Joint Release By

VAPC

OPEN VR LAB

HUAWEI

VR Video

Operator Opportunities in a Booming Market

CAICT 中国信通院

iLab

STRATEGY ANALYTICS
INSIGHTS FOR SUCCESS

February 2018

CONTENTS

VR 1 Executive Summary

VR use cases are varied, including video, gaming, educational content, and enterprise software (such as training). VR video is a key use case for operators, who often run video services themselves, and it is the use case with the broadest market reach.

Streaming VR video at a quality to matching the capabilities of today's high end VR headsets is at the upper limit of fixed line networks, and beyond the capabilities of mobile networks. Although better compression and other bandwidth reducing technologies are becoming standardised, higher resolution headsets with increased demands are also arriving in the market.

Despite some of the hype surrounding VR evaporating, the industry continues to gain traction amongst consumers. Social networks and OTT video providers have continuously launched or improved their VR video offerings over the last 2 years. YouTube now hosts over 850,000 360 videos. Major sporting events such as the Olympics, Champion's League and Superbowl are now routinely broadcast in VR. Developers continue to support the hardware, growing the apps ecosystem. The VR headset installed base will grow from just over 70m at the end of 2017 to 159m in 2022. It is a growing market with clear traction.

Most established video providers (Fox, YouTube, iQiYi) are continuing their core business and adding VR video to their existing offering without changing business model. They are using VR for differentiation, branding, and to reduce churn. Some (Eurosport, NCAA Basketball) are experimenting with new business models for additional revenue, including charging either for VR content or for exploring new advertising opportunities.

Companies in the space have identified some of the key bottlenecks to the development of the VR market. Better resolution in VR hardware is required, although networks today struggle to deliver this. Indeed, network speed is one of the main issues, with companies identifying 50 Mbps as being a minimum for a good user experience. For consumers, some of the biggest issues are related to headset design and comfort, which can reduce the time spent and therefore negatively impact the revenue potential of VR video.

For network operators, unique business opportunities exist because of their key assets: network infrastructure, device distribution, and for some, a video service. Operators are best placed to overcome many of the issues and bottlenecks surrounding VR video and can help grow the market. VR can be leveraged to increase network ARPU. The network can also be leveraged to create new business opportunities around provision of VR video services, both direct to the consumer or B2B.

VR 2 VR Video Network Requirements & Solutions

2.1 VR Use Cases

VR use cases are varied, including video, gaming, educational content, and enterprise software (such as training). VR video is a key use case for operators, who often run video services themselves, and it is the use case with the broadest market reach. We have seen considerable traction in VR video over the past 3 years. VR and sports has been a perfect match and is one of the key categories driving the market, but (as discussed in section 3) many different genres of video and categories of companies have made strong plays in VR video. Social networks, OTT video providers, "traditional" broadcasters, eSports specialists and many others have included VR in their current offerings. A host of start-ups in the sector have also been helping to grow the market.

While video is the immediate opportunity, it is important to note that many of the network enhancements, technologies and business models discussed in this report are also applicable to other types of VR services. Building a network suitable for VR video today will also lay the foundations for addressing other use cases tomorrow.

2.2 What is VR Video?

The simplest definition of Virtual Reality (VR) is that it is a virtual environment that the user can move around in. Using a VR headset (such as slotting a phone into a simple Google Cardboard headset, or the advanced HTC Vive headsets) allows this environment to fill the user's field of vision and let them look around freely, creating a feeling of total immersion. All of the different headsets are "stereoscopic", which means 2 different images are shown, one for each eye. This gives the viewer a sense of depth and spatial awareness. VR video includes a range of different types of video and experiences, discussed in more detail below.

VR "cinema" apps offer the viewer a chance to watch conventional 2D or 3D video in a virtual environment. The advantages are that the user can feel like they are watching a movie anytime, anywhere, on a huge cinema screen. The virtual environment can be social with friends watching with you, and the ability to be isolated from the outside world can also be a feature (useful when travelling, for example).

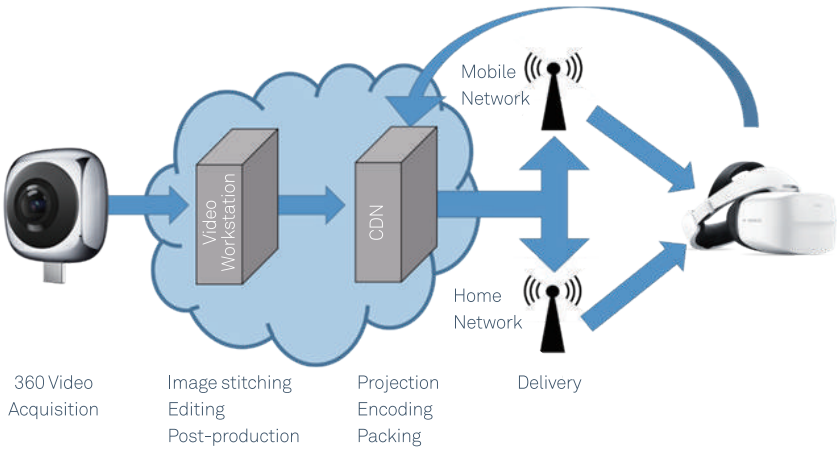
Another form is 360 VR video. In this form, the user is really watching a sphere of video, and while they can look around in any direction (hence the 360), there is not really any interactivity beyond that. Most VR video today is 360 video. A more limited form, 180 video, allows the user to look only at half a sphere. While it is more limited, it is also designed to be easier for both content creators and users, and suits some content better (for example sports, where the camera is placed at the side of the playing surface, and there is no need to see behind the user).

Volumetric VR video (sometimes called "true" VR video) allows the user to move around (or even interact with) the environment. It is a completely 3D virtual environment. One way to think of the difference between volumetric video

and other forms of VR is imagine that with 360 video, you're the passenger in a car. The filmmaker is your driver, who creates a stunning experience and takes you along for the ride. You can look around from your seat and enjoy the scenery. With "true" VR, you are behind the wheel, deciding where you want to go.

2.3 VR Video: From Creation to Delivery

The diagram below shows a simplified view of the steps needed to go from 360 video acquisition through to delivery to a VR headset.



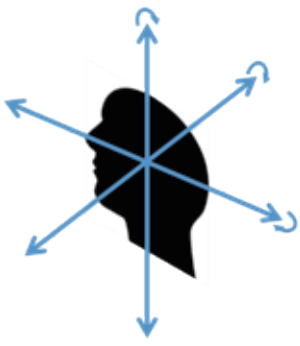
A 360 camera is required to acquire the video. 360 cameras are actually multiple cameras, the most basic with only 2 cameras, while professional 360 camera rigs for broadcasters and movie studios can have 16 or more cameras. The videos recorded by the multiple cameras must first be "stitched" together to create a single composite image. Editing and other post-production techniques are applied to the video using specialist software. This may happen on a local video workstation, or in the cloud. The final video is then delivered to a CDN in the cloud.

At the CDN, the video is transformed by projection, encoded and packed. These functions are performed according to the device the content is being delivered to, as the video must be delivered in the correct format to be played back on the headset. They may also vary according to the network the video is being delivered over – if there is only low bandwidth available, a lower resolution video might be delivered so that the user does not have a poor experience with constant buffering. Finally, the relevant video feed is delivered over a network to a VR headset. If the video is being delivered in a "viewport dependent" fashion (described later in this section), or the VR content includes some level of interactivity, there must also be a mechanism for the VR headset to transmit data back to the CDN over the same network.

