



Cloud X: Driving increased value from 5G investments

Are telcos ready to make their mark on a \$410bn market?

November 2018



IHS Markit™

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Wireless X Labs is an innovation platform operated by Huawei. X Labs is designed to bring together telecom operators, technology vendors and partners from various industries to explore future mobile applications, drive business growth and technological innovations and build an open ecosystem. Wireless X Labs have set up three laboratories, which aim to explore three major areas: people-to-people connectivity, applications for vertical sectors and applications in household.



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Cloud X: Interactive Applications Streamed Over High-Speed Mobile Networks

5G network technology promises to disrupt existing markets, enable new business models and alter the competitive landscape for a wide number of industries. The characteristics of 5G – low latency, increased capacity, faster speeds, and potential for a much greater volume of connections – make it particularly suited as a network technology for interactive cloud-based software and services.

The Cloud X concept – a content and service delivery framework comprised of cloud-based GPU-based servers, applications streamed from the cloud, high-speed mobile connectivity and smart hardware clients – is relevant to three key use cases today: **Cloud PC**, **Cloud Gaming** and **Cloud AR/VR**.

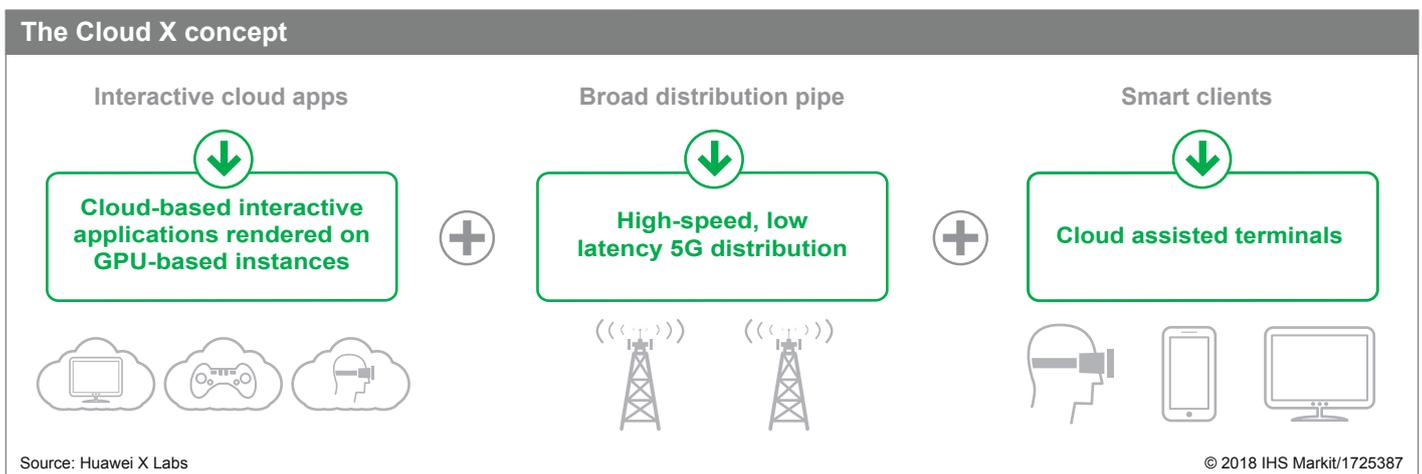
IHS Markit believes there will be a significant positive impact from the introduction of 5G for these emerging cloud rendered applications, which together are poised to disrupt markets worth over \$410 billion in 2018.

Interactive applications streamed from the cloud will be increasingly served through enhanced mobile and fixed wireless access (FWA) services based on 5G technology. IHS Markit expects consumer use cases for 5G to be the first to come to market with enterprise and industrial applications becoming more significant from 2022 onwards. Competition between telcos means that they will increasingly be looking for suitable solution partnerships to drive adoption of 5G services.

This report investigates how mobile network operators can play an increasing role in the value chain for these emerging opportunities not only with the target to drive adoption of their own 5G services but also to leverage their ongoing investments in 5G technology and their network infrastructure to enter new high-growth potential markets.

Interactive cloud applications sit across both consumer and enterprise end users:

- **Cloud PC** – The building blocks of the Cloud X proposition; Cloud-based desktop virtualisation for enterprise and, in the future, consumers;
- **Cloud Gaming** – A gaming specific application for Cloud X. Rendering of games in the cloud and streaming these games to connected devices;
- **Cloud AR/VR** – One for the future. Rendering of interactive AR/VR content in the cloud and streaming that content to smart devices and AR/VR headsets.



Shifting spending from hardware to interactive applications as a service

A key shared characteristic of these application areas is that cloud rendering is upending existing markets by reducing the need for high-end, potentially expensive, dedicated hardware at the user end. For consumers, this lowers the barriers to adoption and for enterprises, this can represent cost saving and a flexible way to manage the fluctuation of business process demand. Offsetting local hardware compute demands to the cloud, provisioning can be virtualised and scaled efficiently to end users. It also alters the business model and sees it shift from a hardware and product oriented focus to one based on on-demand service provision.

Cloud X: Poised to impact markets worth \$410bn in 2018



Cloud PC

B2B—desktop virtualisation

B2C—PC as a service

PC hardware market
2018 \$184bn
SaaS* market
2018 \$76bn

End user examples

B2B: Campus & SME—SaaS instead of Capex

B2C: Mainstream consumers looking for maintenance free PC, Mobile users



Cloud gaming

B2C—gaming PC rental/
game transactions
and subscriptions

Games market
2018 \$145bn

End user examples

B2C: PC gamers that cannot afford the latest gaming PC, family and mainstream consumers that want access to bundle of content



Cloud AR/VR

B2B—AR/VR as a service

B2C—AR/VR as a service

AR/VR market
2018 \$8.4bn

End user examples

B2B: Maintenance, assemblers, supply chain, product design, location based entertainment

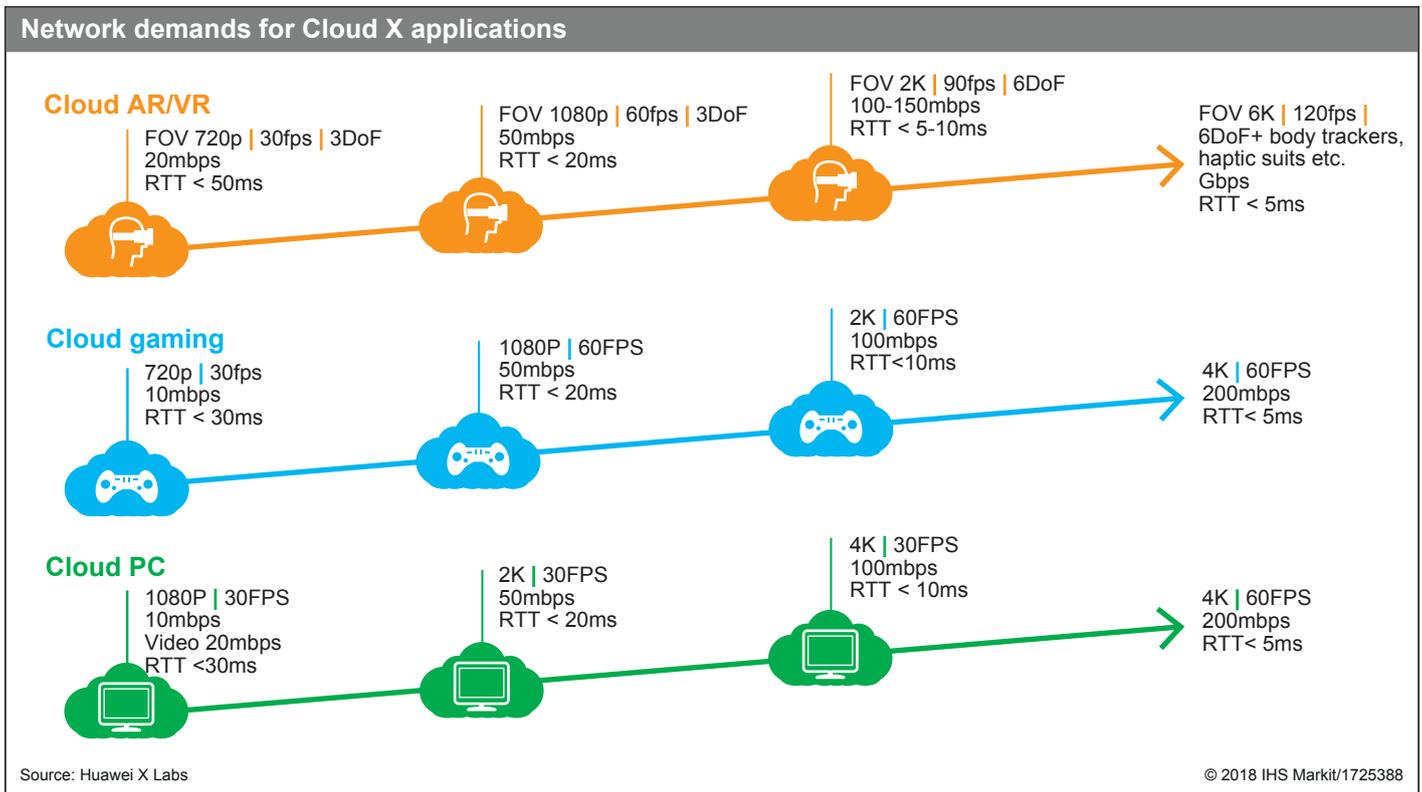
B2C: Ecommerce, entertainment, social media, education

*SaaS – Software as a Service

Source: IHS Markit and Huawei X Labs

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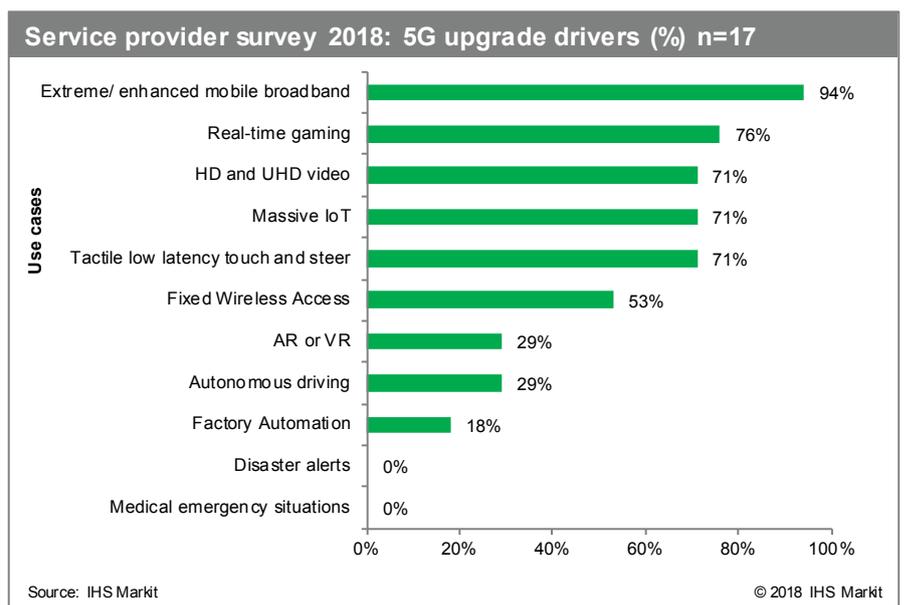
Why 5G is essential for delivering interactive applications from the cloud



