5G-EPICENTRE

5G ExPerimentation Infrastructure hosting Cloud-nativE Netapps for public proTection and disaster RElief

This is a postprint version of the following accepted article:

M. Kamarianakis, A. Protopsaltis, G. Papagiannakis (2022, November). AR-Assisted Surgical Care via 5G networks for First Aid Responders. IEEE International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (CAMAD) 2022.

DOI: [10.48550/arXiv.2303.00458](https://doi.org/10.48550/arXiv.2303.00458)

AR-Assisted Surgical Care via 5G networks for First Aid Responders

Manos Kamarianakis
University of Crete, FORTH
ORamaVR SA
Heraklion, Crete
manos.kamarianakis@oramavr.com

Antonis Protopsaltis
University of Western Macedonia
ORamaVR SA
Kozani, Greece
antonis.protopsaltis@oramavr.com

George Papagiannakis
University of Crete, FORTH
ORamaVR SA
Heraklion, Greece
george.papagiannakis@oramavr.com

***Abstract*—Surgeons should play a central role in disaster planning and management due to the overwhelming number of bodily injuries that are typically involved during most forms of disaster. In fact, various types of surgical procedures are performed by emergency medical teams after sudden-onset disasters, such as soft tissue wounds, orthopaedic traumas, abdominal surgeries, etc [1], [2]. HMD-based Augmented Reality (AR), using state-of-the-art hardware such as the Magic Leap or the Microsoft HoloLens, have long been foreseen as a key enabler for clinicians in surgical use cases [3], especially for procedures performed outside of the operating room. In such condtions, monolithic HMD applications fail to maintain important factors such as user-mobility, battery life, and Quality of Experience (QoE), leading to considering a distributed cloud/edge software architecture. Toward this end, 5G and cloud computing will be a central component in accelerating the process of remote rendering computations and image transfers to wearable AR devices.**

This paper describes the Use Case (UC) ”AR-assisted emergency surgical care”, identified in the context of the 5G-EPICENTRE EU-funded project. Specifically, the UC will experiment with holographic AR technology for emergency medical surgery teams, by overlaying deformable medical models directly on top of the patient body parts, effectively enabling surgeons to see inside (visualizing bones, blood vessels, etc.) and perform surgical actions following step-by-step instructions. The goal is to combine the computational and data-intensive nature of AR and Computer Vision algorithms with upcoming 5G network architectures deployed for edge computing so as to satisfy real-time interaction requirements and provide an efficient and powerful platform for the pervasive promotion of such applications. Toward this end, the authors have adapted the psychomotor Virtual Reality (VR) surgical training solution, namely MAGES [4], [5], developed by the ORamaVR company. By developing the necessary Virtual Network Functions (VNFs) to manage data-intensive services (e.g., prerendering, caching, compression) and by exploiting available network resources and Multi-access Edge Computing (MEC) support, provided by the 5G-EPICENTRE infrastructure, this UC aims to provide powerful AR-based tools, usable on site, to first-aid responders.

***Index Terms*—5G Network, Cloud/Edge computing ,Augmented Reality, Surgical Care, PPDR, First Aid Responders.**

I. Introduction

Main purpose of this UC is to perform various experimentations on the 5G infrastructure via an AR-assisted surgical care application for Public Protection and Disaster Relief (PPDR). Ultimately, the UC aims to provide first-aid responders, situated on a disaster site, with a powerful tool that will help save lives in peril. Using untethered highly-portable AR head-mounted displays (HMDs), the PPDR responders will be able to visualise various deformable internal body parts on top of the patient as if they had super-human vision. Furthermore, an instruction set will allow them to perform various operations with the possibility of remote guidance from a medical expert (see Fig. 1). The current state-of-the-art, driven, among others, by ORamaVR's innovative VR Engine *MAGES*, allows the usage of tethered and untethered VR HMDs to perform similar tasks such as VR surgeries. In the particular setup, VR HMDs have to either be connected with a cable to a VR-ready local computer (tethered device which provides high performance GPU/CPU but limited user-mobility), or run standalone (untethered device provides user-mobility, but relatively decreased GPU/CPU performance), to create a high Frames-per-Second (FPS) VR scene. Within the 5G-EPICENTRE project, the power of MAGES is leveraged to untethered AR HMDs. By offloading the processor-heavy rendering operations to the edge/cloud services provided by the 5G-EPICENTRE infrastructure, we lighten the processing burden of AR HMDs to mostly receive and project the rendered scenes and only broadcast the user interactions back to the edge via a 5G connection. Since the heavy processing will not be performed on the device, a significant decrease in the HMD's energy consumption is expected while the use of inexpensive, light-weight HMDs now becomes a possibility. As the PPDR first-aid responder may be located outdoors at any incident site, the increased energy autonomy of the portable device will reduce environmental impact and enable greater portability of the whole project.