2.4 Image Quality and Bandwidth Requirements

2.4.1 360° Video Delivery Today

360 video is the simplest form of VR video, where only 3 degrees of freedom (DoF) are supported. In essence, the user's viewing perspective is from the center of the sphere looking outward towards the inside surface of the sphere, and the 3 DoF represent the user moving their head around a fixed point.



One of the key challenges of delivering VR video is that the user could be facing in any direction at any time. Today, most 360 video delivery sends not just what the user is seeing in their field of vision, but a complete 360 sphere of video (full view transmission). This sphere of video is actually delivered as a series of flat (2D) geometric shapes which can be thought of as being "folded" together to create a spherical video image. This stage of the process is called "projection". Equirectangluar projection (ERP), the most common technology, uses a series of tiles to make up the sphere. Many popular VR video services today, including YouTube and iQiYi, use full view transmission based on ERP.

Using this type of video transmission, in order to get a good resolution for the users' field of view, a much larger video image must be delivered than the one the user sees. The user is only viewing approximately one quarter of the delivered video sphere at any given time (the exact proportion depending on the field of view that the headset allows). The original HTC Vive's resolution of 1200 x 1080 approximately equates to a 4K video sphere, and for the Vive Pro or equivalent devices, a 6K VR video is required to give the best possible viewing experience. VR headsets are reaching the market in 2018 which can deliver 8K VR video. For an image giving an experience equivalent to a 4K TV set, a 12k resolution or greater VR video is required – beyond the capabilities of VR headsets today. The table below gives an overview of the approximate bandwidth requirements for full view transmission as the quality of the video increases.

Image Quality	Resolution seen by user, per eye	FPS	Bandwidth	Wireless Network	Mobile Network*
Basic smartphone VR	320x180	30fps	6 Mbps	Wi-Fi	LTE
4K VR	1200 x 1080	90fps	50 Mbps	802.11ax, WiGig	LTE-A Pro
8K VR	1920 x 1920	90fps	120-200 Mbps	802.11ax, WiGig	5G
12K VR (4K TV equivalent experience)	3840 x 2160	120fps	0.6-1.4 Gbps	802.11ax, WiGig	5G (real world deployments may not reach this speed)

*Network speeds refer to typical speeds found in "real world" conditions rather than maximum possible data speeds

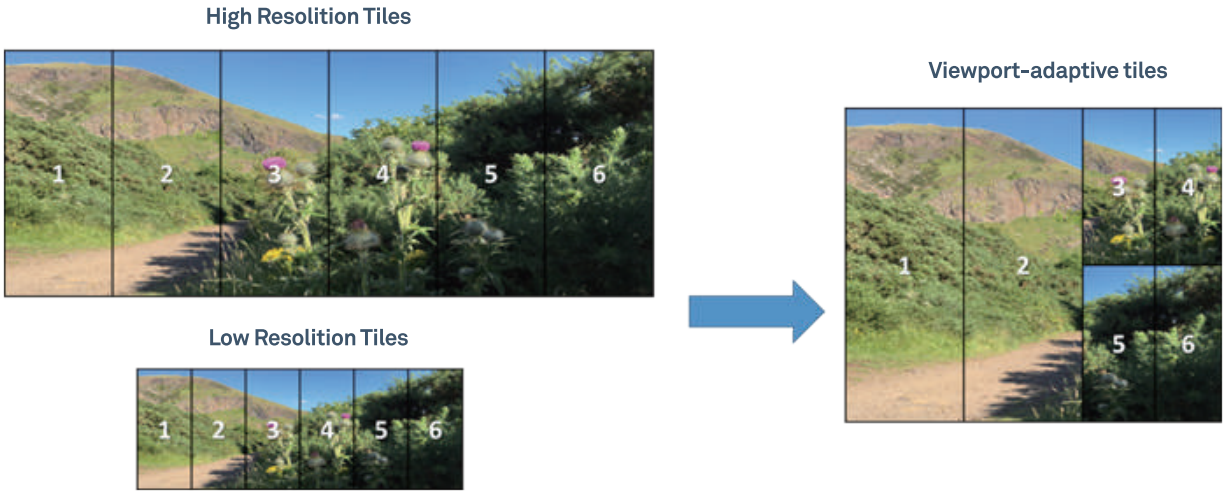
Most current generation Wi-Fi routers are typically not fast enough for HD VR video. This is part of the reason that the HTC Vive, Oculus Rift and other headsets are tethered; the cable is required to get fast enough data transfer speeds (as well as very low latency) as today's wireless networks are not adequate.

2.4.2 Improving VR Video Delivery

Better compression is one of the key ways in which the bandwidth required to deliver VR video can be reduced. As conventional video standards and compression technologies improve, many of these will also be applicable to VR video. One particular aspect of stereoscopic VR video is that although two different images are transmitted simultaneously (one for the left eye and one for the right eye), those images are very similar, and so compression efficiency can be greater for VR video relative to conventional video, even when using the same coding technology. Tests have shown that compression efficiency for stereoscopic VR video can be up to 25% higher than for 2D video.

Alternative projection technologies (such as Cubemap Projection or CMP) divide the sphere into other geometric shapes which are then projected onto a simpler polyhedron. These can offer better compression as well as lower distortion of the image, also resulting in a better user experience. Standards for these alternative projection techniques are not yet finalized.

Another way of reducing bandwidth requirements is not to transmit the entire image in full quality. This is variously referred to as "viewport dependent", "viewport adaptive", "Field of View (FoV) transmission" and "region-wise encoding". The basic concept is that although the complete sphere of video is still transmitted to the user, only the tiles of video in the current field of view are in high quality, and the remainder transmitted in lower quality.



In the example shown above, the user's FoV is tiles 1 and 2, which are transmitted in high quality. The remainder of the tiles forming the video sphere are transmitted at low quality. While this can reduce bandwidth requirements by (typically) 30%, it requires that information on the user's head position must be transmitted back to the server providing the content so that the correct video stream is delivered. Fast head movements will result in the user seeing a poorer quality image for a short period until the correct, higher quality image tiles are delivered. Thus, a very low latency network is preferred. Good caching (at the CDN, the network edge, or on the device itself) can also improve the user experience.

2.4.3 Future Enhancements to VR Video

One of the key enhancements on the near horizon for VR video is volumetric video. Rather than transmit only a sphere in which the user sits passively in the middle, the user is placed into a 3D scene. The user can not only rotate their head around, but can move around inside the scene (often this is referred to a 6 DoF) and look at objects or people from different angles. Various companies including Adobe, Intel, NextVR, and HypeVR are already producing volumetric video. The level of immersion is greater, the possibilities for creative storytelling are greater, and interaction becomes possible. However, all of this will come at the cost of even greater network requirements.

2.5 Standards

A number of bodies are working on standards to improve the delivery of VR video.

Although not specific to VR video, the H.265 compression standard, also known as HEVC (High Efficiency Video Coding) or MPEG-H Part 2, should improve the delivery of VR video through better compression. The standard builds on H.264. H.265 offers compression approximately 50% better than its predecessor. One of the barriers to using H.264 for VR is that it only supports images up to 4K, and so is not suitable for the high-end VR devices in the market today. H.265 supports images up to 8K. Future standards will be required to deliver a 4K TV-like experience to VR headsets.

