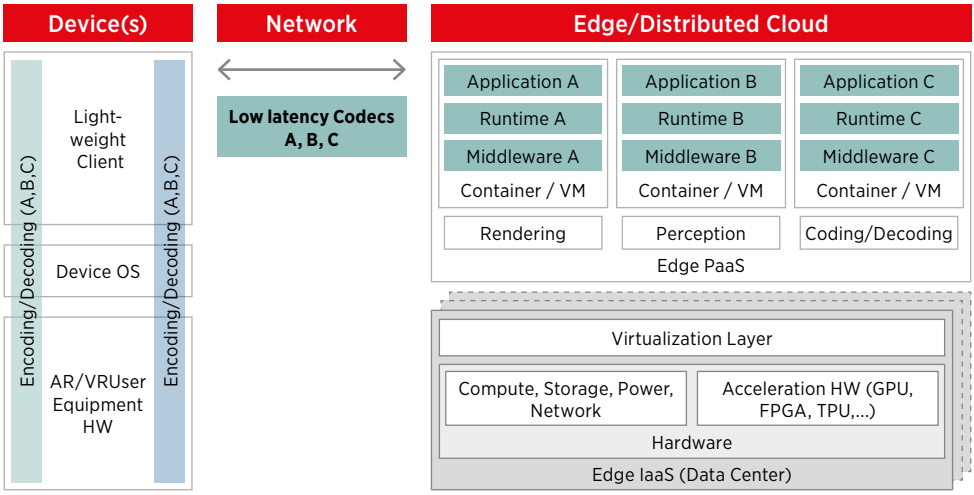
Cloud AR/VR Streaming:

Accelerate mass adoption and improve quality of experience of AR/VR using 5G and edge cloud

Currently, to fully appreciate the benefits of Virtual Reality applications such as gaming, users require expensive hardware, i.e. a high-end PC or gaming console and a head mounted display (HMD). This is because VR applications require a large amount of processing power and storage mainly for visualization of the virtual scenery in order to enable truly immersive experiences.

As a result, users of VR are confined to a particular location and mass market adoption is so far rather low due to the high entry barriers such as equipment costs, bulky headsets and difficult usability. Although the first standalone VR HMDs no longer require an additional PC, their graphics visualization capabilities cannot yet keep up to the expectations of users (e.g. 4K TV experience). Augmented Reality experiences are available today on either smartphones & tablets or on AR glasses such as Hololens, which allow hands-free usage. Due to limited computing power and Filed of View (FoV), however, the overlay and interaction between digital content and the physical world lack harmonization. On the other hand, a solution that allows for mobility and one that uses cheaper equipment does not offer a sufficiently good quality of experience due to the hardware limitations. With the arrival of 5G, the required capabilities to support AR/VR can be moved away from the PC or console into the edge cloud resulting in a lightweight and inexpensive headset that can still provide quality on par with fixed equipment: this is cloud AR/VR streaming technology.

Figure 1: Cloud AR/VR reference architecture



Critical to realizing the benefits of Cloud AR/VR is a 'lightweight client' approach, i.e. an architecture where the device can leverage cloud technology to supplement the processing, storage and application execution away from the device in the cloud. AR/VR technology will become truly mainstream with the broad-scale adoption of 5G networks thanks to the convergence with the cloud and the incredibly fast, low-latency data connection. This combination will allow delivery of ultra-high resolution 4K or 8K viewing experience with a low motion-to-photon latency. In contrast to today, when content is typically downloaded and rendered on a device, with this new architecture it will be possible to stream pre-rendered video content to users on the move. 5G technology will deliver all of these demands via its new network capabilities, providing a more reliable experience and ultra-low latency service through edge cloud technology.

AI Artificial Inteligence

GPU Graphic Processing Unit

IaaS Infrastructure as a Service

Motion-to-Photon the time delay between something happening in the real world such as the user moving their head and the corresponding visualization being rendered in the display

ML Machine Learning

PaaS Platform as a Service

Key technologies

Edge Cloud

As interactive AR/VR services have very stringent requirements on the motion-to-photon latency using central clouds is not an option. Instead, meeting the delay budget will require the usage of in-network edge data centres. This setup will utilize the power and economics of cloud computing while still delivering a very high quality of experience. The edge data centres typically placed within the operator networks host general compute, storage, network and power specifically designed to support the AR/VR accelerator hardware, e.g. GPUs for rendering/AI/ML as well as hardware support for encoding/decoding. The main challenge of edge cloud is to be able to apply the cloud principles to those accelerators in order to achieve similar cost efficiencies as those achieved in cloud computing. Another key aspect is to ensure global scalability of an edge infrastructure to avoid costly local integration efforts. The GSMA proposes to achieve this by logically splitting the edge IaaS typically built and operated by an operator and edge PaaS that is an overarching software layer providing global scale. With this concept, AR/VR applications can use a single interface to deploy over different edge infrastructures.

