

EMPOWERING CONSUMER-FOCUSED IMMERSIVE VR AND AR EXPERIENCES WITH MOBILE BROADBAND

Key topics we will discuss in this paper include:

- › Arrival of VR / AR in the mass market
- › Exploring the true potential of VR / AR
- › Impact of immersive services with enhanced mobile broadband

INTRODUCTION

VIRTUAL REALITY (VR) AND AUGMENTED REALITY (AR) ARE FINALLY READY TO GO MAINSTREAM. VR IS WHERE USERS IMMERSE THEMSELVES IN A VIRTUAL WORLD, OR IN A SIMULATED REAL WORLD, AND INTERACT WITH THESE ENVIRONMENTS BY MEANS OF IN-BUILT SENSORS IN HEAD-MOUNTED DISPLAYS (HMDS). AR IS WHERE VIRTUAL INFORMATION IS OVERLAID ONTO THE REAL WORLD, SO THAT USERS EXPERIENCE AN ENHANCED AND MORE COMPREHENSIVE PERCEPTION OF THEIR ENVIRONMENT.



The summer of 2016 witnessed the first mass-market craze in AR gaming with Pokémon Go. And the growing maturity of VR and AR enabling technologies is opening up a myriad of other content and application possibilities for the consumer market.

Many engaging applications are emerging, including immersive video gaming and new, virtual experiences for watching movies or live sports and entertainment events. There is also a host of consumer-facing enterprise applications. These include virtual tours of popular tourist destinations, immersive panoramas, and even virtual trips to Mars. Virtual guided tours can have benefits in the field of education, bringing immersive experiences for all, unfettered by the traditional cost and time constraints imposed by physical travel.

Retailers can also leverage VR / AR to help market their products and services. Applications are already coming to the fore in the realms of online shopping and marketing luxury homes. In the United States, Sotheby's has started showing luxury homes to prospective buyers using VR. The firm sees great potential for VR in its business once headsets are more widely available to consumers, particularly when it comes to showcasing high-end properties internationally¹.

While some initial VR and AR applications are being delivered over fixed networks, many already rely on mobile devices. Enhanced mobile broadband networks will underpin future VR / AR services, promising an untethered immersive experience that enables people to enjoy a plethora of VR / AR applications anytime and anywhere.

1 - <http://www.bizjournals.stfi.re/losangeles/news/2015/08/12/virtual-reality-makes-house-hunters-feel-at-home.html#aa>

KEY DATA

**300
THOUSAND HMDs**

Annual shipments of HMDs could approach 300,000 units in 2025



**3.5
BILLION DOLLARS**

Venture capitalists ploughed over \$3.5 billion into 225 VR and AR projects in 2014-2015 alone

**390
MILLION USERS**

By 2025, 95 million people will be viewing live events in VR and 79 million enjoying immersive forms of video entertainment, including adult content. Immersive gaming could be even bigger with over 216 million users



VR / AR ARRIVES IN THE MASS MARKET

PART 1

After a series of false dawns – including the overhyped Google Glass – the last year has seen VR / AR finally arrive in a format suitable for the mass market. New consumer electronic devices designed for engaging with VR / AR content are becoming increasingly available, along with compatible content such as immersive games and 360 degree video.

Consumer headsets – commonly called head-mounted displays (HMDs) – are launching in increasing numbers. These wearable devices project a virtual, simulated or augmented reality world close to the eyes, and incorporate eye movement and body motion sensors, so that users can navigate through and interact with the VR / AR environment in a naturalistic way. In future, haptic capabilities will add touch-based sensory perception to further enhance the immersive experience.

Examples include high-end VR / AR headsets such as the Oculus Rift, HTC Vive, Sony PlayStation VR and Microsoft HoloLens, which are aimed at PC users and require top-end graphics cards and processors. At the lower end, and much more affordable for a wider range of consumers, are headsets such as Google Cardboard, Google Daydream View and Samsung Gear VR, which are designed for use with smartphones. Oculus is also working on a cheaper, wireless headset. Applications are being developed for all these platforms (see table).