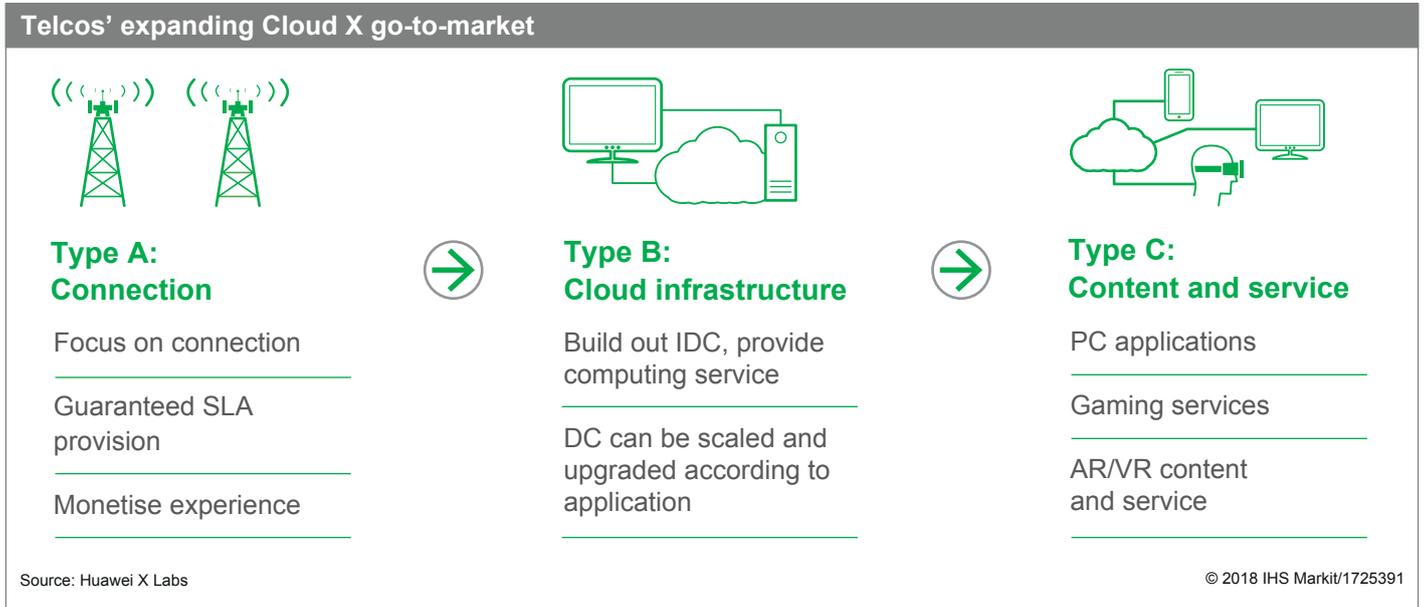
While the hardware replacement value proposition to consumers and enterprises is clear, unless the delivered end-user experience reaches the level of service expected, market adoption will be hindered, and these cloud applications will not reach their full potential. The introduction of 5G mobile network technology alleviates many of the key service delivery pain points for the roll out and adoption of these services, potentially broadens the addressable market and serves up commercial opportunities for participants in the 5G economy value chain.

Telcos already acknowledge interactive content as a key 5G adoption driver

IHS Markit regularly conducts an ongoing telco survey around mobile network investment, 5G and related use cases/applications which they consider will be key to driving demand for 5G services. The latest survey took place in July 2018 and shows that interactive content services are a key consideration



for mobile operators when developing their 5G strategies. Indeed, real-time gaming is considered to be the second most important driver behind the more general enhanced mobile broadband proposition. VR and AR remains important but is naturally behind gaming as a whole which is far more mainstream at this time.



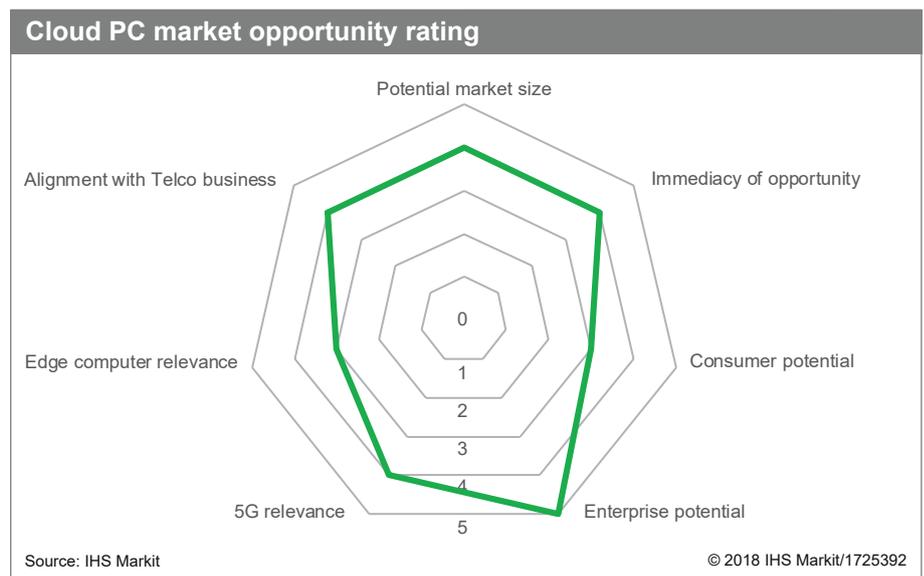
Cloud PC: The building blocks for Cloud X solutions

Many things people used to do on their PCs are now done on their mobile devices, however the PC still dominates many consumer and enterprise tasks. Tasks like browsing social media, checking email and browsing the internet have largely shifted to mobile devices, but the PC still dominates activities such as shopping, managing finances, AAA gaming, movie making and photo editing.

The PC platform is here to stay but standalone PCs have many drawbacks. There is high risk of data loss and hardware failure, they can be difficult to physically secure and the support and maintenance costs can be very high. Certain use cases like gaming and software development can require expensive high powered machines that can cost thousands of dollars. In many cases these are just used for a few hours a week.

There is a rise in the use of virtual PCs for all of the aforementioned reasons, predominantly by enterprises but in an emerging way by consumers, and telcos are well placed to play a role in this growing business. Telcos have many years of experience offering their enterprise customers managed solutions with local support and services. These include connectivity services, unified communications, office security and cloud hosting. Cloud PC is an extension of these services for enterprises and consumers.

The growth of Cloud PC will drive the demand for 5G. Applications increasingly require high bandwidth low latency connectivity to truly rival local desktop experiences. Telco investment in this capability also lays the foundation for more specific Cloud X applications including Cloud Gaming and Cloud AR/VR.



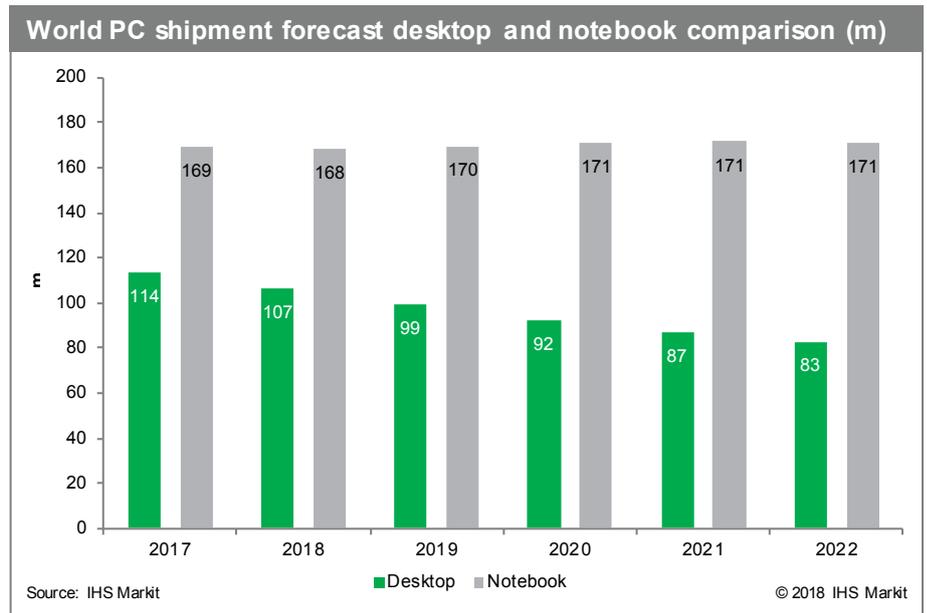
The \$184bn PC hardware market is increasingly disrupted by cheaper client devices and virtualised solutions

IHS Markit forecasts that shipments of desktop and notebook PCs will fall over the next five years from 275 million in 2018 to 254 million in 2022. While shipments of notebooks will essentially stay flat in a declining market, desktop PCs will markedly decline as users shift to other form factors, 2-in-1s for example, and virtualised solutions make an impact. Virtualising desktops results in a shift of enterprise costs away from capital expenditure towards operational expenditure, but in turn allows solution providers access to buckets of spending which were originally centred on hardware.

Enterprise desktop virtualisation: Distributed workforce, new device form factors and GPU-intensive use cases show importance of 5G connectivity

Desktop virtualisation in the cloud, or desktop as a service (DaaS) is the delivery of virtual PCs off-premises in public cloud or hybrid cloud environments. The off-premises characteristic differentiates these offerings from traditional on-premises virtual desktop infrastructure (VDI) offerings which are commonplace in enterprises today.

Generally, enterprises are migrating applications to the cloud to improve agility, reap cost savings, and gain access to the latest technology as a service rather than develop in-house skills. Agility means enterprises can shorten the time to introduce new applications and grow or shrink compute capacity to fit business need. Upfront capital expenditure can be shifted to as-needed operational expenditure by using off-premises cloud services—shifting from investments in equipment and staff to leveraging a cloud service provider’s automated data centre infrastructure and highly skilled experts.



In addition to a shift towards the cloud for enterprise applications the following trends means 5G connectivity is increasingly important to the Cloud PC opportunity:

- Increase in use of GPU-computing for desktop virtualisation
- Increasing support for power users and graphics-heavy applications
- Ability to support full virtual desktop solutions for mobile and remote users

What industries and size of companies are using end use computing solutions?