Low Latency Codec

The current family of H.26X codecs suffers from high latency, which is mainly caused by the following reasons;

- The encoding, transmission, and decoding are performed in a serial mode. Only after the entire frame is decoded can it be delivered for terminal display.
- Jitter occurs during network transmission. In order to suppress screen flickering due to network jitter, a large buffer is used before decoding.
- The decoding time of different frames also jitters. Therefore, a certain amount of buffer is used after decoding to alleviate the screen flickering caused by the decoding time jitter. The latency as a result of network and decoding timing jitter tends to be longer than the decoding latency.
- The entire E2E system running status is also affected by software processing latency, such as the latency between when the data is written and when it is exported from hardware/software, and the latency to perform audio-to-video synchronization.

In order to overcome those limitations new codecs are required. There are interesting solutions already emerging that can dramatically reduce the latency at the expense of increased bandwidth. This is a trade-off that becomes feasible as networks evolve. Still, those new codecs lack standardization resulting in limited support in hardware and in devices. It is our aim to support the industry efforts to either improve existing or create new low-latency codecs.

Lightweight Client

As the compute-intensive parts of the AR/VR application are offloaded to the edge cloud what remains on the device is called 'lightweight client'. What parts are actually offloaded to the network depends on the use case and on the applications. In one model, the entire application that was previously running on the device is moved into the edge cloud. This has the advantage of requiring no or only minor modifications to the existing application. Another possibility is to deploy a hybrid approach, where only some elements of the application are offloaded. The disadvantage of the hybrid approach is that this requires adaptation of existing applications, however the capability of pre or post-process data on the device results in a reduction of the amount of data which needs to be sent over the network.

Business impact

Cloud AR/VR streaming generates different benefits along the value chain that can be used for monetization:

- Benefits for AR/VR users: thanks to the virtually unlimited power of the edge cloud an exceptional quality of experience can be delivered to the user; AR/VR experiences become more immersive providing a bigger pleasure or less stress to the user.
- Benefits for device manufacturers: the hardware prerequisites for tethered AR/VR get lowered and therefore reducing adoption barriers like price and ease of deployment. In turn this results in higher scalability of AR/VR and higher device sales.
- Benefits for AR/VR application providers: applications, which today need to be adapted to every specific AR/VR runtime and device, can be developed to be deployed on any device that supports the lightweight client/streaming codec. Therefore, application development cost is reduced while its market reach is increased.
- Benefits for operators: operators can engage along the whole AR/VR value chain, but most importantly, it will be leveraging the low-latency connectivity 5G provides and the capability of providing infrastructure close to the user. In addition to that, operators can act as AR/VR content aggregators and discovery platforms. For operators that would like to engage higher up in the value chain, opportunities exist e.g. in the area of cloud AR/VR game streaming or as a provider of integrated managed AR/VR services, e.g. as a VR Training service provider for enterprises.

In July 2018, China Mobile (Fujian) launched its commercial Cloud VR services, including VR onsite, VR broadcast, VR IMAX, VR gaming, and VR education services.

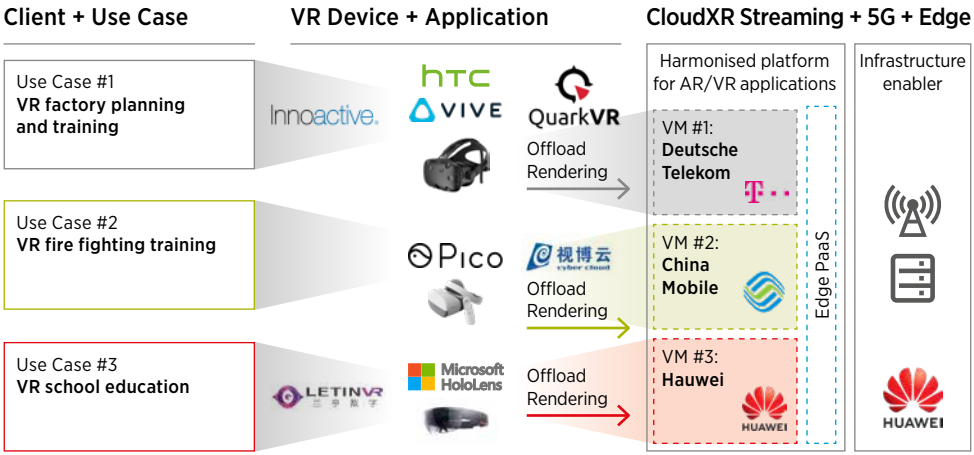
The Cloud VR services use the computing power provided by the cloud GPU rendering and cloud server architecture to ensure stable transmission of VR video streams and high-resolution image display.

