fax: +86 411 8360 3297

Guangzhou
26/F Yuexiu Financial Tower
28 Pearl River East Road
Guangzhou 510623, PRC
Tel: +86 20 8396 9228
Fax: +86 20 3888 0121

Hangzhou
Room 1206
East Building, Central Plaza
No.9 Feiyunjiang Road
Shangcheng District
Hangzhou 310008, PRC
Tel: +86 571 8972 7688
Fax: +86 571 8779 7915

Harbin
Room 1618
Development Zone Mansion
368 Changjiang Road
Nangang District
Harbin 150090, PRC
Tel: +86 451 8586 0060
Fax: +86 451 8586 0056

Hefei
Room 1506 Tower A China Resource Building
No.111 Qian Shan Road
Shu Shan District
Hefei 230022, PRC
Tel: +86 551 6585 5927
Fax: +86 551 6585 5687

Hong Kong
35/F One Pacific Place
88 Queensway
Hong Kong
Tel: +852 2852 1600
Fax: +852 2541 1911

Jinan
Units 2802-2804, 28/F
China Overseas Plaza Office
No. 6636, 2nd Ring South Road
Shizhong District
Jinan 250000, PRC
Tel: +86 531 8973 5800
Fax: +86 531 8973 5811

Macau
19/F The Macau Square Apartment H-L
43-53A Av. do Infante D. Henrique
Macau
Tel: +853 2871 2998
Fax: +853 2871 3033

Nanchang
Unit 08-09, 41/F Lianfa Plaza
No.129 Lv Yin Road
Honggutang District
Nanchang 330038, PRC
Tel: +86 791 8387 1177

Nanjing
40/F Nanjing One IFC
347 Jiangdong Middle Road
Jianye District
Nanjing 210019, PRC
Tel: +86 25 5790 8880
Fax: +86 25 8691 8776

Ningbo
Room 1702 Marriott Center
No.168 Heyi Road
Haishu District
Ningbo 315000, PRC
Tel: +86 574 8768 3928
Fax: +86 574 8707 4131

Sanya
Floor 16, Lanhaihuating Plaza
(Sanya Huaxia Insurance Center)
No. 279, Xinfeng street
Jiyang District
Sanya 572099, PRC
Tel: +86 898 8861 5558
Fax: +86 898 8861 0723

Shanghai
30/F Bund Center
222 Yan An Road East
Shanghai 200002, PRC
Tel: +86 21 6141 8888
Fax: +86 21 6335 0003

Shenyang
Unit 3605-3606,
Forum 66 Office Tower 1
No. 1-1 Qingnian Avenue
Shenhe District
Shenyang 110063, PRC
Tel: +86 24 6785 4068
Fax: +86 24 6785 4067

Shenzhen
9/F China Resources Building
5001 Shennan Road East
Shenzhen 518010, PRC
Tel: +86 755 8246 3255
Fax: +86 755 8246 3186

Suzhou
24/F Office Tower A, Building 58
Suzhou Center
58 Su Xiu Road, Industrial Park
Suzhou 215021, PRC
Tel: +86 512 6289 1238
Fax: +86 512 6762 3338 / 3318

Tianjin
45/F Metropolitan Tower
183 Nanjing Road
Heping District
Tianjin 300051, PRC
Tel: +86 22 2320 6688
Fax: +86 22 8312 6099

Wuhan
Unit 1, 49/F
New World International Trade Tower
568 Jianshe Avenue
Wuhan 430000, PRC
Tel: +86 27 8538 2222
Fax: +86 27 8526 7032

Xiamen
Unit E, 26/F International Plaza
8 Lujiang Road, Siming District
Xiamen 361001, PRC
Tel: +86 592 2107 298
Fax: +86 592 2107 259

Xi'an
Room 5104A, 51F Block A
Greenland Center
9 Jinye Road, High-tech Zone
Xi'an 710065, PRC
Tel: +86 29 8114 0201
Fax: +86 29 8114 0205

Zhengzhou
Unit 5A10, Block 8, Kineer Center
No.51 Jinshui East Road
Zhengdong New District
Zhengzhou 450018, PRC
Tel: +86 371 8897 3700
Fax: +86 371 8897 3710

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