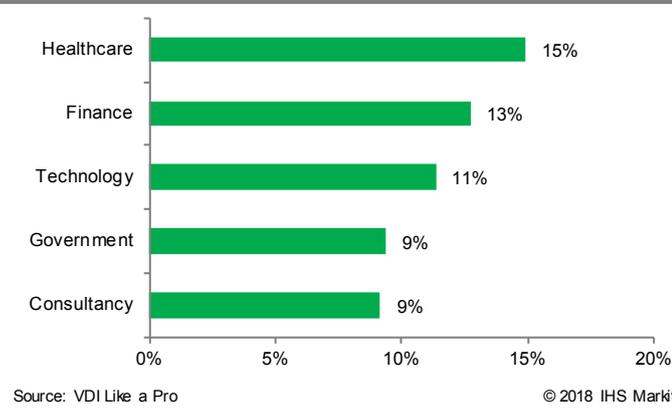
The server-hosted desktop industry organisation - VDI Like a Pro - conducted its fifth worldwide ‘End User Computing – State of the Union’ survey in 2018. The survey provides valuable insights into real-world desktop virtualisation deployments from more than 750 respondents. For more information on the research and for details on the methodology please visit: <https://vдилikeapro.com/>

The VDI Like a Pro survey respondents identified the vertical industries they operated within and also the employee numbers. While this is not confirmed as a representative sample, over the 755 responses most were using these solutions in the healthcare industry, with finance in second place and technology third. Government and consultancies rounded out the top five most popular responses. In terms of the company size by share of respondents, a large majority (82 per cent) were sized 250 employees or larger, suggesting that current solutions are targeted at larger companies rather than SMEs. Indeed, the biggest share of respondents had a workforce of between 1,000-4,999 employees.

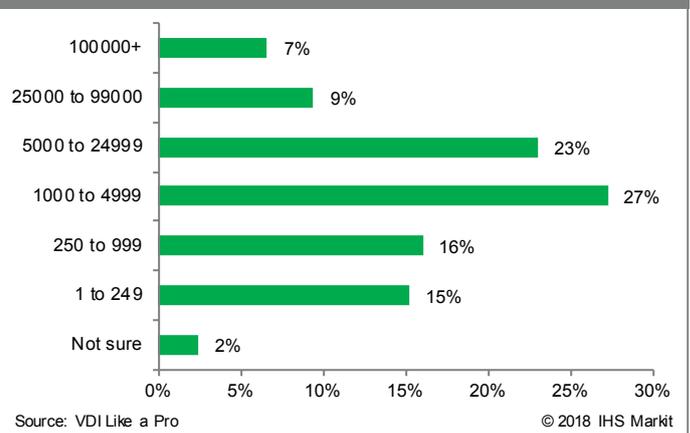
Enterprise first, but a consumer opportunity is emerging

A nascent, under commercialised market, the consumer-focused virtual desktop market is only really starting to find its feet. In the first instance this opportunity is centred on gamers and typical streamed to low-powered PCs, although there are a number of other use cases in the single ad-hoc user space (consumers, students, self-employed) which include photo and movie editing, 3D modelling and animation, and deep learning computation for research projects.

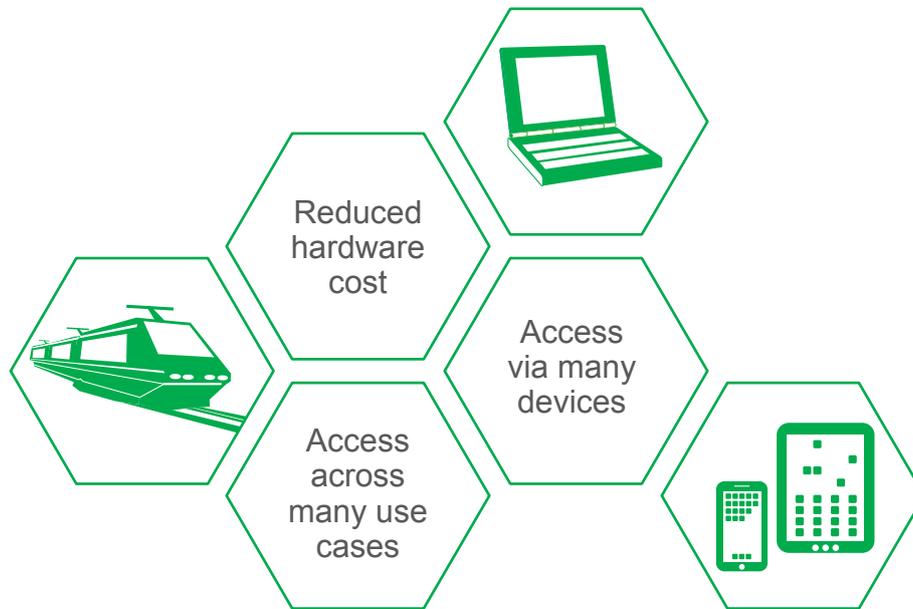
What is the most important business vertical to use your End User Computing (VDI/SBC) environment for? N=755



What is the total amount of users within your business? N=755



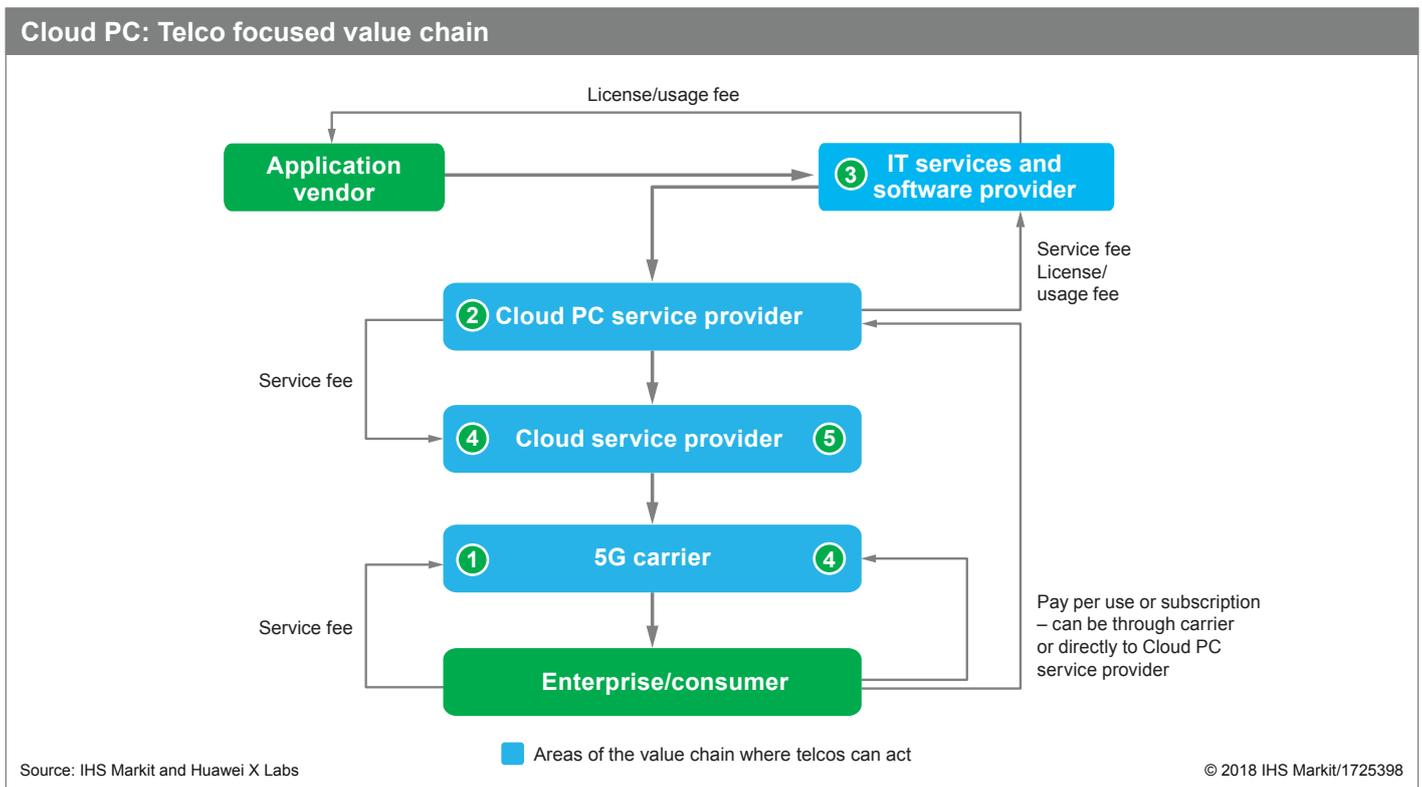
Cloud PC: Consumer proposition



Source: IHS Markit

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IHS Markit expects this demand to become broader as new device form factors are commercialised and 5G services come to market. Foldable displays are expected to debut in 2018 and multiply in 2019, as smartphone manufacturers respond to consumer demand for large-screen smartphones driven by the consumption of content and applications on these devices. Flexible displays have made rapid inroads into the flagship smartphone display market, with panel makers willing to supply differentiated products with innovative form factors, which increases the profit margin from sales of premium products.



Revenue streams

- 1 Connectivity service** – High speed, low latency 5G connectivity that enhances the Cloud PC experience.
- 2 Cloud PC service** – Provide access to Cloud PC services, this can be an own brand or third party. Offering could be a hybrid combination of private, telco or public cloud compute services.
- 3 Managed services** – Complimentary services such as virtual desktop migration, hybrid integration, network and IT helpdesk, security and application management.
- 4 Network-as-a-service** – NaaS enables desktop virtualisation platforms to provide differentiated services to their customers.
- 5 Cloud services** – Telco cloud platform and infrastructure services that help to minimise latency and maximize bandwidth for cloud PC services.

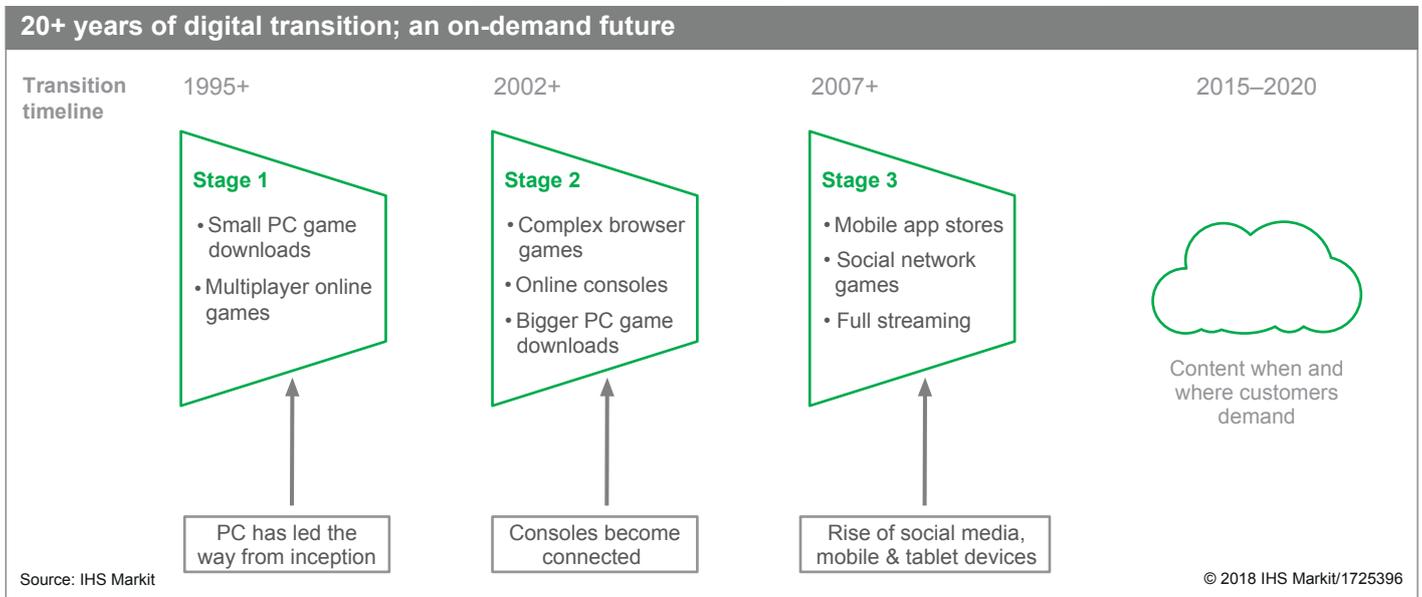
Possible go-to-market approaches

- Connectivity 1**
Sell benefits of 5G for desktop virtualisation.
- Cloud PC and connectivity 1 2**
Promote or resell virtual desktop services to help sell 5G connectivity.
- Cloud and network services 1 4 5**
Open network and Cloud platform to virtual PC platforms.
- Managed services, Cloud PC and connectivity 1 2 3 4 5**
Sell virtual PC, managed services and connectivity, based on telco cloud differentiation and local presence.

