Use Case #7

AR and AI wearable electronics for PPDR [UMA Testbed]

Overview and Objectives

The UC7 experiment on the UMA testbed aims to evaluate the effectiveness of augmented reality (AR) wearable electronics for PPDR using a 5G network. The primary objective is to demonstrate the feasibility and reliability of smart glasses in providing real-time AR overlays and remote monitoring in critical situations. The KPIs measured in this experiment include: (i) time to detect incidents (UC 7.1); (ii) time to present AR information (UC 7.2); (iii) end-to-end latency for video streaming (UC 7.3); (iv) video transmission data rate (UC 7.4); and (v) reliability of the smart glasses (UC 7.5).

Use Case Description

Youbiquo (YBQ) is the manufacturer of the “Talens” Smart Glasses, a wearable computer equipped with AR and AI features. Having achieved several successes in the manufacturing industry, the Smart Glasses come equipped with Smart Personal Assistant and Video Conference software, which YBQ plans to integrate into the rescue and operations environment. In this Use Case (UC7), YBQ aims to experiment with its Talens Holo Smart Glasses in 5G network conditions, targeting a case of interest to the PPDR domain, which is described below.

As shown in Figure 1 below, instance segmentation and edge detection will be used to overlay useful information directly on top of the real world through the optical see-through display worn by civil defence workers (on-field operators), who patrol or operate in a designated area. For the realisation of this scenario, low latency edge device interconnection is a requirement so that ML processes dealing with costly, AI-driven semantic segmentation procedures can run efficiently in order to provide real-time view annotation. The overall situational awareness mechanism for the officers will be complemented by data interchanged between the operation site and the Command & Control Center (CCC). Finally, if drones are available on site, Machine Learning (ML) elaborated info coming from their cameras can be shown on the AR layer such as the number of people injured, fires placement, other public forces on the field and so on.

A set of civil defence workers wearing Smart Glasses are able to see AR information on the disaster scene. The AR layer is composed of information locally elaborated into the wearable processing unit together with information remotely elaborated by ML algorithms in the CCC. The Smart Glasses worn by the operator send an audio/video stream to the CCC for ML situational awareness evaluation. In the CCC a set of views can be developed in order to analyse the different information coming from the disaster field, segmented by its meaning, i.e., a heat map to highlight the movements of operators onto the field. All the operators wearing the Smart Glasses can start an audio/video call with the remote CCC.

In this UC, it is possible to use patrolling drones to effectively support partners working on their deployment and communication.

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The drones could be sent to the disaster field prior to the arrival of civil defence workers. Drone cameras can map the scene, their images can be shared with the CCC and this info can be useful for the people wearing Smart Glasses sent to the field before they arrive.
Moreover, during the action, users wearing the Smart Glasses can receive elaborated real-time info from the video flow acquired by drones. Using the fast 5G connection, the drones' video flow can be sent from the drones to the CCC, can be elaborated with ML algorithms and then sent to the Smart Glasses to have a complete awareness of the situation.
From a technological point of view, a mobile application has to be designed and developed for the Android platform (the OS of the Smart Glasses) and for the management of the drones' communication. In the AR field, there are different AR engines available; the first tests done using the Unity Framework are promising.

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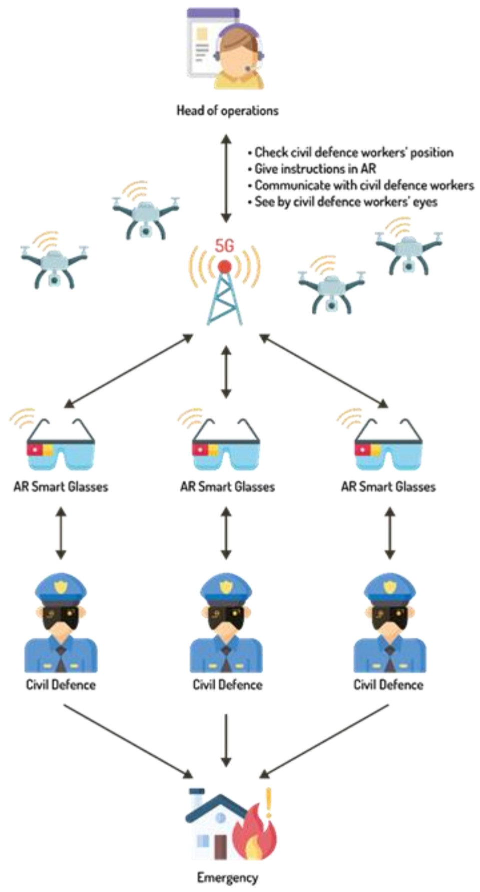