This work is partially funded by the 5G-Epicentre Horizon 2020 project.

II. Benefits from Transitioning to Cloud/Edge Resources

By exploiting CPU and GPU resources that are available on the Cloud/Edge continuum, we gain numerous advantages in comparison to the classic setup, where a monolithic application component is installed and run on (un)tethered HMD.

Indeed, in the classic tethered HMD setup, all processes involving storage, rendering and compression are run on a VR-ready PC and therefore we have a serious limitation in terms

Fig. 1. The PPDR responder uses an AR HMD to see overlayed info and deformable objects on top of the patient. Envisioned example of UI layout.

of mobility/portability. The utilization of untethered HMDs partially lifts the mobility constraint, but with two drawbacks: a) such devices have inadequate hardware specifications, in terms of CPU power (ARM-based processors) and of GPU power (limited RAM, no CUDA enabled), and b) limited battery life, as they execute all processor-heavy rendering processes, that drain battery fast. Finally, in classic multi-user setups, the user initializing a session is considered the host of the multi-user session, also referred as *master server*. The QoE of the multi-user session depends on the master server's hardware and bandwidth resources, which is an additional point to consider when multiple users are involved.

On the other hand, the 5G-EPICENTRE platform allows many of these constraints to be lifted within the context of a cloud/edge based application. Firstly, the platform will provide powerful cloud-edge resources to the AR PPDR application, transforming the monolithic application to a Software-as-a-Service, which will be available for consumption even for untethered, affordable HMDs of lower specifications. By lifting the hardware restrictions, we can a) design a device agnostic framework and b) use lightweight HMDs to achieve high-mobility and increased battery life, which is essential for PPDR missions. Lastly, the deployment of the netapp in cloud/edge resources guarantees flawless multi-user sessions as they will no longer depend on the network characteristics of the first user.

III. Expected Results

The design of an AR-Assisted Surgical Care application that exploits resources on the cloud-edge continuum, is a difficult task that, when completed, will yield satisfying results. In the envisioned setup, the heavy processes such as Physics and Scene Rendering, will be performed on an Edge Node of high CPU/GPU performance. The HMD's resources will be used mainly to send user input (movement and triggers) to the edge netapp and decompress/project the stream. In this way, we expect to achieve increased mobility for existing HMDs, but also enable the usage of low-spec HMDs. The rendered scene will be streamed compressed (e.g., WebRTC) to the HMD via the 5G network, which allows Low latency and high bandwidth. In this way, we may stream high quality and fidelity images, without compromising QoE; as long as a minimal latency is kept, user immersion in AR can be preserved. In case of network characteristics fluctuations, QoE can still be guaranteed by exploiting adaptive resolution techniques. Specifically, we may choose to stream lower-quality images whenever the 5G-EPICENTRE or application analytics engine detects a bottleneck in the sequence.

To be more specific, the key performance indicators (KPIs) that the UC aims to achieve within the 5G-EPICENTRE project are the following: a) Round Trip Time (RTT) less than 7ms, b) total aggregated bandwidth of more than 0.7 Gb/s and c) a battery life increase of more than 30% for untethered AR HMDs, compared to the classic setup.

IV. Deployment of UC Components

The components that are used for this UC, are depicted in Fig. 2. Specifically, the components developed by the ORamaVR team are a) the application running a) on the HMD and b) the application server containerized via kubevirt, on an edge node (depicted in blue). The latter application exploits cloud-based services such as the Azure Cloud for database management and the Photon Server for multi-user sessions (depicted in green). The the application server instantiation on the edge is performed via the 5G-EPICENTRE platform that handles all necessary intermediate tasks such as optimal edge node discovery/availability, network slicing, deployment sequence, handshaking, etc. Furthermore, the platform also monitors and logs useful network metrics throughout the use of the AR application and identifies, in real-time, potential bottlenecks that in turn activate adaptive rendering mechanisms. The connection of the AR HMD application to the 5G network and hence the 5G-EPICENTRE platform is accomplished via a 5G modem, to compensate the lack of 5G connection ports in most AR HMDs.

V. Experimentation

The UC experimentation on the 5G-EPICENTRE platform is expected to be performed in the following phases:

1) Identification of the capabilities of the 5G network architectures and services provided by the testbed provider as well as the edge computing network services.