TABLE: EXAMPLE CONSUMER VR / AR APPLICATIONS (NOTE: THIS LIST IS ILLUSTRATIVE, NOT EXHAUSTIVE)

APPLICATION	PROVIDER (PLATFORMS)	DESCRIPTION
Minecraft VR	Microsoft Minecraft (Oculus Rift, Gear VR)	VR version of popular simulation and building game
Pokémon Go	Niantic Inc. (Android, iOS)	AR character-catching and battling game using smartphone GPS, maps and camera functions
AltSpace VR	AltSpace VR Inc. (Gear VR, Oculus Rift, HTC Vive)	VR social media platform offering 360 degree video sharing and calling, video chat, and games
Apollo 11	Immersive Education (Oculus Rift, HTC Vive)	VR moon-landing simulation game
InCell VR	Ludon (Android, iOS)	VR educational cell-biology 3D racing game
StarChart	Escapist Games (Android, iOS)	AR educational app that identifies stars and planets in the sky when the device is pointed at them; time-shift function
Orbulus	VR Codex (Android, iOS)	AR / 360 degree image sharing site; images are of tourist destinations, and are created with Google Photo Sphere app that enables 360 degree images to be created from smartphone cameras
Wikitude World Browser	Wikitude GmbH (Android, iOS, WindowsPhone, Blackberry)	AR app pushing context-sensitive articles overlaid on smartphone camera image

VR / AR ARRIVES IN THE MASS MARKET

PART 2

The advantage from a mobility perspective is that this type of HMD doesn't rely on the user being tethered to a high-power PC for local image processing, yet they are nonetheless capable of delivering the 360-degree video content on which many current VR applications are being built.

In April 2016, Huawei announced its own headset, the Huawei VR, which is compatible with the vendor's P9, P9 Plus and Mate 8 smartphones. In an industry first, the headset offers 360-degree audio on the move, while also providing a 95-degree field of vision and an anti-blue light filter for eye protection. The device will ship with a free content bundle that includes movies, games, panoramic images and tours.

While it is still early days for the HMD market, analysts expect shipments to reach mass-market volumes within the next decade. A Goldman Sachs report predicts that annual shipments of HMDs could reach 125 million in 2025, amounting to a total spend on VR / AR devices of \$45 billion in that year. In an accelerated adoption scenario, where breakthroughs in cellular and battery technologies facilitate a truly mobile user experience, shipments could approach 300,000 in 2025, according to the report².

Advances are also being made in optimizing smartphone components for the delivery of VR / AR content and applications. For example, Qualcomm's new Snapdragon 820 processor is designed specifically with VR's performance needs in mind, including handset power and thermal constraints. The processor – which supports 1K x 1K eye resolution at 90 frames per second, 360-degree video, lens distortion correction and stereoscopic display, and latency of under 20ms for a motion-sickness-free user experience – will ship in high-end smartphones from 2016.

The investment that is going into developing immersive technologies is huge. According to Goldman Sachs, venture capitalists ploughed over \$3.5 billion into 225 VR and AR projects in 2014-2015 alone.

Facebook bought one of the leading players in the VR headset space, Oculus, for \$2 billion in 2014

The company has since invested \$250 million in creating VR content such as video games and in October 2016 pledged a further \$250 million in funding for VR content creators. Facebook is also busy developing social applications for VR, including live VR chat³.



“Virtual reality was once the dream of science fiction. But the internet was also once a dream, and so were computers and smartphones. The future is coming and we have a chance to build it together. I can't wait to start working with the whole team at Oculus to bring this future to the world, and to unlock new worlds for all of us.”

- Mark Zuckerberg, CEO of Facebook⁴

2 - Goldman Sachs Group, Virtual & Augmented Reality: Understanding the Race for the Next Computing Platform, January 2016
3 - <https://www.cnet.com/news/facebook-mark-zuckerberg-shows-off-live-vr-virtual-reality-chat-with-oculus-rift/>
4 - <https://www.facebook.com/zuck/posts/10101319050523971>

MOBILE OPERATORS EXPLORE VR / AR'S POTENTIAL

Mobile network operators are keenly eyeing the emerging trends in VR / AR consumer electronics and applications. Many of the world's largest operators have already started offering headsets alongside the latest smartphones, as immersive gaming and other VR applications come to the fore.