MPEG is also working on standards for viewport-dependent VR video delivery, called OMAF (Omnidirectional MediA Format). At the time of writing, this has reached its final draft but is not yet published by ISO/IEC. In order to create a standard for viewport-dependent 360 video, it specifies a coordinate system for 3 DoF 360 video and region-wise packing. It also includes standards for different projections, storage, encapsulation, signaling and streaming.

Other standards work includes:

• As well as the standards listed above, MPEG are also working on improved standards for spatial audio (part of MPEG-D) and the MPEG-V standard, which aims to standardize models of interactivity within virtual worlds, potentially allowing for more interactive forms of VR video

• ETSI and VRARA are working on the MEC (Multi-access Edge Computing) standard to ensure the specifications address the requirements for delivery of VR applications

• The IEEE's VR and AR working group began its efforts in 2017 and is looking at standards for a range of relevant areas, including VR video and audio, and like MPEG-V, interactions between the virtual and real world

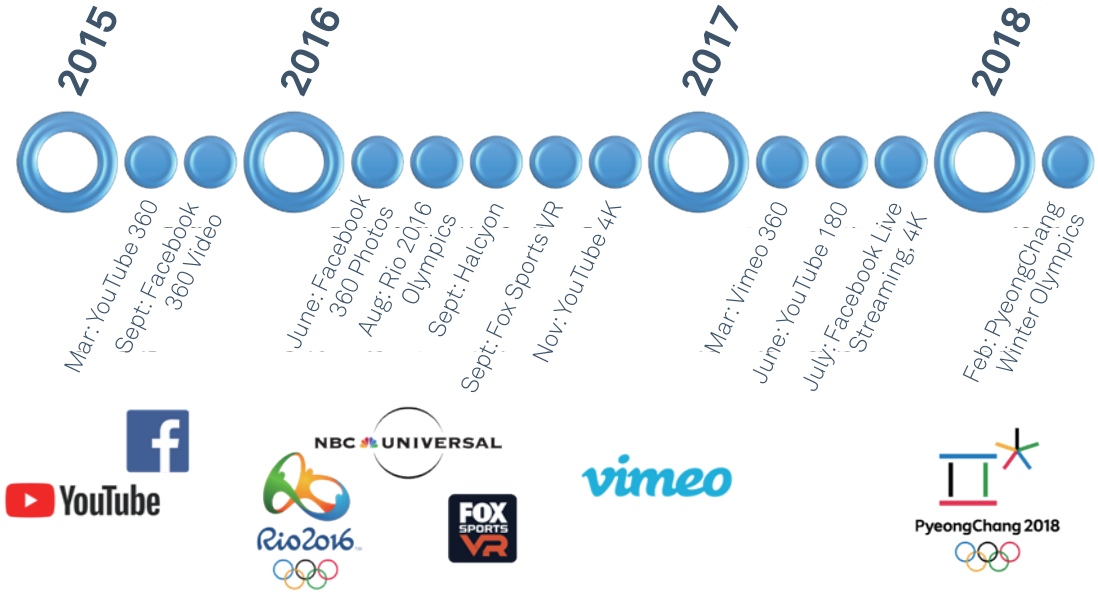
Some of the companies interviewed for this report highlighted standards, and in particular the need for a standard on viewport-dependent video:

• iQiYi believes that the industry should move forwards quickly on a standard for interaction between the VR headset and the content platform to provide feedback on the user's motion. This is a requirement for viewport dependent VR which can reduce the bandwidth requirements and improve the user experience

• Letin VR also believes this is an area where standardization is required. The company has been working with MPEG and IEEE to help define a standard interaction mechanism, and believes chipsets supporting this will become available within the next year

3 VR Video Industry Trends: Service Traction

Although some of the hype may have left VR in the past year, in fact VR video has been gaining traction amongst consumers and usage of VR video continues to grow. This section looks at some interesting case studies showcasing the continued growth of the VR video market. The timeline below shows a brief summary of some of the key market developments over the past 3 years.



3.1 VR Cinema Apps

A number of different companies have offered VR cinema apps. As described earlier, typically this is a fully virtual environment usually designed to look like a cinema, and the user watches "conventional" 2D or 3D video on the virtual cinema screen. Many different categories of companies have developed this type of app, including operators, OTT video companies and OEMs. Examples include the Orange Cinema Series app, which provides users of its pay TV movie service with a VR cinema app. OTT providers Netflix, Hulu and iQiYi have VR cinema apps. VR device vendors also supply the same, and often these apps allow users to view their own content in the virtual cinema environment. Samsung Gear, Oculus and Vive all have cinema apps created by the vendor, although typically content for these is limited. Perhaps the most interesting of the device vendor apps is Huawei's VR cinema app for the VR2 headset, developed in partnership with IMAX. The partnership brings a strong consumer brand, has helped to create a visually compelling environment, and most importantly gives users access to a much wider range of content than that of other OEM-developed VR cinema apps.

3.2 Sports

The usage of VR video in sports has been one of the key trends. Many broadcasters are using VR to enhance live coverage, replays and highlights packages, and provide richer "behind the scenes" content, and other content focused around the journey of individual athletes. The Olympics has helped to showcase VR sports, and Fox Sports has been one of the most innovative broadcasters incorporating VR into its coverage of many sports. These case studies are detailed below.

The use of VR in sports is being driven in part by the competitive dynamics in a given market, with operators launching VR services to keep pace with innovation by rivals. For example, in the UK, pay TV broadcaster Sky has been experimenting with VR to enhance sports coverage including soccer, cycling and Formula One. UK operator BT, which has launched its own pay TV sports channels to rival Sky, broadcast the UEFA Champion's League final in VR in 2017. Terrestrial free-to-air UK broadcasters BBC and ITV have also been innovating using VR; the BBC carried coverage of the Rio Olympics in VR while ITV has experimented with VR to enhance its horseracing coverage. Similarly, in the US, not only has Fox Sports been investing in VR (see case study below), its rivals CBS Sports and Turner Sports have also launched VR sports coverage to compete.

As well as Europe and North America, VR sports have taken off in Asia, with many examples. The Olympics VR coverage has been taken by many Asian networks, including NHK (Japan) and KT (South Korea). NowTV launched its VR sports coverage with the Hong Kong Sevens rugby tournament. In China, at the recent AFC (Asian Football Confederation) U23 Championship, LetinVR's VR live broadcast got 5+ million page views per game, and simultaneous online fans reached 650,000.

3.2.1 Case Study: Fox Sports

Having launched its VR sports app in 2016, Fox Sports has been constantly improving and expanding its VR offering over the past 2 years. The first game to be broadcast in VR was the college American football match between Ohio State and Oklahoma. Since then, the company has expanded its coverage, not only increasing the number of games shown, but also the number of sports, the camera views available, and the features available in the app. Fox has broadcast more games from more leagues in VR, notably including the 2017 and 2018 Superbowl. As well as college football, soccer has been added, including the Champion's League final. Basketball games, boxing, NASCAR, golf, hockey and even monster trucks have since been added to the different sports broadcast in VR. The VR content is free, but only to Fox Sports subscribers, so the business model for VR is marketing and brand positioning for its core proposition.

Many new features have been added to the VR coverage. Additional camera angles allow the viewer to see the action from a different view point. These have included adding the "skycam", and even a player's perspective from cameras mounted on players. Social features have been added, allowing viewers to interact with each other in a virtual environment. In order to deliver VR sports, and to add these new features, Fox has adopted a partnership model, using a number of different partners including NextVR, LiveLike, Intel, Beyond Sports, and GoPro.