Figure 1: UC7 real-time semantic segmentation

Experiment Setup/Methodology/Deployment

The experiment was carefully planned to ensure comprehensive evaluation of the UC7 objectives on the UMA testbed. The hardware setup consists of an AR visor connected via a USB cable to the main computing unit, housing the 5G Quectel modem (Figure 2). Researchers wore this setup in the campus zone with direct visibility to the antennas. Users can communicate with the remote C&C Centre through audio-video communication, with video streamed from the wearable camera to the visor and onward to the C&C Centre, while audio is established during the video call.

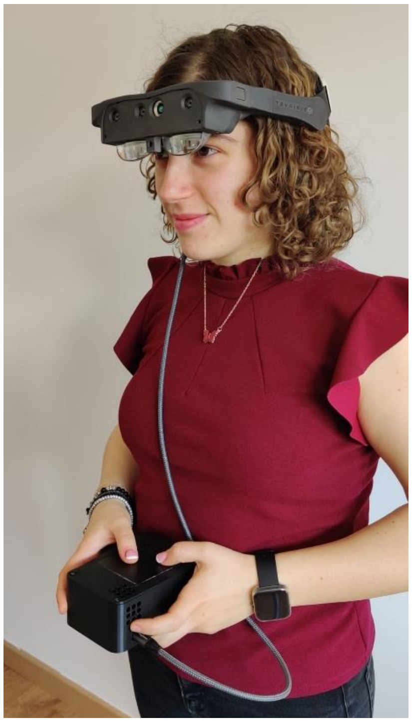

Figure 2: UC7 User Equipment at the UMA testbed

The deployment of the UC7 experiment on the UMA testbed utilized containerized environments managed via Kubernetes and Helm charts. The deployment requirements included:

- Kubernetes clusters to host the web applications and services;
- Helm for managing the deployments of these applications;
- RabbitMQ as a message broker to facilitate communication between the C&C Centre and field operators;
- A media server for handling WebRTC streaming; and
- KPI collector services for gathering and analysing performance data.

This deployment ensured robust, scalable, and easily manageable environments across the UMA testbed, enabling seamless integration and operation of the various components involved in the experiment.

Experiment Execution and Results

During the experiment's execution on the UMA testbed, various metrics were recorded to assess performance against the predefined KPIs. In Table 1, details of the measurements of the metrics for UMA are presented, respectively. In Table 2 the collected KPIs for UMA testbed is described.

Table 1: UC7 UMA measurements results

Measurement	Description	Average over experiments
Negotiated link upload speed (Mbps)	Upstream channel speed as indicated by the core manager. *Note: in UMA testbed, this value never changed due to low traffic in the cell, and no QoS intervention.	60 Mbps constant over time.
Negotiated link download speed (Mbps)	Downstream channel speed as indicated by the core manager. *Note: in UMA testbed this value never changed, due to low traffic in the cell, and no QoS intervention.	145 Mbps constant over time.
SS RSRP (dB)		-70dB
SS RSRQ (dB)		-11dB constant over time
RTT Latency (ms)	Roundtrip Latency, two ways measured against SYN/SYN-ACK response time for a TCP socket. No special low-ring permission applied to the running code (i.e., no kernel-level socket calls involved, the measurement is from a user-space perspective).	13ms
Effective upload speed (Kbps)	Real upload speed tested vs. a TCP service.	>45 Mbps
Effective download speed (Kbps)	Real download speed tested vs. a TCP (HTTP) service	>100Mbps

Table 2 : UC7 KPIs – UMA experimentations results

KPIs	Results expected	UMA experimentations results
UC 7.1	Time to detect U ≥ 1.000ms > A ≥ 500ms> O	RTT (13 ms) + application elaboration (100 ms) = 113 ms [Optimal]
UC 7.2	Time to present U ≥ 1.500ms > A ≥ 1.000ms> O	RTT (13 ms) + mobile application elaboration (500 ms) + CCC application elaboration (200 ms) = 713 ms [Optimal]
UC 7.3	E2E latency U ≥ 100ms > A ≥ 20ms> O	RTT: 13 ms [Optimal]
UC 7.4	Video transmission data rate U ≤ 20Mb/s < A ≤ 40Mb/s < O	Negotiated link upload speed (Mbps): 60 Mb/s [Optimal]
UC 7.5	Smart Glasses reliability U ≤ 5 fps < A ≤ 20 fps < O	2*1080P30 video stream in H.264/HEVC: 5Mbps -> total upstream/downstream bandwidth of 10MBpsat 30 fps < effectively measured of 50Mbps [Optimal]

YBQ tested both nominal and effective RF parameters of the device under test (DUT) once registered in the 5GC. Considering the need to rely on the services with full local accessibility, no difference in significance of the measurements occurs whether being taken in a standalone or non-standalone core configuration.