Reference Case 1: China Mobile Fujian Cloud VR

Based on China Mobile's home 5G Wi-Fi, the VR video program (4K panoramic video with bitrate of 40Mbps) requires 60Mbps to ensure smooth video playing without frame freezing. For the Cloud VR gaming service, excellent VR gaming control experience is achievable when the network roundtrip delay (including the air interface) is below 20ms.

To demonstrate the scalability of VR Streaming solutions across different infrastructures Huawei, China Mobile and Deutsche Telekom worked together with their partners to deploy different AR/VR Training applications for different AR/VR devices/ ecosystems. Scalability is achieved through a common edge PaaS solution which abstracts individual infrastructures and provides runtime management and orchestration services to the cloud streaming applications.

Reference Case 2: Scalable AR/VR Training deployment (Huawei, China Mobile, Deutsche Telekom)



Benefits across Verticals

- **Easy & cost-effecient deployment** of new AR/ VR-based use cases (e.g., no HW setup necessary; stream AR/VR content similarly to movies on Netflix)
- **Cross-platform** availability of **high-fidelity content** for photo-realistic experiences

Benefits for OEM and Application

- Increased **market reach** (lower device pricing & adoption barriers for customers)
- Significantly **improved content quality** and **new use cases enabled** on non-GPU powered HMDs

Benefits for Operators

- Showcase **relevance of 5G & Edge** for AR/VR
- New **revenue stream** via Edge Computing
- **Harmonised platform scales** across ecosystem and allows monetization of 5G & Edge capabilities

What's next? GSMA 5G Cloud XR project objectives

While single solutions for cloud AR/VR use cases already exist today, they do not scale as the whole stack has to be custom built for every single case. It is questionable if long-term investments based on this paradigm are sustainable both because of its complexity and the lack of scale.

The GSMA 5G Cloud XR project has been established to harmonize requirements and implementations and therefore stimulate the whole ecosystem both for AR/VR, but also wider "reality" frameworks. The project will establish common positions that will help operators to commercialize Cloud XR based products and services. To drive towards mass adoption, it is critical that the work of the GSMA 5G Cloud XR project provides benefit across the whole value chain. To ensure the widest possible collaboration among stakeholders, participation to parts of the project is open also to non-GSMA members through the GSMA 5G Cloud XR forum.

To find out more, or to get involved in the GSMA Cloud XR Forum, please email **futurenetworks@gsma.com**

Summary

For Cloud XR to realize its full potential, the industry must collaborate. In contrast with current technology, typically requiring a user to have an expensive PC or a gaming console supplying the required amount of processing power and storage to which the user is tethered, with Cloud AR/VR it will become feasible to use services – especially AR –on the move with less expensive equipment.

5G and edge cloud are the technologies that can deliver the high-quality connectivity and processing power needed to realise this vision.

However, this will only become reality with a common approach and industry-wide collaboration that focuses on avoiding market fragmentation from the outset. For example, it is critical that mobile network operators work together to ensure that businesses offering XR products, can reach 100% of their customers in a market independently of the customer's mobile network.

To foster the widest possible cooperation, we have been working to create a forum with multiple global mobile operators, vendors and other players in the ecosystem to encourage all parties to collaborate on accelerating the delivery and deployment of 5G cloud-based XR services.

Through this collaboration, we are set to take XR to the next level.

The GSMA represents the interests of mobile operators worldwide, uniting nearly 800 operators with almost 300 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces industry-leading events such as Mobile World Congress, Mobile World Congress Shanghai, Mobile World Congress Americas and the Mobile 360 Series of conferences.

For more information, please visit the GSMA corporate website at www.gsma.com

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