Although viewer stats have not been released, the constant integration of new sports, new features and new camera angles, all of which require significant investment, show that VR has been delivering value to Fox Sports over 2

years. The Android version of the app has been downloaded over 50,000 times; stats for iOS are not available but are likely to be higher than for Android.

3.2.2 Case Study: Olympics

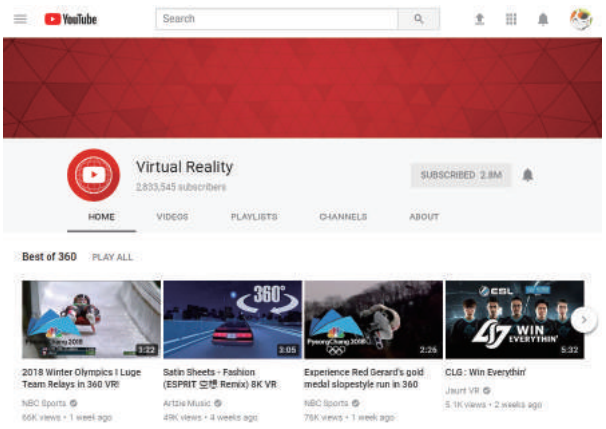
The Olympic Broadcast Services (OBS) company is the host broadcaster for the Olympic Games, providing the video feeds for broadcasters which have bought rights to show the Olympics. The 2016 Olympics in Rio de Janeiro was the first games to be broadcast in VR. OBS distributed more than 85 hours of live VR coverage, captured by custom 360 camera systems, to a total of 14 rights holders across 31 countries, including NBC (US), BBC (UK) and NHK (Japan). Few viewer figures for the VR content are available, but the BBC reported 13,500 viewers in the UK alone.

50 hours of 30 different events at the 2018 Winter Olympics in Pyeongchang will be broadcast in VR, along with some "behind the scenes" content following the journey to the games of various Olympians. Rights holders are experimenting with different business models for the VR content. Eurosport (the rights holder for most European countries) will be providing VR video through an app which costs €0.99. NBC is distributing the content via a free app to its pay TV subscription base, using this as a differentiator. Intel is a sponsor, and the Intel True VR platform will be used to provide end-to-end VR video, from capture (using Intel's own cameras) through to distribution (Intel has worked with NBC to develop their end-user app). The 2020 Olympics in Tokyo will feature further VR coverage, and Intel will again be a sponsor of that event.

3.3 Social & Live Streaming

Social networking services were some of the earliest movers in adopting VR. Both Facebook and YouTube have offered both live streaming and pre-recorded VR video since 2015. As shown in the case studies below, there has been signification traction from both services around their VR coverage. Other social networks have also been launching VR services. In China, Sina set up the subsidiary Sina VR, which has launched a VR Media Center, VR Live Room, and VR Video production. 360 photography has also been introduced to the Sina Weibo network.

3.3.1 Case Study: YouTube



Name	Views	Category
Caught on 360 Cam	29.1M	Vlog
Great White Shark	26.3M	Factual
World Surf League	18.8M	Extreme sports
Avicii	18.7M	Music
Five Nights at Freddy's	16.0M	Games
Skydive in 360	14.1M	Extreme sports
Foals	13.7M	Music
360 Shower	13.0M	Softcore adult
360 Fighter Jet	11.1M	Factual

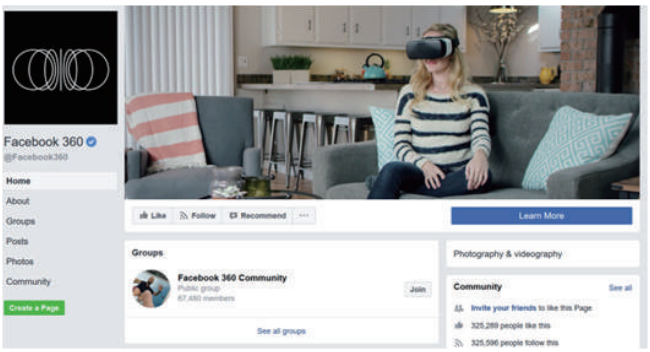
YouTube originally launched 360 video in March 2015, and added 4K video resolution support in November 2016. In June 2017, the company announced a new format, "180 video". As the name suggests, the user can only turn 180o, but the video is still stereoscopic and the format is designed to be easier for content creators and more comfortable for viewers. Finally, YouTube also has a number of online classes available to help 360 video content creators.

There are over 850,000 360 videos on YouTube. The curated "YouTube 360 Channel" includes just over 350 videos and has 2.8M subscribers, up from 2.3M in April 2017. It's worth noting that "subscribers" are simply users signed up to alerts; many more users can watch videos. In fact, there are clearly many more users than the subscriber numbers – below is a list of all 360 videos on the YouTube 360 channel with more than 10M views.

The single most popular 360 video on YouTube with 70M views is a VR "raid" from popular gaming franchise Clash of Clans. Overall, the most popular other videos generally fall into the categories listed above – a mix of factual, sports, music, gaming, and softcore adult content. Most of the popular videos are produced by either professionals or "prosumers" (typically vlogger or extreme sportsperson).

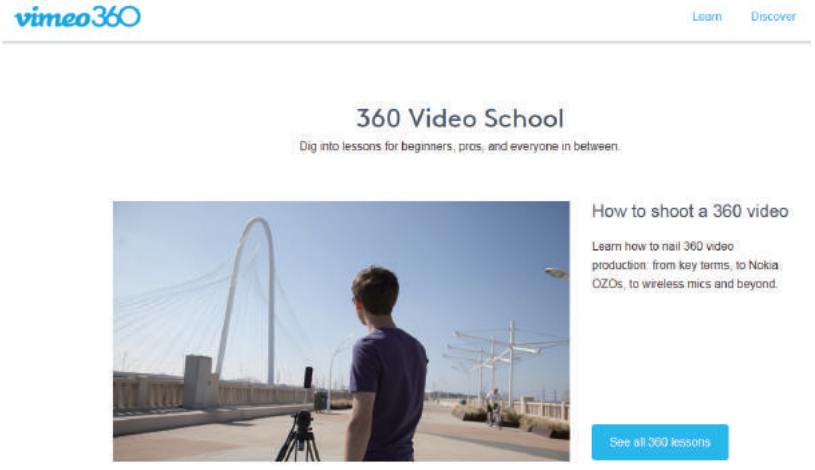
3.3.2 Case Study: Facebook 360

Facebook originally launched 360 video in September 2015. At launch a number of brands including Star Wars, Discovery, GoPro, NBC's Saturday Night Live, and VICE published videos to connect with their existing Facebook audience. As well as content from brands, Facebook also includes a lot of user generated content. By February 2016, a total of 20,000 videos had been uploaded, and users had spent more than 1 million hours watching these clips. By March 2017, this had increased 50-fold, with over 1 million 360 videos shared on the platform. The company's own Facebook 360 community, which provides help for content creators, has over 67,000 members and over 325,000 followers.



Most recently in July 2017 it added live streaming of 360 video, along with support for up to 4K resolution. Facebook has also introduced 360 photo sharing, although this came later than video (arriving in June 2016). Over 25 million 360 photos we shared by March 2017.