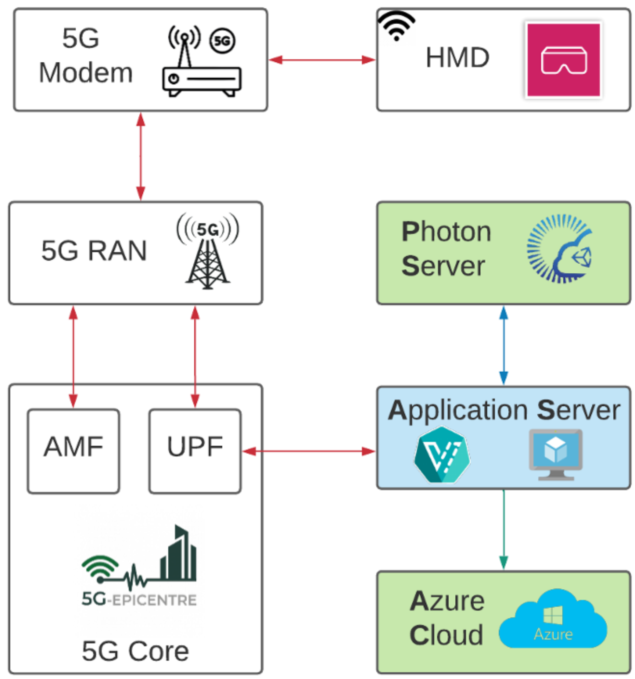

Fig. 2. Envisioned layout of the UC components (see IV). Blue and Green nodes correspond to edge and cloud resources respectively.

2) Implementation of a suitable netapp version of an AR application, which will run on the edge.
3) Development of the necessary VNFs to manage data-intensive services (e.g., prerendering, caching, compression), exploiting available network resources and multi-access edge computing (MEC) support provided by 5G-EPICENTRE.
4) Determine potential performance bottlenecks of operating a monolithic AR application.
5) Suggest offloading of the software architecture through microservices without adding excessive inter-services latency.
6) Fine tuning of the AR application to fully exploit available network resources and MEC support provided by 5G-EPICENTRE.
7) Fulfilment of the KPIs regarding bandwidth usage and latency, as well as device energy consumption.
8) Compilation of a list of insights towards a better understanding of the 5G network utilisation in conjunction with state-of-the-art AR applications and present the tools that were used throughout the experimentation.

To demonstrate the added value of the experiment, various test cases have been specified:

- Measurement of end-to-end latency using different configurations of data compression.
- Conduct load testing to determine the optimal number of users that the network allows within the latency threshold.
- Conduct stress testing to determine the number of users that the network can accommodate without inducing network congestion while preserving QoE.
- Experimentation with state-of-the-art object recognition methodologies to provide 3D model optimal overlay.
- Evaluation of different user interfaces in search of the optimal solution that provides a smooth user experience while visualising the proper amount of information streamed from the edge.

The deployment and experimentation will take place in Barcelona, from June 2022 to June 2023, where the high CPU/GPU node capabilities of the CTTC testbed will be exploited. The lab experimentation will focus on RTT, Bandwidth Throughput and Package Loss. As already mentioned, all tests aim to stress-test the capabilities of the 5G-EPICENTRE platform. The ultimate goal is to draw QoE-related conclusions from the experimentation results and fine-tune various network settings that will be reported by the project for future reference.

VI. Acknowledgment

The work presented is funded by the 5G-EPICENTRE Horizon 2020 EU-funded project.

References

[1] C. A. Coventry, A. I. Vaska, A. J. Holland, D. J. Read, and R. Q. Ivers, “Surgical procedures performed by emergency medical teams in sudden-onset disasters: a systematic review,” *World journal of surgery*, vol. 43, no. 5, pp. 1226–1231, 2019.

[2] T. Birrenbach, J. Zbinden, G. Papagiannakis, A. K. Exadaktylos, M. Müller, W. E. Hautz, and T. C. Sauter, “Effectiveness and utility of virtual reality simulation as an educational tool for safe performance of covid-19 diagnostics: Prospective, randomized pilot trial,” *JMIR Serious Games*, vol. 9, no. 4, p. e29586, Oct 2021. [Online]. Available: https://games.jmir.org/2021/4/e29586

[3] P. Zikas, S. Kateros, N. Lydatakis, M. Kentros, E. Geronikolakis, M. Kamarianakis, G. Evangelou, I. Kartsonaki, A. Apostolou, T. Birrenbach *et al.*, “Virtual reality medical training for covid-19 swab testing and proper handling of personal protective equipment: Development and usability,” *Frontiers in Virtual Reality*, p. 175, 2022.

[4] G. Papagiannakis, P. Zikas, N. Lydatakis, S. Kateros, M. Kentros, E. Geronikolakis, M. Kamarianakis, I. Kartsonaki, and G. Evangelou, “Mages 3.0: Tying the knot of medical VR,” in *ACM SIGGRAPH 2020 Immersive Pavilion*, 2020, pp. 1–2.

[5] G. Papagiannakis, N. Lydatakis, S. Kateros, S. Georgiou, and P. Zikas, “Transforming medical education and training with VR using MAGES,” in *SIGGRAPH Asia 2018 Posters*, 2018, pp. 1–2.