Cloud Gaming: Streaming is ready to disrupt a \$145 billion market opportunity

Cloud gaming services give consumers access to a portfolio of games content on-demand and across different screens and devices. The concept of cloud gaming – being able to access games whenever a user wants and on a screen of their choice – has long been held up as a theoretical end game for the distribution of games content.

Of course, the entertainment industries have already seen this disruptive transition occur in the video and music entertainment sectors, so it is natural that there is speculation that games content will follow this trend. This is particularly true of high-end games which normally need to be played on specialist consoles and gaming PCs.

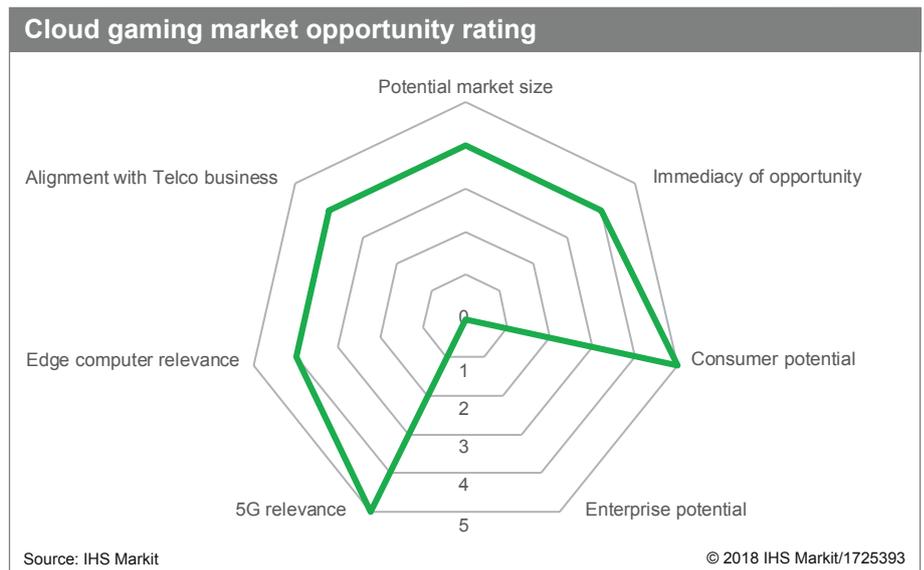


Cloud gaming in context: Consumers are forecast to spend \$129 billion on games content and services in 2018

IHS Markit forecasts that in 2018 consumers will spend \$129 billion globally on games content and services and that this will grow to \$145 billion by 2022. As of 2018, cloud gaming’s share of this market is negligible at less than 1% but there is a collection of reasons why this is going to change in the medium and long term.

The make-up of the games market value chain

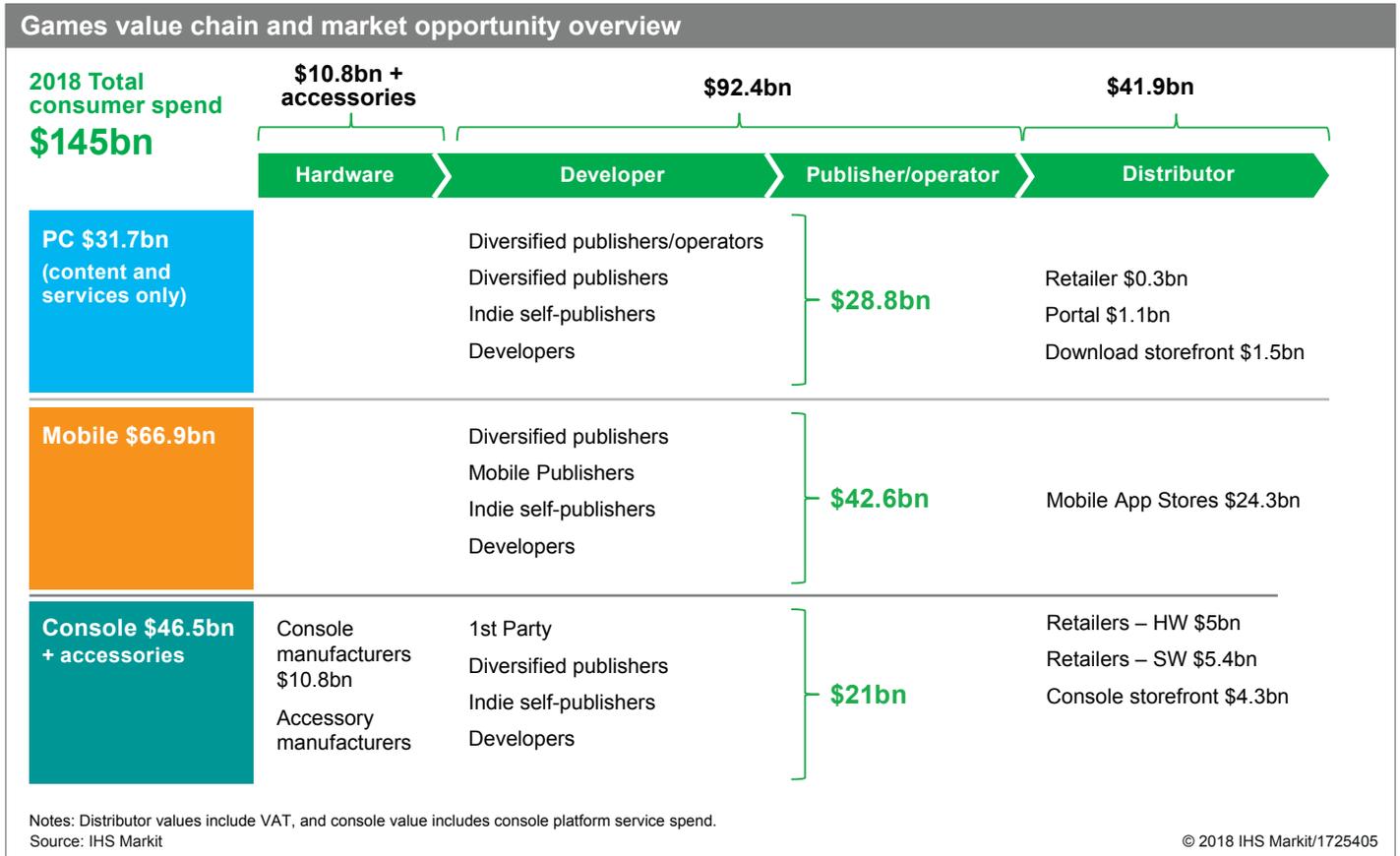
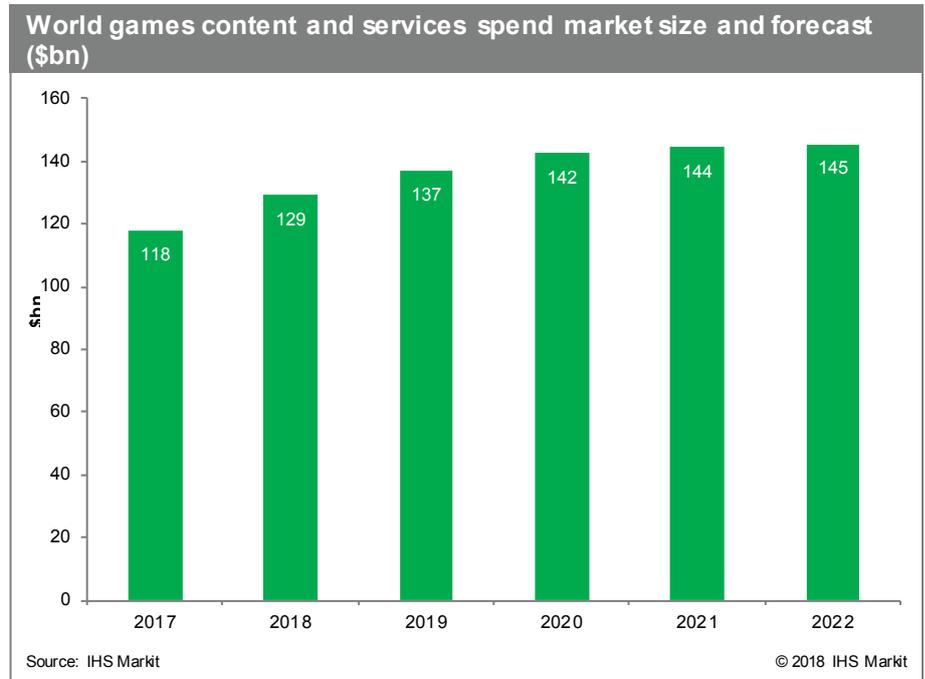
The value chain for the games market opportunity is currently split between hardware manufacturers, the developers and publishers



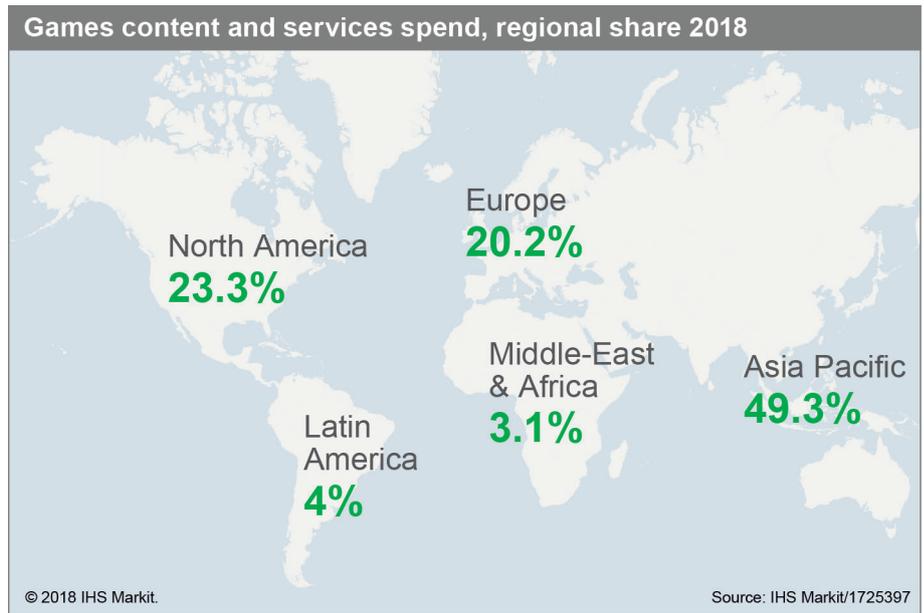
of games content and services, and distributors of content and hardware to end users. A significant majority of the market value is in content, services and distribution. Cloud gaming has the potential to disrupt all three main areas of the value chain and is likely to be one of the most significant industry developments in the long term.