3.3.3 Case Study: Vimeo



Vimeo added 360 video in March 2017. Despite the relatively recent launch, there are already around 10,000 360 videos uploaded to Vimeo. As a site which focusses on professional video content, Vimeo has higher quality than its competitors YouTube and Facebook. Content creators can upload 360 video in 8K resolution using H.264, although it is downscaled to 4K for viewing. The

curated 360 video channel, "360 Cinema", has 43 videos and 123,000 followers. Like the rest of the site, the curated content is primarily short films, documentaries and music videos. The most popular video on the site, "Zurich 2.0", has over 250,000 views and is a tour of Zurich. The site's creator community includes many 360 video tutorials for content creators, and, as with "conventional" video on Vimeo, creators can sell or licence their 360 videos to third parties.

3.4 Game Streaming & eSports

One major use case for VR is gaming, and game streaming websites such as Twitch (recently acquired by Amazon) have also integrated live video streaming of VR games. Twitch has integrated with the PSVR, Vive and Rift headsets to allow user to stream videos of VR gameplay directly. Twitch apps are also available to allow users to watch both VR and conventional 2D video streams in a VR environment. Typically, these include social elements, allowing multiple users to watch the same streams "together" in a virtual environment.

The world's biggest eSports event, The International Dota 2 tournament, is shown in VR. Developer Valve has created a "VR Hub" specifically for coverage of Dota 2 tournaments. The hub features social elements, allowing up to 15 users to simultaneously watch the same stream and interact with each other. League of Legends, another major eSports title, has also experimented with broadcasting 360 video footage of its tournaments.

Dedicated VR gaming video streaming sites have also started up, including Sliver.tv and VReal. At the IEM World Championship in March 2017, Sliver.tv's broadcast had attracted 340,000 peak concurrent viewers. VReal is a pre-launch VR esports network, but has raised over $15M in funding to date.

3.5 Other

VR video is varied and diverse as "conventional" video, and although the categories of sports, social and gaming have been major drivers, there has been no shortage of VR activity in other video genres.

Many broadcasters, including HBO and Discovery (US), BBC (UK), NHK (Japan), Orange (France) have added VR to enhance their offering. Discovery has one of the most advanced VR offerings from "traditional" broadcasters with multiple VR video documentaries watchable via its dedicated app. The BBC has trialled over 30 different VR experiences with consumers through its range of "taster" apps and programming. Also of note is NBCUniversal's Halcyon TV series, detailed in the case study below.

OTT video providers such as Netflix, Hulu, Amazon and iQiYi have also been adding VR video content to their mix of programming. In their case, as well as a VR cinema app, they have typically also created specific VR content. This has usually been associated with their most popular shows. Netflix has a VR experience for Stranger Things, Amazon has a VR episode for Mr. Robot. Hulu offers a range of VR content from its various content partners, while iQiYi has one of the widest ranges of VR content available, including 20,000 360 video clips, 10,000 films, 3,300 TV series, and 3,000 cartoons in iQiYi's VR content platform.

3.5.1 Case Study: Halcyon

The Halcyon TV series, created by SyFy/NBCUniversal, was the first broadcast TV series with multiple VR episodes. The 15-part series, first broadcast in September 2016, included 5 episodes filmed in VR, which included interactivity, allowing the viewer to become immersed in the narrative and discover clues. In addition to the episodes, VR content included a VR "museum" featuring items from the show, and promotional activity included a live audience Q&A in VR using the VR social network AltSpace.

VR 4 VR Video Business Models

As shown in the case studies, VR video can be used to enhance the business and profitability of broadcasters and other content providers, either through enhancing their existing offering or opening up new business models.

4.1 Business as Usual?

All of the "traditional" video business models can be applied to VR, and in fact are being applied to VR video. Most broadcasters and other content providers already in the video space have extended their offering to include VR video, and typically this extension has not involved any change in business model. From our selection of case studies, YouTube, Vimeo, Facebook, Fox Sports and iQiYi have all added VR video without making any business model changes. Whether paid or ad-funded, it remains business as usual despite the changing technology.

These cases also demonstrate that direct revenue generation from VR is not the only reason to provide VR video. Differentiation can be a key commercial driver. Also from a branding perspective, companies providing VR video can be seen as more innovative than competitors. The greater immersion that VR provides can be a selling point for certain categories of video, particularly sports. So while Fox Sports may not make additional revenue directly from VR video, it can keep its existing users more engaged (and less likely to churn) and attract new users to subscribe. As noted in the case studies with the example of all major broadcasters in the UK delivering VR sports, deploying VR may also become a commercial requirement depending on the competitive dynamics in the market. This is not limited to only sports; in South Korea, LG U+, KT and SKT all launched VR entertainment video (rather than sports) within a 6-month period.

In the cases of Google's YouTube, Facebook and iQiYi, while the VR content may not be a direct revenue generator, these companies also sell VR hardware. Having an ecosystem of compelling content provides them with a major selling point for their hardware business. This model can also work in reverse. Sony typically sells PlayStation hardware at close to zero margin, building an installed base of users for which third party developers create games. Sony then takes a share of the games revenue. Zero profit on hardware can create profit from content, just as zero profit on content can create profit from hardware.

4.2 New Business Models

New business models, or new business opportunities, have also arisen from VR video, and these too have been explored by video providers.

• **VR charged as an add-on:** there are broadcasters charging extra for VR coverage. In the case of the Olympics, not all the broadcasters showing the games have VR coverage. This indicates that OBS is selling the VR coverage as a separate B2B package to its broadcast partners. Eurosport, which has the European rights, is also subsequently selling VR coverage at an additional cost to its viewers. The app to watch Eurosport's VR coverage costs €0.99.

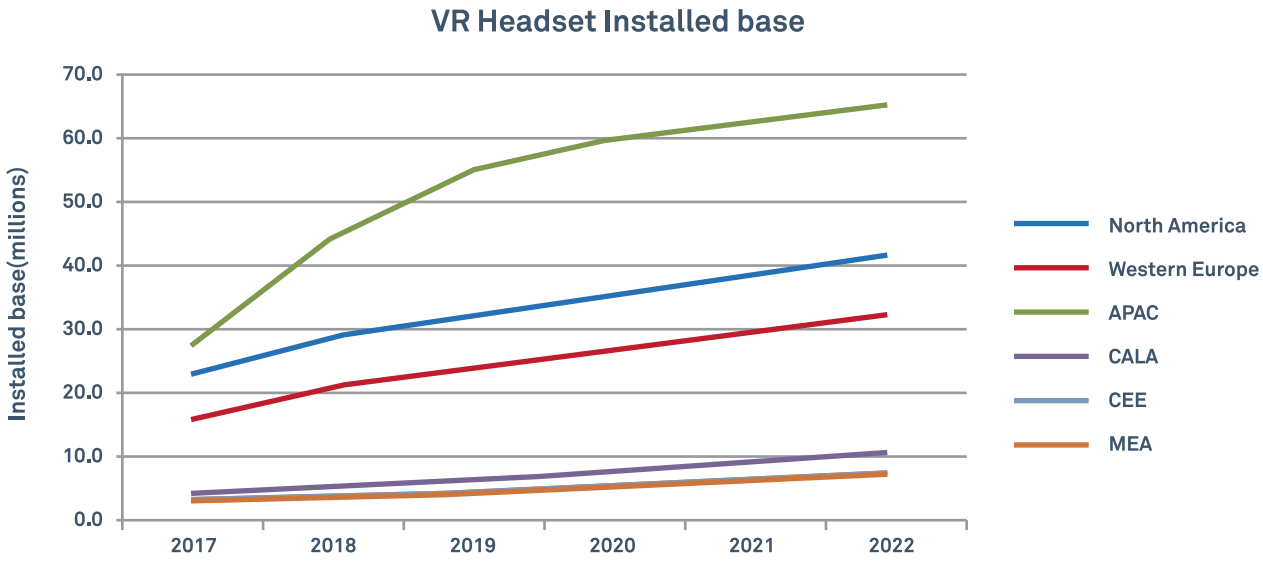
• **New camera angles:** as part of the NCAA Basketball (broadcast by CBS Sports and Turner Sports), not only is watching in VR an extra cost, viewers could choose 2 ways to watch games in VR. The "silver" ticket, priced at $1.99 per game, allows the viewer to watch from a single courtside camera with the conventional commentary. A "gold" ticket, costing $2.99 per game, gave the viewer access to footage from multiple 360 cameras along with a dedicated commentary specific to the VR coverage.