A growing number of mobile operators are engaging in VR pilots, together with various hardware, application and content partners. One of the most intriguing possibilities offered by VR is simulating the user's virtual presence at major events, such as a football matches, athletics championships, or live concerts. Several trials are examining these types of use cases.

Among the Orange group of companies, EE teamed up with the BT Sport TV channel in September 2016 to offer visitors to its four flagship London stores the chance to enjoy a pitch-side experience of a Premier League football match in VR. Fans were provided with VR headsets and tablets to use during the match.

In October 2016, Orange launched its own-brand⁵ V1 headset in several European markets. The mid-priced headset, which is compatible with iOS and Android smartphones, ships with access to 360 video content including a gaming experience, a sci-fi action clip and an educational video. The application will be updated with new content and experiences over time. Customers in France will also be able to access premium VR videos, as well as the full OCS catalogue in a virtual environment⁶.

Also in September 2016, Deutsche Telekom premiered Germany's first 360-degree HD live concert stream on YouTube. The operator said that more than half of the 100,000 viewers who watched the stream did so on mobile devices and tested the VR experience⁷.

"We want to position Orange at the forefront of the VR revolution, creating new virtual experiences for our customers in an effortless manner. With the Orange VR1 headset, our ambition is to propose a device that makes VR accessible to our customers and in doing so, provides them with a user-friendly experience allowing them to enjoy VR content using their existing smartphone, whether iOS or Android."

- **Yves Maitre**, Executive Vice President for Orange's Connected Objects and Partnership team

For the 2016 Rio Olympics, world-renowned broadcaster BBC rolled out an experimental service bringing live and on-demand coverage to viewers in 360-degree video⁸. The BBC Sport 360 service can be viewed on devices compatible with Samsung VR headsets or on a low-cost mobile VR headset using Android or iOS smartphones. "There's huge potential for immersive video in sport coverage, as well as many other genres, and we want to explore that potential directly with audiences," said Will Saunders, Editorial Lead, BBC Taster.

For now, the mobile operator community is focusing on assessing the potential impact of VR and AR on their businesses and networks, and clarifying the most attractive use cases and business models. Going forward, operators will be keen to maximize the opportunity for service innovation that these new technologies bring and to capture their share of the burgeoning market.

Both VR live events broadcasting and immersive video entertainment are expected to be big business in the future. By 2025, Goldman Sachs predicts that 95 million people will be viewing live events in VR and 79 million enjoying immersive forms of video entertainment, including adult content. These figures equate to more than one in four people who own a VR / AR headset taking up these services. Immersive gaming could be even bigger still, with over 216 million users by 2025. This compares to around 230 million video games consoles in use today⁹.

"Deutsche Telekom exceeded all expectations with their 360-degree live stream on YouTube. The enormous number of people watching proves just how much this innovative, technical approach, and the prominent placement on the landing page, met users' needs."

- **Karin Gerhardy**, Industry Leader Telecommunication, Google Germany.

5 - <http://newsroom.ee.co.uk/bt-sport-brings-virtual-reality-to-ee-stores>

6 - <http://www.orange.com/en/Press-and-medias/press-releases2016/Orange-expands-virtual-reality-offering-launching-mid-range-universal-VR-headset-in-Europe>

7 - <https://www.telekom.com/media/company/322674>

8 - <http://www.bbc.co.uk/mediacentre/latestnews/2016/bbc-sport-360>

9 - Goldman Sachs Group, Virtual & Augmented Reality: Understanding the Race for the Next Computing Platform, January 2016.

DELIVERING IMMERSIVE SERVICES WITH ENHANCED MOBILE BROADBAND

As a mass market for VR / AR applications emerges, mobile network operators will need to upgrade their networks to facilitate high-quality, and truly mobile, immersive experiences. Beyond the network, there are also implications for terminal design, including power consumption, battery life and thermal management.