IHS Markit data shows the global spread of the market opportunity. China is the biggest games market in the world at \$29.3 billion in 2017 and is now a mobile first opportunity, but with heavy residual gaming on PCs as well. Japanese consumers spend more on mobile gaming per capita than any other territory and have a long history of heavy adoption of handheld consoles.

North America remains the biggest console market and well penetrated for other devices for playing games, while Europe is understandably more fragmented and mixed in terms of platform usage and penetration.



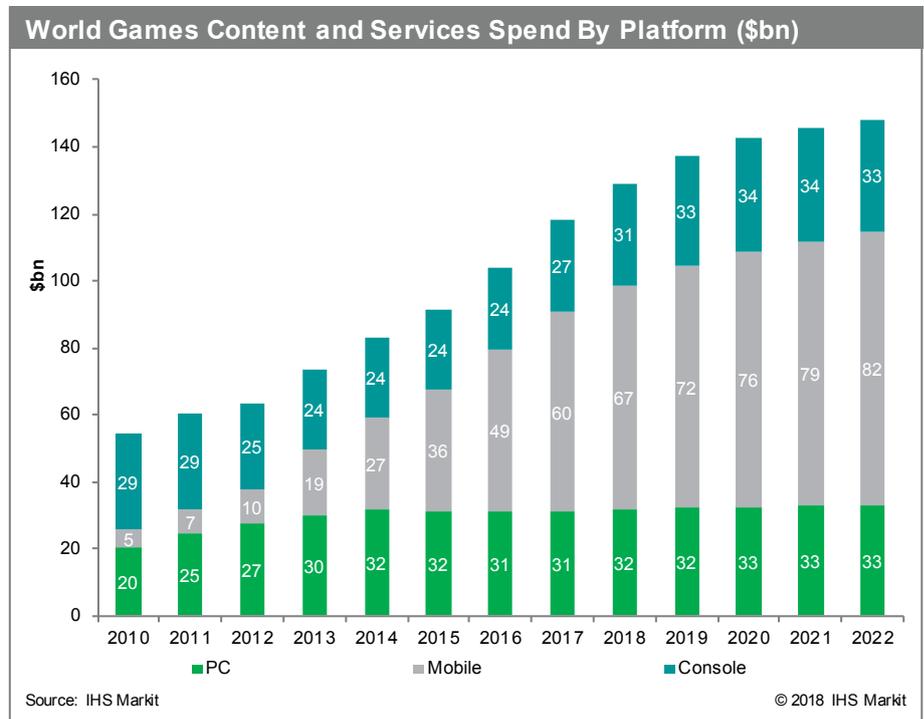
IHS Markit data also shows the spread of consumer spending on games content and services across device types. Over the last ten years the market has transitioned from a console and PC-based opportunity to one that is increasingly mobile first in consumption terms. As mentioned above, across many major markets mobile gaming is now the biggest games opportunity and the broadest in terms of audience size and demographic spread. In key territories – such as China, Japan and South Korea – consumers are happy to play a wide variety of games on mobile devices including those types of games that originate on PC and console platforms.



Console gaming is ripe for disruption

The game console market remains a large and significant part of the overall games market opportunity. In 2018, IHS Markit data shows console content and services spend will represent 24 per cent share of the \$129 billion market. In addition, world consumer spending on console hardware will reach \$15.8 billion bringing the overall console market opportunity to \$46.5 billion.

Most significantly, console gaming is still dominated by three incumbents: Sony, Microsoft and Nintendo and has yet to have been significantly disrupted by new technology and platforms, but with the shift towards cloud gaming this status quo is unlikely to remain.



All three console manufacturers are embracing cloud gaming to a greater or lesser extent and this inevitably means a slowly decreasing reliance on client hardware. As this transition takes place, there is an opportunity for new market entrants to disrupt the existing platforms and build their own services. This opportunity extends to games publishers, cloud service providers and telcos.

Similarly, AAA PC gaming is also a strong fit for cloud gaming

While Sony, Microsoft and Nintendo control what games are published through their platforms and have their own studios to bolster exclusives on their respective devices and online platforms, the PC gaming market is

relatively open in comparison. However, high-end PC games demand the best PC hardware, which means this is another part of the market that is open to disruption from cloud gaming services.

Six trends within the games market suggesting a cloud gaming future sooner rather than later

<p>1 </p> <p>The games sector has been through a rapid transition to digital content and services, but often the user experience is poor due to big downloads and constant patching of games. Cloud gaming overcomes these issues and improves the user experience significantly in these areas.</p>	<p>2 </p> <p>Playing the same games across different use cases and on different platforms is becoming a reality. Gamers are enthused by the idea of playing higher-end games out of the home and on the move. Nintendo's Switch success is evidence of this appeal, as is the success of blockbuster PC and consoles titles such as Fortnite and PlayerUnknown's Battlegrounds on mobile. Cloud gaming technology enables distribution onto more platforms more easily.</p>	<p>3 </p> <p>The cloud service providers are mobilising and building their own cloud gaming services. This includes Microsoft and Google, but it's expected that Amazon and Tencent will also enter this market sooner rather than later. Google's entry into the market illustrates the value in leveraging existing service delivery infrastructure to compete with the incumbents in the market. Telcos also have an opportunity to leverage existing distributed compute power to compete with global players.</p>	<p>4 </p> <p>Electronic Arts, Microsoft and Google can sense an opportunity to engage a mainstream audience beyond the current console and PC gaming market. Telcos already serve this audience with multi-channel offerings and have an existing billing relationship, which can be leveraged.</p>	<p>5 </p> <p>Games publishers and platforms are already building a streaming capability for video content, a result of the burgeoning live games video market and esports video. Cloud gaming is a natural extension of that streaming expertise, which companies such as Microsoft are leveraging.</p>	<p>6 </p> <p>Subscription monetisation models are in fashion again. Subscription monetisation make more commercial sense because revenue can be supplemented by the sale of in-game items and currency.</p>
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Source: IHS Markit © 2018 IHS Markit/1725422

Cloud gaming benefits

<p>Consumers </p> <ul style="list-style-type: none"> • Thin or low-powered client devices can be used to access high-end gaming content. Consumers do not need to buy expensive consoles or gaming PCs to enjoy high-end games content. • The support of non-specialist hardware including mobile devices means that gamers can play high-end games across different use cases including out of home and on the move. • Access to games—once available on the server end—takes a matter of seconds. There is no need to download the game to the end-user device. It is a better user experience in this respect. <p>Source: IHS Markit</p>	<p>Publishers and service providers </p> <ul style="list-style-type: none"> • Addressing an audience that does not use consoles or gaming PCs including late adopters or consumers in markets where specialist game devices are under penetrated. • Cloud gaming is a way to access a market largely dominated by a handful of established platforms – the consoles and major PC game distribution storefronts. • Cloud gaming services offer an appropriate tool to acquire new customers or upsell other services to existing subscribers. • Cloud gaming services offer another way to monetise catalogue titles. • Games in cloud services are less prone to piracy. <p>© 2018 IHS Markit/1725421</p>
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Challenges to the cloud gaming market

Latency: Latency is a core issue that has yet to have been fully overcome. There is no doubt that a round trip time for a cloud gaming solution has improved over time - some solutions boast of sub-100ms latency - but often under real world network conditions latency remains an issue, which makes playing a game on a cloud gaming service a lesser experience compared to direct play on a console or gaming PC. Users that are nearer data centres will often have a better experience due to shorter round trip times but this limits the addressable audience. Since there is no ability to buffer using these solutions as there is in video on demand, any form of increased network latency or packet loss can ruin the end user experience. Several cloud gaming companies have developed their own technology to minimise latency or to reduce the impact of packet loss.

5G technology will deliver improved network latency which will enhance the usability of cloud gaming services. Telcos that have developed edge computing infrastructure will have an advantage over cloud service providers where proximity to the end user is important for reducing latency.

Compression challenges: Under a GPU-based cloud gaming solution, video frames are rapidly compressed and encoded to reduce transit time to the client device. They are then rapidly decoded at the client end to try and keep latency down. Speed of compression has a negative impact on video quality, so even if the output is achieving good latency and high frames per second, the actual presentation of the video is likely to look worse than playing a game locally on console or PC. Again, some cloud gaming companies have built their own compression technologies and it continues to improve, but quality of compression is inherently hampered by the need to reduce latency as much as possible.

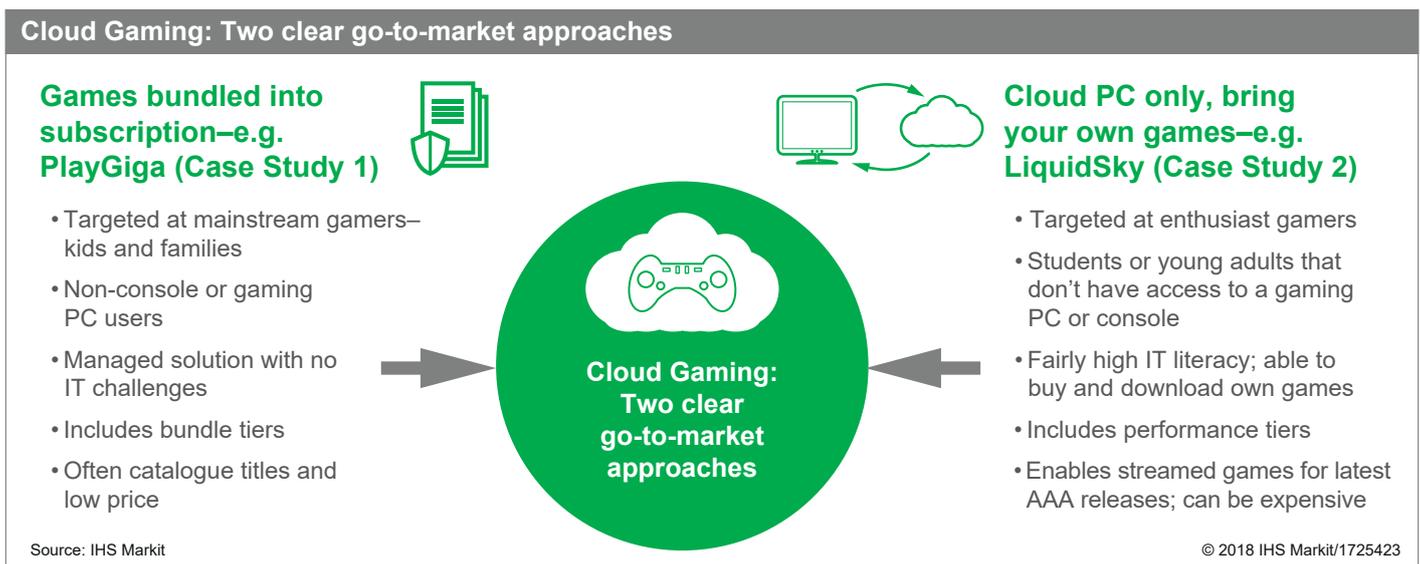
5G technology will deliver improved network latency which will lead to enhanced video quality of cloud gaming services. If network transit time is reduced, video compression time can be optimised without impacting on overall latency and end user experience.