A comprehensive set of 20 distinct experiments have been conducted, with and without data communication load, with a sampling interval of 1 second per each group of measurements. Smaller delta time (dT) would have made no real difference due to the implicit restrictions imposed by Android OS (from version 10 and newer ones), as most of the networking probing points have been bounded to the Location services policies. Indeed, it is possible to precisely localize a mobile user in a local or global mobile phone cell mesh system with an appropriate speed in estimating RF parameters. Android prevents this, by caching most of the SS parameters in the relevant Application Programming Interface (API) calls.

It is noteworthy that each testbed had its specific setup and configuration, tailored to the particular experimental requirements and environmental constraints. Despite differences in hardware and software components, the overarching goal of evaluating system performance and compliance with KPIs remained consistent.The results highlight the consistent performance across different metrics, reinforcing the feasibility and effectiveness of the proposed UC7 systems under 5G conditions on the UMA testbed.

Overall evaluation

The numerical results of the UC7 experiment on the UMA testbed were positive and aligned with expectations. The "time to detect" and "time to present" KPIs demonstrated rapid response times, which are critical for PPDR scenarios where every second counts. The low E2E latency for video streaming and high video transmission data rates highlighted the capabilities of the 5G network in supporting real-time, high-bandwidth applications.

- **Time to Detect (UC 7.1):** The measured detection time of 113ms was significantly faster than traditional systems, showcasing the efficiency of AR integration.
- **Time to Present (UC 7.2):** The total presentation time of 713ms was well within the acceptable range, ensuring that critical AR information is promptly available to field operators.
- **E2E Latency (UC 7.3):** The achieved latency of 13ms indicated minimal delay, essential for effective real-time communication and coordination.
- **Video Transmission Data Rate (UC 7.4):** The high negotiated upload speed of 60Mbps ensured smooth, high-quality video streaming, crucial for remote monitoring and situational awareness.
- **Smart Glasses Reliability (UC 7.5):** The smart glasses consistently provided stable performance, confirming their suitability for demanding operational environments.

Overall, the 5G network had a profound impact on the application's performance on the UMA testbed. The high-speed, low-latency characteristics of 5G enabled seamless AR visualization and real-time video streaming, which are critical for enhancing situational awareness and operational efficiency in PPDR scenarios. These results underscore the potential of 5G technology to revolutionize PPDR by providing reliable, high-performance communication and data transmission capabilities.

Conclusions

The experiments performed can be summarized as follows:

- Hardware Configurations and Issues:
  - The utilization of specific hardware configurations, such as Android tablets and custom AR visors, was essential in the testbed set-ups.
  - Issues related to the Android system in the custom computing unit prompted researchers to adapt and use Android tablets instead, ensuring smoother operation.
- Software Deployment:
  - Various software components were deployed across the testbeds to facilitate different functionalities.
  - These included Android applications for AR visualization, video streaming, and KPI acquisition, as well as web applications deployed on Kubernetes clusters for remote monitoring and control.
- Communication and Connectivity:
  - Communication between different components, such as AR visors, computing units, and remote command and control centre, was established through audio-video channels.
  - The results align with the predefined KPIs, underscoring the robust performance of the 5G networks in both the UMA and HHI testbeds.
- KPI Compliance:
  - Results obtained from the tests demonstrated compliance with the KPIs outlined in the experimental setups.
  - These KPIs encompassed various aspects such as time to detect incidents, time to present AR information, and overall system responsiveness.
- Testbed Variability

The conducted analyses across the testbeds showcase the feasibility and effectiveness of the implemented systems in meeting the specified objectives. By addressing hardware issues, deploying appropriate software solutions, and ensuring seamless communication and connectivity, the experiments successfully demonstrated the capabilities of the proposed UC7. Moreover, the observed compliance with predefined KPIs underscores the reliability and performance of the systems under test. These findings highlight the potential for further advancements and applications in fields requiring augmented reality, remote monitoring, and real-time communication. Moving forward, continued research and development efforts can further refine these systems, potentially leading to broader adoption and utilization in various practical scenarios.