- **New advertising opportunities:** VR as a more immersive medium creates opportunities for new types of advertising.
  - Many brands and advertisers have embraced VR in their ad campaigns. As well as helping them to be seen as an innovative brand, it allows them to interact with consumers in new ways.
  - Advertising space in VR video could be more valuable than other forms of ad delivery, since when the user is wearing a VR headset they have 100% of their attention focussed in the virtual environment. They are not checking their Facebook feed on their phone instead of looking at the TV screen, for example.
  - The sensors in VR headsets can also be used to improve the analytics provided back to advertisers to help them judge the effectiveness of the ad. For example, was the user looking at the product, or were they looking elsewhere? This data can also be monetised.

5 VR Video Industry Trends: Tools and Enablers

5.1 Hardware

5.1.1 VR Headsets



Strategy Analytics market data shows that just over 70 million VR headsets were in use at the end of 2017, and this is projected to grow to 159m by 2022. The largest market is Asia Pacific, with over 54m headsets in use. APAC is also expected to continue to drive the market for VR headsets, reaching an installed base of over 64m by 2022.

While VR has a lower installed base compared to mass-market media (such as TV), it is still represents a sizable addressable market. VR also represents an opportunity for video service providers to increase ARPU by launching VR video as a premium service. As an innovative new technology, VR video services can also be leveraged to help with marketing and brand positioning.

The installed base of hardware is likely to be exceeded by the number of users, since more than one user can access content from a single device. Examples of this include VR cinemas (such as Samhoud in Amsterdam) and the use of VR in theme parks (Disney's Star Wars experience at Disney Springs in Orlando). Strategy Analytics expects this effect to be particularly pronounced in China where users are more likely to experience VR in arcades and internet cafes rather than at home. The real market impact of VR will reach beyond the installed base figures.

5.1.2 Other Hardware

Aside from the headsets, other hardware requirements are also showing positive market progress:

• VR-ready PCs are coming down in price and therefore becoming more accessible to a broader range of consumers. For example, at CES 2018, Dell announced a range of VR-ready PCs starting at $799. This has 2 important market effects. Firstly, it broadens the potential market for PC-tethered VR headsets. These are typically the high end headsets in the market today, such as the HTC Vive and Oculus Rift devices. Secondly, it also increases the number of people who have a workstation capable of stitching and editing VR video. This should lead to more VR UGC.

• 360 cameras are also decreasing in price. For example, the original Samsung Gear 360 camera launched at $350, but a year later an improved version was launched at $229. Across all 360 cameras, resolutions and frame rates are continuously improving, and one notable feature which has been added to several cameras is image stitching on the camera itself. This speeds and simplifies the workflow for content creators. Overall, the market remains aimed at the professional and "prosumer" price brackets with many cameras priced at over $500 (the prosumer price bracket) and up to tens of thousands of dollars for professional rigs.

• As discussed in section 2.3, the resolutions of VR headsets outstrip the capabilities of networks to deliver content. However, many new technologies have either recently launched, or are shortly due to launch, which will change this situation.

- Next generation Wi-Fi such as 802.11ax and WiGig can provide better wireless delivery in the home
- 5G networks should start to launch in 2020 and will improve wireless delivery outside (and even potentially inside) the home
- New network technologies such as MEC and network slicing can further improve network QoS

5.2 Software

The most well-known professional video editing and post-production tools have all integrated VR in 2017.

• Adobe acquired Mettle in June 2017. Mettle was previously an independent company creating "plug-ins" for Adobe software such as Premiere Pro and After Effects. These plug-ins now form part of Adobe's Creative Cloud suite of tools. These VR video tools are available at no extra cost.

• Avid has created new VR tools for audio, launched in October 2017, but relies on third party plug-ins (such as Mocha) for VR video editing

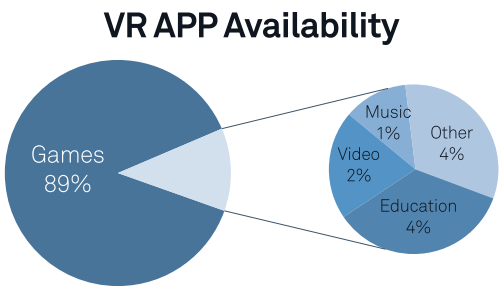
• Final Cut Pro added VR video editing capabilities in December 2017

However, these tools primarily target the professional market (broadcasters and movie studios) and the "prosumer" market. Aside from the price point, these tools are feature-rich and have a very steep learning curve, making them unsuitable for the mass market. In terms of simple and low-cost tools for the broader market, more and more are launching from multiple independent app developers and start-ups. They include VeeR (by VeeR), V360 (Avincel) and PowerDirector (Cyberlink). Some 360 camera vendors are also supporting their hardware with their own editing software, such as Theta+ (Ricoh) and Gear 360 ActionDirector (Samsung).

5.2.1 VR App Store Content

The selection of VR apps currently available to end users through dedicated VR app stores also sheds light on how the VR market is developing. Apps are an important way of consuming content, such as VR video. Strategy Analytics has collected data from the top international dedicated VR app stores, including the stores for Samsung Gear VR and Oculus Rift, and the VR apps available via Steam and Sony's PlayStation Store. Across these stores, the total volume of apps has grown from 1,608 to 4,184 (a 260% increase) in less than a year, demonstrating continued support for VR hardware from developers and brands.

The Steam store is the leader with over 2,000 VR apps available.



Data from Samsung Gear VR Store, PlayStation VR Store, Steam, and Oculus Rift Store

The Samsung Gear VR store has the second largest catalog of VR content, and although it is also dominated by games, it has the highest proportion of non-games apps. Examining the non-game apps available highlights the importance of educational, video and music content.

The Movie/Video category includes video streaming apps and "movie experiences". Video streaming includes the VR distribution channels of some well-known video apps from major international OTT video providers (such as Hulu, Netfilx and YouTube) and specialist VR video companies (such as Jaunt, Within and NextVR). Movie experiences, often from blockbuster movies such as Ghostbusters, The Martian and Spiderman, typically feature a mix of VR video content along with other content, such as the ability to explore sets from the movie in VR. The Music category includes a mix of apps including music videos, while many "Other" apps also feature video content.

While the available movie/video apps only account for just over 2% of the total volume of apps available (games account for 89%), this does not reflect their overall importance to the VR ecosystem. Video apps account for a disproportionately high volume of downloads and usage. For example, Samsung indicated that 50% of time spent by users of Gear VR headsets is VR video, although video apps account for only 4% of available apps on its store.