Cost of service delivery: Using public cloud enables a quick go-to-market and flexibility in service provision. However, it is relatively expensive and can break the commercial model with cost per streaming hour often in the \$1-2 range or more depending on the specification of the virtualised PC. For those service providers that have their own cloud or have invested in their own data centres already, this represents a significant advantage over those relying on public cloud solutions.

Companies that are best positioned to mitigate cloud compute and storage costs are those that have an existing compute and content delivery capability. Cloud service providers are well positioned as well as telcos.

Cost of building a cloud gaming infrastructure: The cost challenges of using GPU instances from established cloud service providers – Amazon AWS and Microsoft Azure for example - has led some companies to build their own GPU-instance infrastructure. This is hugely capital intensive and requires ongoing large rounds of investment in upgrades. Additionally, companies with specific CPU requirements – such as SIE with the launch of PlayStation Now – have had to invest heavily in their own cloud infrastructure. For Sony, this is likely part of the reason the service is only available in a limited number of markets. Telcos can benefit from leveraging their ongoing investment in distributed content delivery.

Companies that are best positioned to mitigate cloud gaming infrastructure costs are those that have an existing compute and content delivery capability that can be leveraged for cloud gaming. Cloud service providers are well positioned as well as telcos.



Case Study 1: PlayGiga's B2B cloud gaming offer to telcos

Javier Polo, CEO
info@playgiga.com

Spanish 'Games as a Service' company PlayGiga builds white label cloud gaming solutions for telcos and media companies. The company was founded in 2013 and since coming to market with its cloud gaming solution in 2017 has secured commercial implementations with Telecom Italia in Italy and media company Turner in Argentina and Chile.

Like other solutions, PlayGiga's cloud gaming technology works through GPU rendering in the cloud and then streams video to connected devices. Gamepad inputs are captured within an application on the client device and routed back to the server where the game responds. The nature of this approach means it performs best with a high-speed internet connection and low latency.

PlayGiga offers an end-to-end solution which includes interfacing with public cloud providers, their own cloud gaming hardware, streaming technology, client-end applications and, significantly, a curated portfolio of pre-negotiated games content. PlayGiga's technology is fully compliant with 5G technology. It can even deliver service-branded gamepads to telcos through its peripheral partnerships. The company recently announced that it is building a network of demo centres with leading telcos and technological partners to research the application of Cloud Gaming with Edge Computing to further optimise network latency to be able to deliver compute intensive and bandwidth hungry VR content from the cloud.

'Streaming high-quality videogame AAA content to the mass market is one of the key ways telcos can promote and monetize their 5G network investments'

Javier Polo, CEO of PlayGiga

PlayGiga is also flexible enough to work with clients to insert its cloud gaming solution into the infrastructure, hardware and network environment of the telco. Other customisation comes in the form of content bundles, with both basic and premium tiers of catalogues allowing telcos to position the offering in different ways to the consumer. PlayGiga is targeting the family audience with its subscription offer and the portfolio also includes a catalogue of games specifically curated for younger players. It believes there is an under-served casual audience that likes to play high-end games and that telcos are well positioned to take advantage of this market opportunity.

Telecom Italia: Cloud gaming used in several ways to engage consumers

Telecom Italia (TIM) licensed PlayGiga's technology for its own cloud gaming implementation



WADE – PlayGiga also offers a boxed retail version of its cloud gaming service

which was launched in 2017 to support the company's consumer fiber offers, which now cover 80% of the Italian population. As it stands only fiber customers gain access to the TIM Games subscription offer and have the opportunity to spread the cost of TIM's Android TV decoder box and TIM-branded gamepads across a number of months making the charge to subscribers between €7 and €10 a month depending on what hardware is required.

TIM is using this content offer in three ways:

- **Retention:** To drive an upsell opportunity for broadband customers;
- **Customer acquisition:** To illustrate the benefits of subscribing to TIM fiber compared to other fiber offers;
- **Expand role in the content value chain:** To build an additional revenue stream from content rather than simply acting as a distribution pipe.

While cloud gaming is centered on the fixed internet opportunity in Western markets today, 5G technologies open the market to a cross-section of mobile telcos that don't currently play in the home entertainment interactive content space. In addition, the promise of 5G widens the use case for cloud gaming to gamers on the move and therefore broadens its appeal.

How 5G could transform PlayGiga's market opportunity

PlayGiga's has identified that the introduction of 5G will help transform its market opportunity and product offering in three key ways:

- It will help PlayGiga and its partners deliver a better product to the consumer: better latency, better network speed and better capacity. These traits are key requirements for robust and reliable cloud gaming service delivery;
- It will open the cloud gaming market to new mobile telco competitors, which means more potential clients for PlayGiga;
- It will open the cloud gaming market to use cases beyond the home: While some cloud gaming services theoretically operate on higher speed 4-G networks, the speed promised by 5G means a much better end user experience for consumers.

Case Study 2: LiquidSky sees rich pickings in cloud visualisation of interactive and 3D content

Jason Kirby, Chief Revenue Officer

Jason@LiquidSky.com

Probably best known as one of a new breed of cloud gaming companies, US-headquartered start-up LiquidSky offers cloud visualisation of interactive content to both consumers and enterprises. While it is known for operating in the cloud gaming market, it does not offer bundled content to consumers making it a different proposition from many existing cloud gaming services. It offers access to a virtualised gaming PC in the cloud leaving gamers free to buy their own PC games from the most established digital storefronts such as Valve's Steam.

The company has designed its own GPU-based server hardware, the software that manages the use of this hardware by end-users and has also developed a proprietary streaming technology focusing on low latency and operational efficiency. It believes this proprietary approach differentiates it from other start-ups that also offer cloud-based GPU rendering of interactive applications which are streamed to the end user, and reduces

overall service running costs. LiquidSky works with all the major public cloud vendors and is also testing its technology over 5G networks and edge computing environments.

LiquidSky started its commercial journey by offering virtualised gaming PCs to consumers from the cloud. Since early 2017 it has served over 250,000 users who have streamed their own PC games to over 900,000 devices enabling the company to fine tune its solution performance and thoroughly test its technology in what it believes is the most demanding of application environments.

Expanding to the enterprise customer

During 2018, LiquidSky evolved its offering to target enterprise customers that are either looking to commercialise their own services based on LiquidSky's technology or are seeking to implement cloud visualisation within their own enterprises. Key applications where the company can make an impact include gaming, virtual reality, augmented reality, video editing and computer aided design.

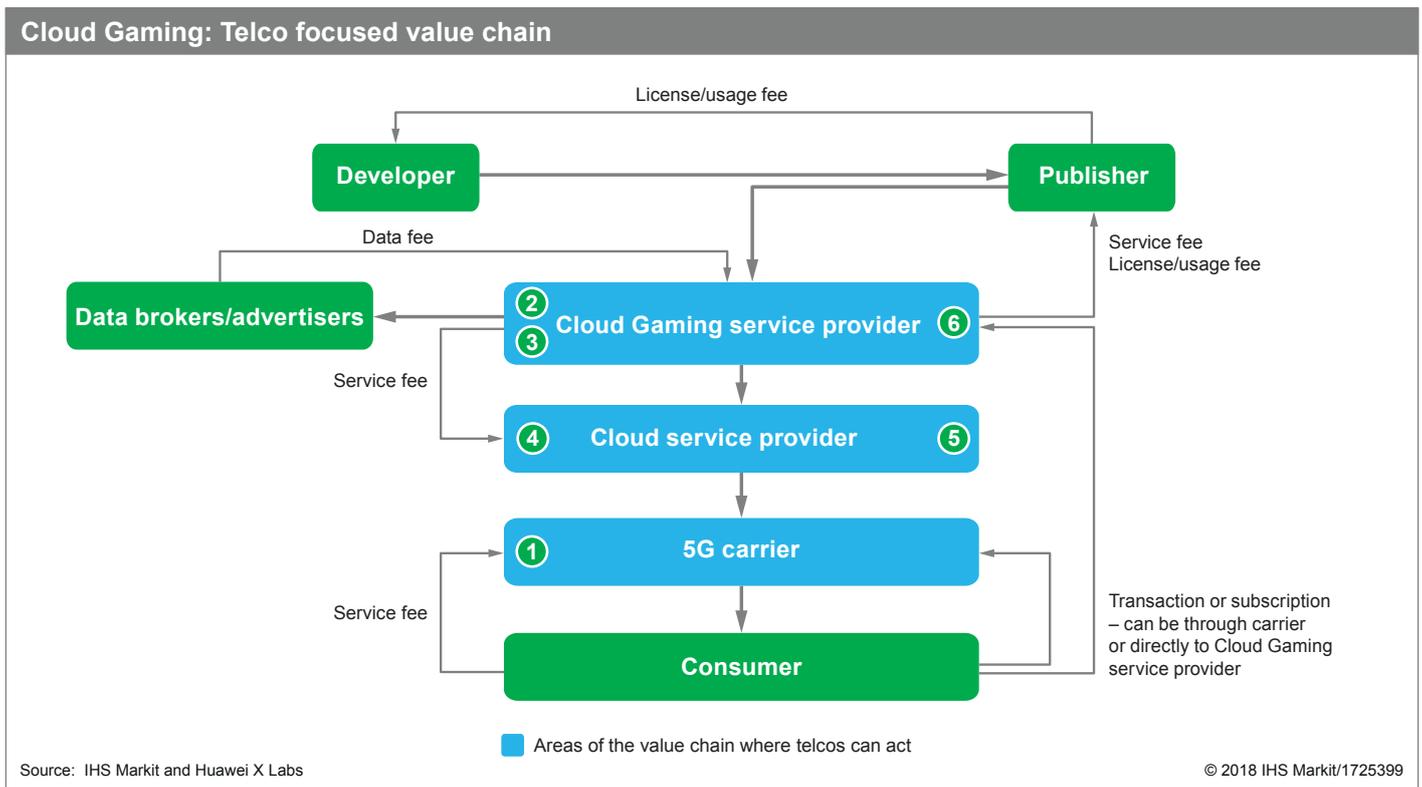
Vertical industries that are interested in LiquidSky's technology are as varied as telcos looking to launch their own cloud gaming services, the energy sector looking for 3D visualisation of CAD software on low powered end-user devices, visual effects companies that often need to scale their teams up and down depending on their pipelines, or even digital signage companies that want to deliver interactive, high-resolution advertising experiences to consumers in-store.

