**3GPP TSG-SA WG4 Meeting #132S4-25xxxx**

**Japan, Fukuoka, 19 – 23 May 2025**

**Source: Tencent**

**Title: Discussion document on 3D Gaussian splat for mobile (FS\_6G)**

**Agenda item: 17.2**

**Document for: Information**

# 1. Introduction

Recent advances in 3D content delivery and immersive experiences such as extended reality and volumetric communication have encouraged the exploration of new 3D representations. Among them, 3D Gaussian Splatting (3DGS) has emerged as a compelling approach for real-time rendering and efficient storage of photorealistic 3D scenes. Initially proposed by academic researchers, 3DGS has seen rapid adoption within the research and open-source communities.

This contribution proposes to discuss the opportunity for SA4 to study the relevance and technical feasibility of integrating 3DGS as a multimedia format in mobile scenarios.

# 2. Current challenges in SA4 multimedia workflow

## 2.1. Limitations of existing 3D formats

Some 3D representation formats currently under study in FS\_Beyond2D, such as Multiview and point clouds, support volumetric representations. However, they present several challenges:

* Complex scene creation and capture pipelines are required, including multi-view camera arrays and advanced pre-processing
* High encoder complexity and substantial computational demands at the sender-side
* Limited scene realism, as represented objects are primarily surface-based, often lacking full photorealism or dense volumetric depth

These aspects limit the deployment of such technologies for real-time or bandwidth-sensitive mobile scenarios.

## 2.2. Technical constraints specific to SA4

The role of SA4 in delivering multimedia to mobile and bandwidth-sensitive devices is detailed:

* Compatibility with real-time and low-latency rendering pipelines
* Network scalability and adaptability
* Efficient metadata signaling and media encapsulation
* Energy efficiency and minimal processing load on mobile hardware.

# 3. Overview of 3DGS (3D Gaussian Splatting)

## 3.1. Presentation

3D Gaussian Splatting (3DGS) is a representation of 3D scenes that combines powerful data structures and real-time rendering techniques [1]. It encodes a 3D scene as a set of anisotropic Gaussian ellipsoids storing spatial and luminance information. 3DGS directly supports photorealistic rendering by exploiting the properties of luminance fields and leveraging GPU-accelerated rasterization.

The fundamental idea is to replace explicit connectivity (i.e., triangulation), describing the surface of the objects, with volumetric primitives (Gaussians) that can be efficiently projected and fused onto a 2D image plane.

Each Gaussian comprises the following attributes:

* Position (𝑥,𝑦,𝑧 ): Location of each Gaussian in 3D space
* Opacity (𝑜): Transparency or visibility of each Gaussian
* Rotate (q\_𝑤, 𝑞\_𝑥, 𝑞\_𝑦, 𝑞\_𝑧 ): Rotation of each Gaussian.
* Scale (s\_𝑥,s\_𝑦,s\_𝑧 ): Size and shape of each Gaussian along its principal axes.
* Colors (𝑑𝑐\_𝑟, 𝑑𝑐\_𝑔, 𝑑𝑐\_𝑏): Base color of each Gaussian primitive.
* SH: (𝑠ℎ\_(𝑖\_𝑟 ),𝑠ℎ\_(𝑖\_𝑔 ),𝑠ℎ\_(𝑖\_𝑏 ) ): How color changes from different directions.

The rendering process involves transforming on-screen Gaussians, projecting them, and performing a weighted accumulation based on their projected footprint and transparency.

This GPU-powered and inherently progressive pipeline enables real-time updates and responsiveness, particularly beneficial for augmented reality and mobile applications.

Compared to traditional neural radiance field (NeRF) approaches, 3DGS does not requires complex rendering process. It enables high-quality rendering at real-time frame rates without sacrificing photorealism, making it particularly attractive for mobile applications where performance and power efficiency are critical.

## 3.2. Technical description

3DGS represents 3D scenes as collections of anisotropic Gaussian distributions in 3D space. Each Gaussian encodes spatial location, scale, orientation, opacity, and spherical harmonics coefficients for view-dependent shading. Rendering is performed by a point-based rasterizer rather than full geometry reconstruction including connectivity information.

The standard rendering pipeline for 3DGS typically involves a multi-pass approach. First, the Gaussians are sorted by depth (from back to front) to ensure proper blending of semi-transparent elements. In the vertex shader, each Gaussian is transformed to screen space and its shape is adapted based on the view direction. The geometry shader (when used) may expand the primitive into a screen-aligned quad. In the fragment shader, each pixel within the footprint of the projected Gaussian is evaluated for opacity and color contribution. Finally, the blending stage accumulates these contributions using alpha compositing, producing a final image that captures complex lighting and volumetric effects.