6 VR Broadcast Challenges

6.1 Bottlenecks

In order to identify the bottlenecks in the VR market today, Strategy Analytics interviewed a range of companies in the VR space. These include content creators and distributors, social networks, hardware vendors, and tools providers.

6.1.1 Hardware

Although the smartphone and low-end VR products (such as Cardboard) have helped build the market for VR and make it accessible to many consumers, views of the companies interviewed are quite negative.

• SINA believes that since VR is an experience-centric product, retail channels (where consumers can try out the hardware) will be important for consumers to get the real experience and select the right product

• 3D BoBo has seen a clear trend in their online shop that consumers are moving from low end VR products (such as Cardboard) to mid/high end. Low cost products can't meet consumer's expectation, so the growth has been slowing as the requirements are different between VR and smartphone. There is not a strong demand for 4K display for smartphone but a 4K display is a must-have for VR experience

• iQiYi believes that hardware is bottleneck, including power consumption, the chipset, comfort factor and particularly the display. 4K screens are a minimum for VR, and is investing in 8K content, which cannot be met by low end VR

• Letin VR believes the low end VR does not give a good enough user experience, and is also investing in 4K and 6K VR content for high end hardware

• Whaley VR also mentioned the hardware as a bottleneck, particularly the comfort, and they are also promoting 6K content for high end hardware

While many companies were negative about low-end VR, overall there was positivity about newer hardware.

• 3D BoBo is optimistic since some heavyweight companies will enter the VR hardware business in this year. 3D BoBo hopes these large vendors could push the development of a VR supply chain independent of smartphone OEMs. Meanwhile, telecom operators could also play a role through providing subsidies

• iQiYi thinks that the standalone VR headsets coming in the near future will become the standard, although since standalone isn't as powerful as a PC, they are more suited to video content than gaming. The company is developing its own standalone VR headset

• Letin VR sees affordable standalone headsets, possibly subsidized by operators (as China Telecom is doing for its 1 Gbps Fiber service) will boost adoption

Improvements in cameras were also seen as important, particularly by content creators.

• SINA VR expects the integration of 360o photo sharing to SINA Weibo to give consumer VR a boost

• Whaley VR wants to use aerial and underwater VR cameras to create novel content, and is also investigating cameras with light-field to produce volumetric VR content to improve content creation

• NextVR has been investing in its own camera technology in order to create volumetric VR

6.1.2 Network

Speeds are the main issue for VR today, although other network elements can also be improved in order to help grow the market for VR.

• SINA VR feels network speed is having a negative impact on the user experience, particularly high quality VR video and for social apps

• 3D BoBo feels that at least 50 Mbps is required for a good user experience, but that the VR industry can also help in this regard by improving video coding

• iQiYi also feels that 50 Mbps is a minimum for a good experience. However, most of their consumers can't get this speed, particularly during peak hours. They believe that increased fiber rollout and the use of content delivery on the network edge can accelerate the market

• Whaley VR believes that network bandwidth is important, and that network operators can play a role by guaranteeing bandwidth, and distributing VR headsets aligned with to the quality of VR content which can be delivered over their networks

• Letin VR targets a 30-50 Mbps network speed as a minimum, but also notes that VR content distribution can be improved by optimization of the entire network including CDN and cloud server infrastructure

6.1.3 Content

Higher resolution video (and the required network speeds) is the main concern for most of the VR industry. However, there are also bottlenecks in content creation and the types of content available.

• iQiYi does not believe that UGC offers a good user experience and are focussing on professional content to guarantee the quality and user experience of VR

• Whaley VR believes content offerings could be improved. More sports content could help drive the market, as there is a big crossover between sports fans and high tech early adopters. Strict content regulation in some markets is also creating a barrier; for example "adult" content is popular in many markets, but forbidden in others

• Letin VR hopes that content production tools are a barrier, and could be improved in future

• NextVR has had to invest in its own production tools specific to volumetric VR video to provide functions which current production tools cannot perform

6.2 Consumer Pain Points

Strategy Analytics has compiled consumer feedback from owners of a range of VR headsets including the Samsung Gear VR, HTC Vive and Sony PSVR. What are the key "pain points" for consumers?

• Nausea is a common complain across all devices, and is a typical consumer pain point about VR in general. We also find a correlation between the type of content and the level of nausea. Content where the user remains in a static position (such as video) led to fewer complains, compared to gaming and particularly games which involve a high degree of motion (such as driving games)

• For smartphone-based VR, the most common complaint was heat. VR content typically uses the maximum capabilities of the smartphone, generating a lot of heat and draining the battery.

• For the HTC Vive, the most common complaint was the difficulty of setup. In order to provide a high quality experience with rich user input mechanisms, the device uses "outside in" lighthouse sensors which must be placed around the room by the user and calibrated before use.

• For the Sony PSVR, nausea was by far the most common complaint and indeed the only complaint of significance – consumers rated the device extremely positively.

• The cable was an issue for Vive users. In contrast, the cable was not an issue for PS VR users – but Vive is room-scale VR rather than seated so the cable is more likely to become a trip hazard as the user moves around. Also, several users noted that the cable felt heavy, particularly after prolonged use

7 Opportunities for Operators

Network operators, particularly those with (or planning) video services are in a unique position to leverage VR video. With an innovative media offering, control over network infrastructure, and a role in device distribution, unique opportunities and business models are open to network operators.

7.1 Overcoming Bottlenecks

7.1.1 Hardware

Most of the participants interviewed for this study identified the need for higher quality content resolution needed to improve the user experience. Today's delivery of 4K video will soon be superseded by 6K and 8K video. This obviously requires appropriate hardware, and operators can play a role in distributing devices to consumers. This could be via retail channels or bundled with a service or content offering. Since VR is primarily an "experiential" technology, VR in retail channels can also be used to provide consumers with an experience of VR, stimulating demand. Operators can also play a role through hardware in reducing the cost of VR to end users. This can be done by distributing "thin client" hardware (see below "Creating a compelling user proposition by using cloud technology"), although the appropriate network features need to be in place to support content delivery to such devices.

7.1.2 Network

From our interviews with current industry players, it is clear that 50 Mbps is regarded as the target for delivering today's 4K VR video. In order to open up the opportunities around VR video, operators should be targeting this speed or higher. This can be delivered through FTTX or 5G networks. Bandwidth is not the only important consideration for VR. Low latency in the network is also important, especially if technologies such as viewport dependent encoding become commonplace. Operators can influence this primarily by moving CDNs to the edge of the network, which can also open up some B2B models (see below).

For user's home networks, operators can again influence perceived QoS. Most current generation Wi-Fi routers are typically not fast enough for HD VR video. This is part of the reason that many headsets are tethered; the cable is required to get fast enough data transfer speeds and very low latency, as today's wireless networks are not adequate. Depending on their service proposition to consumers, operators can be in a position to supply suitable home network equipment for end users.

Network requirements can be lowered through the use of better standards. Operators should consider taking a role helping to shape standards. This could be through standards associated directly with VR video, such as those from MPEG. Operators can also input into network standards which could influence VR service delivery, such as in the case of ETSI and VRARA's work on the MEC standard to ensure specifications address the requirements for VR.

7.1.3 Content

The emphasis in VR video today is from professional content rather than UGC. Even on sites such as YouTube and Facebook, most often associated with UGC, the top 360 videos are produced by professionals.