Video is already demanding in terms of bandwidth, latency, and capacity. With VR / AR, these requirements become even more stringent.

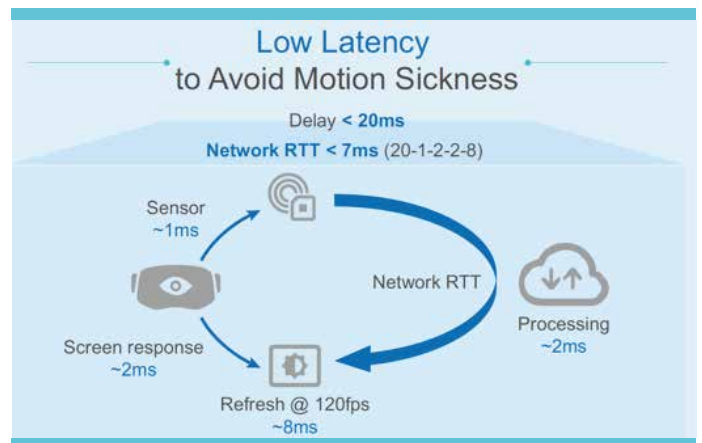
The 360 degree video on which VR / AR applications are based is today mostly low resolution, requiring a bandwidth of around 25 Mbit/s for streaming. But as display quality improves towards high definition (HD) and eventually retina resolution (5073 x 5707 per eye and upwards), the bandwidth required will ramp up significantly. For retina experience VR / AR, estimates suggest that bandwidths ranging from hundreds of Mbit/s through to several gigabits per second will be needed for a fully immersive mobile experience.

Mobile networks will also need to support VR and AR services while the user is on the move, on trains as well as in cars. In-vehicle services such as intelligent navigation¹⁰ using AR could require throughputs of up to 20Mbit/s.

Interactive VR / AR applications are extremely sensitive to delay and so require very low end-to-end latency. Less than 20ms roundtrip is essential to avoid users experiencing disorientation and dizziness (also known as cyber-sickness), which can occur if there is too much delay between the perception of an action and image display. Complex tasks that add to processing latency include 3D image processing, correction of lens distortion and colours, dynamic tracing of 3D audio and echo strength, and AR scene identification and reconstruction. Taking all these factors into account, on the network side latency must be within 5 to 9ms (see figure).

A mass adoption of bandwidth-hungry mobile immersive services will have a significant impact on network capacity, requiring ultra-dense networks to support up to 10Tbit/s/km².

Latency to avoid motion sickness in AR/VR



Mobile operators must also keep an eye on coverage, as VR / AR users will expect the same quality of experience wherever they are. As Pokémon Go showed, users who encounter patchy coverage have no qualms in switching to an alternative carrier. The game also showed that they may jump to another operator in search of a more attractive data package¹¹.

The rapid growth of video traffic is already putting mobile broadband networks under strain. As VR / AR applications increase in popularity from 2020 and beyond, the next-generation wireless technologies that are under development today will be essential for managing the challenges that the pervasive use of VR / AR bring.

10 - <https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White-Paper-on-Automotive-Vertical-Sectors.pdf>
11 - <https://disruptiveviews.com/pokemon-players-switch-telcos/>

LTE-ADVANCED PRO

- ▶ Higher data rates of 3Gbps and over
- ▶ Aggregation of up to 32 carriers to provide 640 MHz Of bandwidth across both licensed and unlicensed spectrum
- ▶ Reduced latency to around 2ms round trip time

Huawei is helping its customers benefit from the very latest LTE standards, including LTE-Advanced and most recently LTE-Advanced Pro. Rolling out these enhancements in their mobile broadband networks will be essential to help prepare operators for the imminent growth of the VR / AR services¹².