While this sorting-based approach enables high-quality rendering, it imposes computational overhead and increases memory usage, which can be limiting for mobile GPUs.

To address these limitations, recent research has introduced sorting-free methods for 3D Gaussian splatting [2]. These methods avoid depth sorting by using order-independent blending techniques or visibility-aware approximations. This evolution significantly simplifies the rendering pipeline and reduces GPU workload, making 3DGS more suitable for mobile platforms. As these methods are still under active development, it would be beneficial for SA4 to evaluate their applicability, constraints, and potential for standardization in immersive media scenarios.

## 3.3. Aligned with mobile environment

The properties of 3DGS make it particularly well-suited to the technical goals and challenges usually addressed within SA4. Its structure offers a potential bridge between photorealistic immersive content and the practical limitations of mobile platforms and wireless network environments.

* Compression: 3DGS enables compact scene representations without explicit connectivity.
* Progressive splatting: LOD rendering and viewport-aware rendering are inherent to the model.
* Low-latency rendering: Rasterization-based rendering is fast and mobile-friendly.
* Network adaptability: Gaussians can be selectively transmitted or refined.

# 4. Use cases and relevance for SA4

The capabilities of 3DGS enable a wide range of immersive experiences that align closely with SA4's objectives for XR, streaming, and media delivery on mobile and constrained devices. Its flexibility in rendering and progressive streaming makes it a viable candidate for next-generation applications requiring interactivity, fidelity, and adaptability.

* Telepresence and XR communication: Avatars and environments streamed via 3DGS.
* Mobile virtual tours and cultural heritage: Interactive tours rendered in real time.
* Volumetric advertising: Lightweight delivery of interactive 3D ads.
* Education and healthcare: Visualization of training or anatomy scenarios.

These scenarios are part of the SA4 use case studies in XR and immersive media.

# 5. Proposed next steps

We propose to initiate a study item focused on evaluating 3DGS as an emerging 3D media format. The following objectives are anticipated to be addressed:

* Analysis of the representation format with the identification of stable parameters and those that may evolve or be specific to certain usages.
* Analysis of the mapping into the XR reference client and service architecture.
* Analysis of the different workflows and the media types depending on the service scenario (this includes traffic characteristics)
* Analysis of the compression aspects following different approaches (video, graphic… based) where not only the compression efficiency is to be addressed but also the implementability and the compatibility with existing media platforms (hardware decoders, GPUs…)
* Identification of encapsulation and signaling requirements (ISOBMFF, DASH)
* Feasibility of real-time rendering on mobile chips
* Collaboration with MPEG on format standardization if necessary
* Develop a reference end-to-end implementation from content capture to rendering, including content generation using AI/ML models.

# 6. Additional requested information

1. Preliminary work plan
   * TBD, given some evaluation and development objectives it is anticipated to
2. Anticipated normative work (e.g., same release or the following one, on which specs…)
   * Depending on the outcome of the study, the inclusion of a 3DGS format into 26.119 Media capabilities for AR, as well as some 3GPP services supporting immersive experiences.
3. Any intent to provide corresponding implementations: test vectors, APIs, reference implementation (internally developed by 3GPP, supported externally e.g., by MRP…)
   * Intent to develop within SA4 a mobile 3DGS renderer, source test sequences (multi view, videos…) as well as 3DGS content. The 3DGS content generation is TDB.
4. Expected SA approval date (package 1 or 2).
   * Package 1, September 2025
5. Indication of 5GA or 6G topic
   * 6G topic
6. Expected SWG(s) to host the proposal (may be joint).
   * VIDEO SWG for the format analysis, then joint with RTC/MBS for system integration aspects.

## References

[1] Kerbl, B., Kopanas, G., Leimkühler, T., & Drettakis, G. (2023). 3D Gaussian Splatting for Real-Time Radiance Field Rendering. ACM Transactions on Graphics (SIGGRAPH Conference Proceedings), 42(4), July.

[2] Kheradmand, S., Vicini, D., Kopanas, G., Lagun, D., Yi, K. M., Matthews, M., & Tagliasacchi, A. (2025). StochasticSplats: Stochastic Rasterization for Sorting-Free 3D Gaussian Splatting, submitted at Computer Vision and Pattern Recognition (CVPR).