LiquidSky's strategy aligns strongly with the adoption trend within the virtualised desktop market which has seen a rapid increase in demand for GPU-based virtualised solutions to support not only traditional GPU-hungry applications but also more mundane but essential applications which depend on graphics acceleration including Microsoft Windows 10, Microsoft Office 365, Adobe Acrobat and the latest versions of the major web browsers. There are also other benefits to placing virtualised desktop solutions in the cloud rather on premises which include scalability, security, reliability and redundancy.

How 5G could transform LiquidSky's market opportunity

It goes without saying that LiquidSky's technology will benefit significantly from the introduction of 5G technologies and use of distributed networking environments as implemented by telcos to get closer to end users. The types of application that LiquidSky is targeting means that high-speed, very low latency and high-capacity are all important network traits which support the end user experience, whether that is experienced by a consumer or enterprise user.

For telcos, LiquidSky's product roadmap underlines that there are GPU-based streaming solutions that span both consumer and enterprise opportunities. LiquidSky specifically targets GPU-heavy applications and is offering an end-to-end white label solution that can be leveraged by telcos for consumer-facing services such as cloud gaming.



Revenue streams

- 1 Connectivity service** – High speed, low latency 5G connectivity ideal for Cloud Gaming.
- 2 Cloud Gaming service** – Provide access to Cloud Gaming services - this can be an own brand or third party.
- 3 Hardware sales** – Sales of hardware – controllers, input devices or connected devices suitable for streaming games from the Cloud.
- 4 Network-as-a-service** – NaaS enables Cloud Gaming platforms to provide differentiated services to their customers.
- 5 Cloud services** – Telco cloud platform and infrastructure services that help to minimize latency and maximize band width for Cloud Gaming services.
- 6 Advertising space/broker profile data** – Ad space and anonymous gamer profile data sold to ad networks or advertisers.

Possible go-to-market approaches

- Connectivity 1**
Sell benefits of 5G for Cloud Gaming.
- Third-party Cloud Gaming and connectivity 1 2 3**
Promote, resell or build Cloud Gaming services to help sell 5G connectivity. Partner with Cloud Gaming technology vendors.
- Cloud & network services 4 5**
Open network and cloud platform to Cloud Gaming platforms.
- Own brand Cloud Gaming and connectivity 1 2 3**
- Data Broker and advertising 1 2 6**
Add advertising and data brokering to own brand Cloud Gaming platform.

Cloud AR/VR: Next-generation interactive applications streamed over 5G

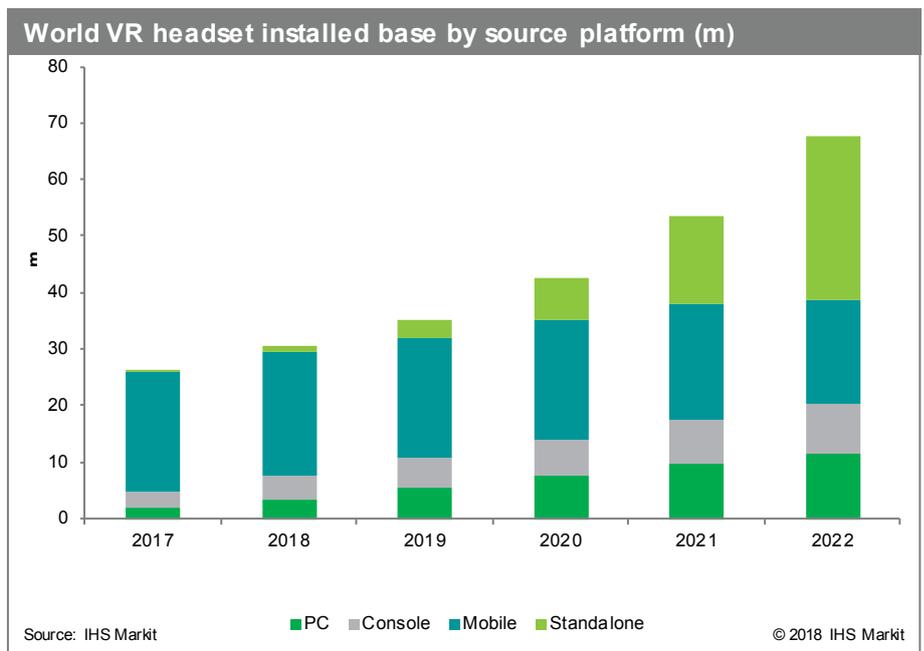
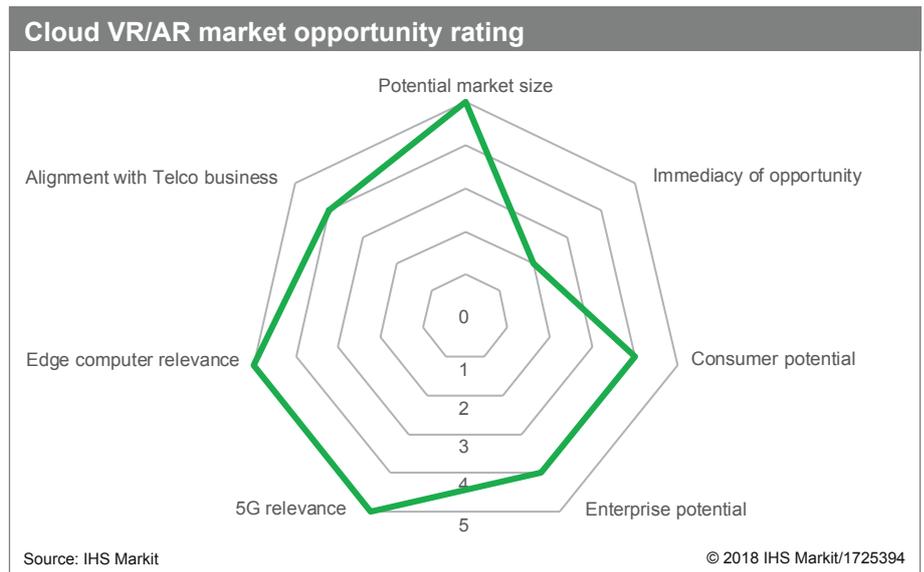
The immersive computing market – a term which covers hardware, software and services related to virtual reality (VR) and augmented reality (AR) – is made up of a collection of commercial opportunities which will become increasingly tied to cloud service provision as 5G networks are built and rolled out to both consumers and enterprise customers. The adoption of immersive computing is inextricably linked to 5G as they are mobile first technologies: VR headsets are increasingly standalone and wireless in format, whilst most AR hardware is mobile focused.

Cloud AR/VR represents the future end-game for Cloud X services as the network demands of these interactive applications means they will only be relevant for more developed 5G implementations that are very high speed and incredibly low latency.

However, once in play, Cloud AR/VR will enable immersive computing technologies to flourish by reducing the cost of ownership for hardware and transitioning the AR/VR market from being hardware centric to one built on interactive software and services. Only with the introduction of 5G will mobile-first immersive computing applications become more accessible, usable, intelligent and start to deliver fully on the promise of the technology.

Virtual Reality: Overcoming the challenge of hardware costs and capability

VR technology has made progressive inroads into the consumer and enterprise marketplaces over the last few years. IHS Markit forecasts that the world installed base of consumer VR headsets will reach 31 million at the end of 2018 and is currently expected to expand to 68 million by the end of 2022. This shows a good adoption progression but clearly falls short of mass market penetration.



Unfortunately, VR technology adoption remains hindered for a variety of reasons:

Hardware and source device cost: PC and console-based VR headsets remain expensive to buy and are on top of the source device to play back the interactive VR content. This limits the addressable audience.

Cloud VR solutions could help overcome this challenge by running and rendering applications in the cloud and streaming the content to thin client headsets, which would be cheaper to buy.

Resolution and graphical quality remains lacking: Display resolution of VR headset is improving slowly, but still lacks the detail of today’s highest definition video. Even as hardware improves to support better resolutions, rendering interactive content at higher resolutions takes high amounts of local computing power, which leads to more expense for the end user.

Offloading the GPU-compute requirements to the cloud, the resolution of content could be optimised and improved before streaming to end user headsets over 5G networks.

Mobility remains an issue and impacts usability: High-end VR headsets are often wired impacting usability. Even with the use of wireless solutions, which are expensive, the need to recharge those units and maintain a separate piece of technology adds to complexity.

Cloud-based rendering of content delivered to thin client headsets could support a more mobile implementation of VR and support longer battery life.

Limitations of standalone headsets: The availability of standalone, or all-in-one, headsets is the major trend in VR hardware, but they naturally suffer from technological limitations in terms of compute power, display resolution and battery life. According to Facebook, its latest standalone headset, Oculus Quest, is 100 times less powerful in compute power terms than an average VR-ready PC, which illustrates the difference between the capabilities of standalone and PC-based headsets.

Offloading compute workloads to the cloud could help standalone headsets deliver high-end experiences to drive uptake of VR.

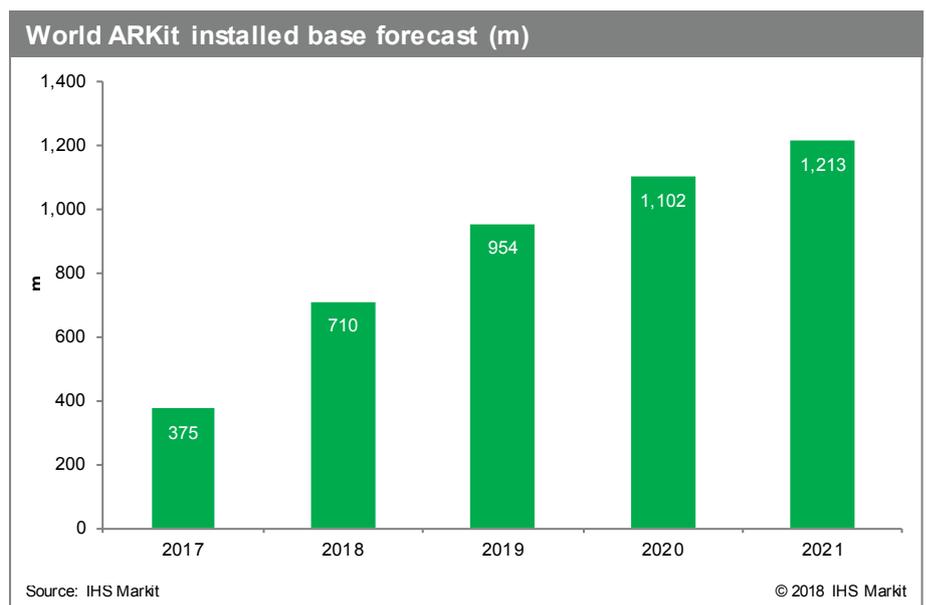
Enterprise challenges: Enterprise VR solution deployments need to meet certain conditions to drive uptake and these include aligning with existing cloud IT strategies, fitting into existing hardware and software maintenance strategies, enabling collaboration across workplaces, supporting a distributed workforce and delivering a successful VR content delivery network.

Telcos are well positioned to build out their managed services to support enterprise use of VR supported by the Cloud X infrastructure proposition.

Augmented Reality: 5G provides the network environment for AR to flourish

Consumer AR will remain focused on the smartphone and tablet over the next few years:

There is a clear consensus forming that AR has the potential to be a transformative technology that can disrupt consumer content, services, applications, advertising and consumer electronics markets.