This may be because of some barriers to UGC VR today, such as the relatively high price of 360 cameras and the lack of consumer VR video editing tools. There are also skills required in creating 360 video content that many consumers will

not be familiar with, such as avoiding excessive camera shake or movement, how to direct the audience to look in a particular direction, or how to prevent the camera operator from being seen. Therefore, professional VR content is most likely to provide a good end user experience, at least until the barriers to entry come down and the required skills and knowledge become more widespread.

Also because of these unique skills, cameras and other tools required, operators should look to use the partnership model when creating content. This is typical in the case studies given earlier in the report. For example, Fox Sports has a number of different partners including NextVR, LiveLike, Intel, Beyond Sports, and GoPro. The Olympics is delivered in partnership with Intel which, through its 2016 acquisitions of Voke and Replay Technologies, has the expertise and the cameras to create good quality VR video. Another example is specialist VR content producer LetinVR creating a channel on education of English and science for China Telecom Shanghai branch's IPTV service.

7.1.4 Consumer Pain Points

Operators can play a role improving the aspects of VR discussed in the "Consumer Pain Points" section.

• **Consider the users' comfort levels.** Smartphone-based VR seemed to cause discomfort, especially the heat generated. In contrast, consumers felt that the PS VR has a comfortable design that can be worn for extended periods. For Vive users, the cable had a negative influence on comfort. These factors should be taken into account. For example, the length of videos aimed at smartphone-based VR users should be limited. Hardware distributed to consumers should consider the comfort of the user in their device design, and if possible use wireless connectivity rather than a cable. Operators can use next generation Wi-Fi such as 802.11ax and WiGig to provide better wireless delivery in the home, and in the future 5G networks will improve wireless delivery outside (and even potentially inside) the home.

• **Have a simple setup process.** Users clearly appreciated the ease of set up for the PSVR compared to the HTC Vive. For video services in particular, "time spent" is an important metric, especially for advertising-funded video. As well as increasing end-user satisfaction, the less time a user spends setting up equipment, the more time is spent consuming content, leading to higher revenues.

• **VR can make people nauseous.** Industry observers have noted that factors influencing this can include the screen resolution and the screen refresh rate. Technical specifications may not be the only solution – many of the mentions of nausea by consumers also mentioned that specific content were worse than others (with driving games being a notable offender). Operators can help to overcome this by looking to improve the quality of the screen of hardware distributed to consumers. Content creators (operators or their content partners) should also consider what can be done when filming content or creating apps in order to minimise nausea. The more nauseous a user feels, the less time they will spend consuming VR content.

7.2 Business Models for Operators

7.2.1 Using VR to increase network ARPU

VR video provides a compelling use-case for consumers to upgrade to faster and lower latency networks. VR video services (either run by the operator or OTT services) can showcase the capabilities of better networks. This is particularly true of mobile operators with 5G networks about to be deployed. Operators are also in the optimal position to ensure quality of experience. Operators can use VR video to develop pricing plans in two dimensions:

• Volume-oriented pricing: from fully unlimited data plans to zero-rated video or content bundles and sponsored data options. These all focus on taking the worry out of data use from a consumer perspective. Revenue uplift is dependent on encouraging users to upgrade for the security of some form of an unlimited option (either for overall usage, for VR video usage, or the operator's own VR video service specifically)

• Experience-oriented models: where operators are differentiating plans based on performance or features, to provide an entry point for basic users and ARPU uplift potential for those who want the higher quality required for VR content

7.2.2 Creating a compelling user proposition by using cloud technology

Cloud VR delivery can decrease equipment costs for end users and drive the market. Cloud rendering can reduce the cost of entry into VR for consumers. If the computational power is shifted from the device and into the cloud, the VR headset can be little more than a screen and a network connectivity module (a "thin client"). Consumers need not already have (or need to purchase) a games console or high-end PC in order to enjoy high quality VR video content. This could increase the addressable market for operators wishing to provide VR services. Rather than only being able to deliver VR to consumers already owning expensive hardware, a cheap, thin-client, wireless VR headset is all that is needed – along with appropriate network coverage.

A particular challenge with "tethered" VR headsets (i.e. those attached to a PC or console) is the lack of both mobility

and portability. The cable also causes comfort issues and adds extra weight, which can limit time spent using the device. Using a network to transmit data over the "last 2m" from a device to the headset can therefore improve both the user experience and the business case (since "time spent" is often a key metric for media services). Service providers can improve this aspect of VR video delivery. This could be through the use of mobile networks, especially 5G. For fixed line operators, this can also be achieved by providing consumers with good quality routers with later generation Wi-Fi capable of fast data transfer speeds. Integration with set-top boxes is also a possibility.

7.2.3 B2B Models

Operators can more easily use multicasting technologies while OTT providers rely on unicast for video. As well as using multicasting to improve delivery of their own service, network operators could potentially open up multicasting to OTT partners. VR video could be particularly suited to this, as event-driven categories (such as sports) have many users watching a video simultaneously.

There are many elements of cloud computing which operators can put in place to facilitate VR video, such as providing video editing or storage capacity, and CDNs closer to the edge of the network can provide lower latencies suited to VR video delivery. There could be future opportunities for operators to open up some of these elements to partners. These can of course be used to deliver VR video, but CDNs also play a role in content creation (as described in section 2.3) so operators can place themselves in a good position to supply service to content creators as well as distributors.

VR 8 Key Takeaways

1. Operators should not ignore VR. Despite the hype reducing, there is clear evidence of market traction.

2. Although many people associate VR with gaming, VR video is showing strong traction, and account for a very high proportion of VR usage.

3. Headsets today are bulky and uncomfortable. Operators often play a role in device distribution, and through utilising network assets and shifting more processing into the cloud, can help expand the market with lighter, high quality hardware.

4. New standards will improve VR video delivery and operators should consider how they can be implemented in order to improve QoS. Simultaneously, headsets will improve in resolution, placing greater demands on the network.

5. The network is a bottleneck for VR video delivery today. Companies routinely cite 50 Mbps as a minimum speed requirement for a good quality experience of VR video. If networks can deliver this, then there is an opportunity for operators to build a consumer proposition for direct revenue, to increase network ARPU, and open up new B2B business opportunities.

Main Contribution Teams


Steven He
Huawei iLab


Yang Yang
Huawei iLab


David MacQueen
Strategy Analytics


Guang Yang
Strategy Analytics


Xi Chen
CAICT


Zheng Gong
CAICT

Huawei iLab

Huawei iLab is the scenario lab for the network product line, which is dedicated to studies on scenarios, experience, ecosystems, and friendly networks. It is willing to work with industry partners to facilitate business and technical innovation, industry development, and development of an open industry ecosystem for a better connected world.

Strategy Analytics

Strategy Analytics is a global market research and advisory company that provides insights and strategic business solutions for the market dynamics and industry trends of information, communications and entertainment technologies.

CAICT

China Academy of Information and Communications Technology (CAICT) is a scientific research institute directly under the Ministry of Industry and Information Technology (MIIT) of China. CAICT provides strong support for the development and innovation of China's information and communications industry, such as VR/AR, 5G, AI, IoT, industrial internet and so on.

Other main contributors

Letin VR、Whaley VR、3D BoBo、iQiYi、Sina VR

HUAWEI TECHNOLOGIES CO.,LTD.
Huawei Industrial Base
Bantian Longgang
Shenzhen 518129,P.R.China
Tel: +86 755 28780808

www.huawei.com