The commercialization of LTE-Advanced Pro is still ramping up. Network equipment based on LTE-Advanced Pro 3GPP R13 (frozen in March 2016) is becoming commercially available and is starting to be rolled out. According to the GSA, around 50 operators had trialed, deployed or commercially launched LTE-Advanced Pro networks by July 2016¹³. One of the early adopters is China Mobile Hong Kong, which in partnership with Huawei plans to upgrade its entire TD-LTE/LTE-FDD converged network to the 4.5G standard, bringing higher speeds and lower latency through the introduction of network function virtualization .

LTE-Advanced Pro heralds the beginning of a new epoch of Gigabit enhanced mobile broadband service, which will underpin a high-quality user experience for early mobile immersive services. Building on 3GPP R13, the second release of LTE-Advanced Pro (R14) will further enhance network performance when the standard becomes available in mid-2017.

The improvements will include speed enhancements, a significant reduction in over-the-air latency, and tighter interworking between LTE and WiFi networks.

However, as VR / AR services grow in popularity and become pervasive, mobile operators will need the speed, latency, capacity and performance enhancements that are being proposed for 5G networks. The enhanced mobile broadband capabilities are expected to include peak data rates of 10Gbps, user-experienced data rates ranging from 100Mbit/s in the wide area to Gbps in hot-spots, 1ms over-the-air latency, and high-speed mobility (up to 500 km/h)¹⁴, coupled with improved traffic capacity, spectral efficiency and energy efficiency. The new 5G system will incorporate a New Radio (NR) technology, which will complement evolutions of the current LTE technology.

The first 5G standard (3GPP R15, scheduled for completion in September 2018) will target mobile operators' most urgent requirements for enhanced mobile broadband and ultra-reliable and low latency communications, and will include the use of spectrum above 6 GHz for higher bandwidths. A complete 5G specification covering all the identified use cases and requirements, including massive machine-type communications, will become available in Release 16 (March 2020).

Huawei and its partners have conducted many trials of the new technologies that could be embraced within future 5G standards and will be ready to commercialize these technologies as soon as the standards are defined. As a core member of the IMT-2020 5G Promotion Group, Huawei is working alongside the China Academy of Information and Communication Technology and the Chinese mobile operator community on a series of 5G field trials. Huawei's NR technology, which it demonstrated in these trials, includes a new optimized air interface, full duplex and massive MIMO technologies. These enabling technologies will help achieve a superior end-user experience for emerging mobile broadband services including VR and AR.

12 - <http://www.huawei.com/en/news/2016/5/Huawei-Completes-5G-Key-Technology-Tests>
13 - GSA, Evolution to LTE Report, July 2016.

KEY TAKEAWAYS

01 VR / AR are poised for growth in the consumer market. While we are still in an early adopter phase, the increasing availability of affordable headsets and compelling content will quickly start to extend the penetration and use of such services.



02 By 2025, there will be over 200 million people using immersive gaming and 95 million enjoying live events in VR, according to Goldman Sachs. Mobile network operators will need to decide how their businesses can make the most of the opportunities from delivering mobile immersive services.



03 VR / AR services have demanding performance requirements which will require mobile operators to upgrade their networks to the latest LTE standards, and eventually to 5G, to ensure a high-quality immersive user experience. In the medium term, the enhancements specified in LTE-Advanced Pro will help operators meet the bandwidth and latency requirements.





Copyright © 2016 Huawei Technologies Co., Ltd. All rights reserved. No part of this document may be reproduced or transmitted in any form or by any means without prior written consent of Huawei Technologies Co., Ltd. Trademarks and Permissions Huawei and other Huawei trademarks are the property of Huawei Technologies Co., Ltd. All other trademarks and trade names mentioned in this document are the property of their respective holders.

NOTICE

The product, service, or feature that you purchase should be restricted by the Huawei commercial contract and the clauses in the contract. All or a part of products, services, or features described in this document may not be purchased or used. Every effort has been made in the preparation of this document to ensure the accuracy of the contents, but the statements, information, and recommendations in this document do not constitute a warranty of any kind, expressed or implied. The information in this document is subject to change without notice. Every effort has been made in the preparation of this document to ensure the accuracy of the contents, but the statements, information, and recommendations in this document do not constitute a warranty of any kind, expressed or implied.