The scale of this disruption depends on a wide number of factors including the roll-out of 5G networks and compelling AR applications, and on the development of compelling and usable hardware. We expect AR headsets to eventually play an important role in delivering hands-free and convincing AR content and services to consumers but due to various constraints on the technology, mobile devices will play the dominant role in the short to medium term.

With Apple's release of ARKit and Google release of ARCore there is now a huge addressable market of AR capable consumer devices. Apple's ARKit alters the game for AR because it makes it significantly easier and cheaper for third party developers to create AR content. Before Apple, developers had to create their own software foundations to detect surfaces, align virtual content, and do positional tracking. IHS Markit expects there to be over 1.2 billion ARKit devices active in the market by the end of 2021.

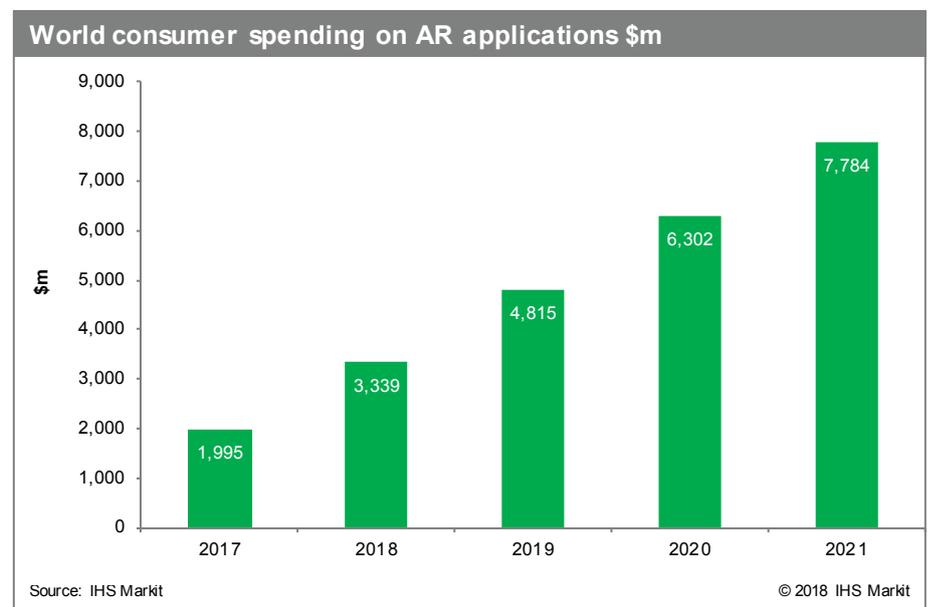
AR application opportunity will eclipse VR: IHS Markit expects that mobile AR apps will present a much bigger opportunity to developers than the current outlook for smartphone VR apps. The main reason for this is that the scale of the opportunity for smartphone VR is limited by the relatively small installed base of smartphone and standalone VR headsets, especially when compared with the billions of smartphones in use.

Apple and Google's moves to ease AR app development will also boost the market. AR features will not simply drive new app downloads but can also be implemented in existing apps – which may already have audiences of millions of users (e.g. social, messaging and entertainment platforms). Existing apps can be updated with AR features meaning that unlike smartphone VR – which largely relies on new dedicated apps – there will be fewer user acquisition challenges.

Enterprise adoption of AR solutions is increasing steadily as the hardware improves, enterprise software extends to include support

for immersive computing technologies and pilot programs deliver a positive return on investment. As of today, there are hundreds of trials and pilot programs using smartphones, tablets smartglasses and AR headsets across different vertical industries where digital overlays or a hands-free solution is key to delivering usability across processes such as field maintenance, assembly and warehouse management. Some of these pilot programs are now shifting to full-scale commercial deployments.

Enterprise customers are less acutely concerned about the issues that need to be addressed to deliver a compelling AR hardware solution to the consumer including aesthetic of the hardware, its weight, how it compares to other displays, and price point, as long as it delivers on the requirements of the use case. Often these deployments are transformational to working practices so putting up with a bulky form factor or having to change batteries is not a deal breaker. However, enterprise deployments add a whole host of other conditions which need to be met including integration into existing systems, the creation of content, maintenance of hardware, software patching, security, and service delivery.



Industry and AR use case prioritisation for telcos

The benefits of 5G and other technology advantages held by the telco, such as edge computing, means that some AR use case are likely to be sweet spots for telco engagement above others.

Alongside partners, telcos should be prioritising industries that are relatively mature in the use of AR solutions. Not only will these companies be aiming to scale up their solutions and looking for connectivity and cloud support to make that happen, they are also likely be looking for more complex implementations which will require better connectivity and larger amounts of GPU compute power in the cloud. Manufacturing has been particularly active in use of AR including graphically ambitious implementations which involve 3D renders to aid with maintenance, quality assurance and assembly.

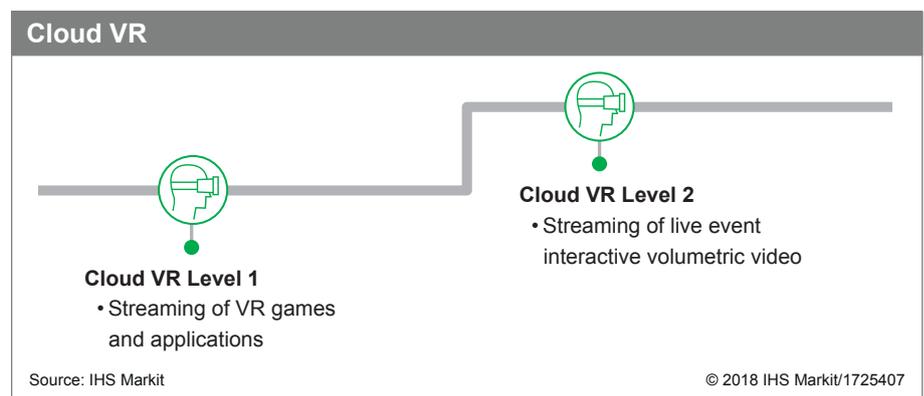
Telcos should be targeting implementations for mobile workforces that are large and distributed, and that often work remotely. The inherent strengths of 5G mean that these use cases are a solid fit for next generation mobile network deployments.

The other key area of consideration is looking for industries that will be using large amounts of 3D content and remote video calling rather than simple notification-based systems, as these use cases will be more demanding on compute power and connectivity.

Cloud AR/VR

The Cloud AR/VR proposition combines GPU-compute power in the cloud, interactive applications for VR and AR, 5G distribution capability and smart client end user devices. While immersive technologies are often lumped together, Cloud VR and Cloud AR are distinct opportunities with different use cases and applications.

Cloud VR content can be split into two levels of complexity as set out below, both of which require very low latency connectivity to ensure a comfortable experience for the end user. Cloud VR is relevant to a cross section of B2B and B2C use cases including specific industry applications such as education or training, VR location-based entertainment and mobile consumers. 5G connectivity will be able to support these solutions in the home or enterprise through FWA and, more distinctly, on the move through mobile networks.

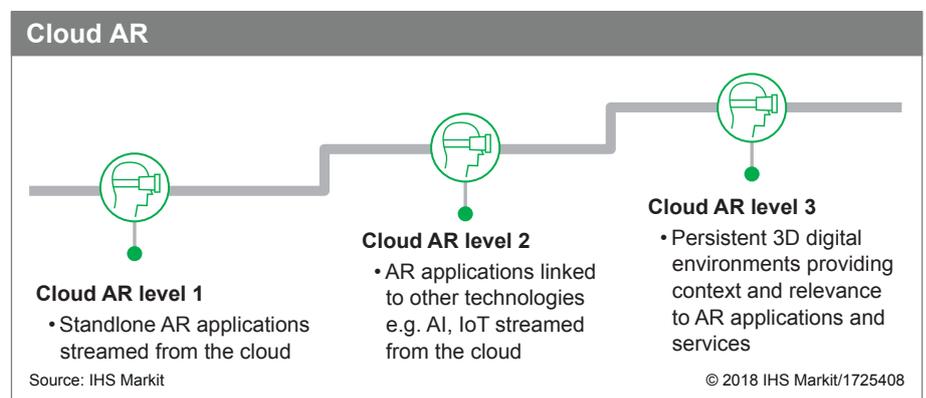


- **Cloud VR Level 1:** The streaming of VR games and applications using the same approach as cloud gaming or GPU-heavy virtualised desktop applications. These solutions have yet to be commercially implemented but will require very high GPU compute power and very low latency delivery networks to be successful.
- **Cloud VR Level 2:** Volumetric video capture of 3D objects and people is used as a content production technique in VR games and applications. Eventually, IHS Markit believes that volumetric capture will extend to whole scenes and, for example, live sports events or concerts, delivering deeper interactivity to live action video. The additional challenge of volumetric capturing, upstreaming to the cloud, processing and distributing live events means that this is still several years away from commercial deployment.

Like VR, the demand for **Cloud AR** solutions is nascent, but following the update of mainstream mobile platforms – iOS and Android – with higher level AR functionality, the demand is expected to increase substantially over the next five years. IHS Markit data shows Apple ARKit devices will reach a global installed base of 1.2 billion devices by 2021 and consumer spending on AR apps is expected to grow to almost \$8 billion a year in the same time frame. By this point consumers and enterprises will be buying 17 million AR headsets. Indeed, as a mobile-first technology, the sophistication of AR applications is directly linked to the quality of mobile connectivity which serves smartphones, tablets and AR headsets.

The Cloud AR opportunity can be split into three levels of complexity which place increasing demands on network connectivity. Again, 5G connectivity will be able to support these solutions in the home or enterprise through FWA and, more distinctly, on the move through next-generation mobile networks.

- **Cloud AR Level 1:** Cloud rendering of standalone AR applications which are then streamed to end user devices enabling use of thin clients, cheaper hardware and more powerful AR applications.
- **Cloud AR Level 2:** Cloud rendering of AR applications and services linked to other cloud-based technologies such as AI, location services, advertising and IoT which are then streamed to end user devices.



- **Cloud AR Level 3:** Cloud rendering of persistent 3D digital environments providing context and relevance to cloud-rendered AR applications and services streamed to end user devices.

Telcos are best placed to deliver the Cloud X proposition

In a 5G future, telcos are naturally advantaged as they not only own the distribution pipe and control the roll-out of 5G technology, but their evolving edge computing capability means that they can potentially provide better content service delivery than the public cloud providers, which is especially important for graphically rich and GPU-compute hungry applications that require low latency connections to the end user.

Cloud service providers are keenly aware of the disadvantages of a centralised cloud proposition, so are investing in their own edge and hybrid computing solutions building capabilities and offerings that will be aligned to support emerging technologies such as IoT, autonomous vehicles and edge analytics. While telcos may still hold an advantage over these emerging solutions, the window of opportunity to leverage this existing mobile edge computing capability is slowly narrowing.

IHS Markit Customer Care

CustomerCare@ihsmarkit.com

Americas: +1 800 IHS CARE (+1 800 447 2273)

Europe, Middle East, and Africa: +44 (0) 1344 328 300

Asia and the Pacific Rim: +604 291 3600

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