Use Case #7

AR and AI wearable electronics for PPDR [HHI Testbed]

Overview and Objectives

The UC7 experiment aims to assess the effectiveness of augmented reality (AR) wearable electronics for Public Protection and Disaster Relief (PPDR) within 5G network environments. The primary objective is to demon-strate the feasibility and reliability of using smart glasses for real-time AR overlays and remote monitoring in critical operations. Additionally, the HHI testbed integrates video streaming from on-site flying drones, ena-bling on-demand display of remote streaming directly on the AR visor.

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) E2E 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 the figure 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.

This project has received funding from the European Union's Horizon 2020 Innovation Action programme under Grant Agreement No 101016521.

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

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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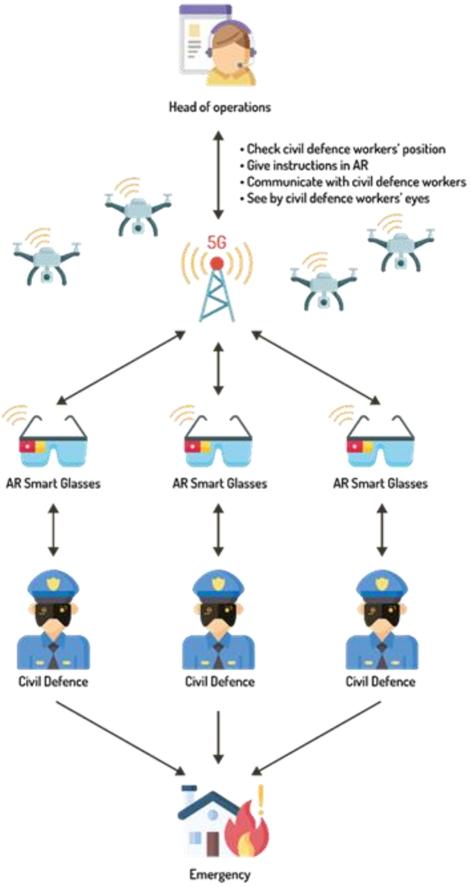

Figure 1: UC7 real-time semantic segmentation

Experiment Setup/Methodology/Deployment

The experiment was planned to ensure comprehensive evaluation of the UC7 objectives. The hardware configuration included Youbiquo custom AR visor connected to the Android tablet (Samsung Galaxy S8) via USB cable (see Figure 2). This setup was necessary due to initial issues with the custom computing unit's compatibility with the 5G network, which led to the adoption of Android tablets for smoother operation. The software environment involved Android applications for AR visualization and video streaming, as well as KPI acquisition. Additionally, a suite of web applications was deployed on Kubernetes clusters for remote monitoring and control. The testbed was equipped with 5G infrastructure to support high-bandwidth, low-latency communication essential for real-time AR and video streaming applications.

Figure 2: HHI setup with AR visor connected with the Android tablet via USB cable

The deployment of the UC7 experiment 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.
- KPI collector services for gathering and analysing performance data.

This setup ensured robust, scalable, and easily manageable deployments across the testbeds, enabling seamless integration and operation of the various components involved in the experiment.

Experiment Execution and Results

During the execution of the experiment, various metrics were recorded to assess performance against the predefined KPIs. The following KPIs outlined in D1.6 require consideration:

- **Time to Detect (UC 7.1):** This KPI measures the time between the start of the incident and the task assignment to the on-field operator wearing the smart glasses. It consists of three elements:
  - RTT for low-level message transmission on the 5G channel.
  - Time taken to display the incident on the web application (indicated by a red alert on the interface).
  - Time taken to assign the task to the on-field user, automatically determined by distance algorithms.

  The second and third elements are governed by web application algorithms, independent of network communication, relying solely on server computational capabilities. During testing, these contributions were consistently under 100ms, with potential for improvement through additional computational resources.
- **Time to Present (UC 7.2):** This KPI measures the time elapsed from the start of the video streaming from the smart glasses to the visualization of information in AR. It includes four components:
  - The RTT for low-level message transmission on the 5G channel.
  - The time taken to commence video streaming from the smart glasses to the Central Control Center.
  - The duration to evaluate the video stream at the Central Control Center and integrate AR information, managed automatically by AR algorithms.
  - The time taken to present AR information on the smart glasses.

  The second and fourth components are driven by mobile application algorithms, independent of network communication, and rely solely on mobile computational capabilities. The third component depends on the computational power at the Central Control Center. During testing, the Central Control Center's contribution was consistently under 200ms, while the mobile contribution remained under 500ms.

YBQ tested both nominal and effective RF parameters of the DUT once registered in the 5GC. Considering the need for full local accessibility, there was no significant difference in the measurements taken in standalone or non-standalone core configurations.

A comprehensive set of 20 distinct experiments were conducted, with and without data communication load, with a sampling interval of 1 second per group of measurements. Smaller time intervals would have made no significant difference due to the restrictions imposed by Android OS (from version 10 onwards), as most networking probing points are bound to Location Services policies. Android prevents precise localization of a mobile user in a local or global mobile phone cell mesh system by caching most SS parameters in the relevant API calls.

In Table 1, details of the measurements of the metrics for HHI are presented. In Table 2 the collected KPIs for HHI testbed is described.

Table 1 : UC7 HHI measurements results

Measurement	Description	Average over experiments
Negotiated link upload speed (Mbps)	Upstream channel speed as indicated by the core manager.	45 Mbps constant over time.
Negotiated link download speed (Mbps)	Downstream channel speed as indicated by the core manager.	85 Mbps constant over time.
SS RSRP (dB)		-75dB
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).	17ms (see Figure 3).
Effective upload speed (Kbps)	Real upload speed tested vs. a TCP service.	>40 Mbps (see Figure 4).
Effective download speed (Kbps)	Real download speed tested vs. a TCP (HTTP) service.	>80Mbps (see Figure 4).

Table 2 : UC7 KPIs – HHI experimentations results

KPIs	Results expected	HHI experimentations results
UC 7.1	Time to detect U ≥ 1.000ms > A ≥ 500ms> O	RTT (17 ms) + application elaboration (100 ms) = 117 ms [Optimal]
UC 7.2	Time to present U ≥ 1.500ms > A ≥ 1.000ms> O	RTT (17 ms) + mobile application elaboration (500 ms) + CCC application elaboration (200 ms) = 717 ms [Optimal]
UC 7.3	E2E latency U ≥ 100ms > A ≥ 20ms> O	RTT: 17 ms [Optimal]
UC 7.4	Video transmission data rate U ≤ 20Mb/s < A ≤ 40Mb/s < O	Negotiated link upload speed (Mbps): 45 Mb/s [Optimal]
UC 7.5	Smart Glasses reliability U ≤ 5 fps < A ≤ 20 fps < O	4KP30 + 1080P30 video stream in H.264/HEVC: 25Mbps at 30fps < effectively measured of 40Mbps [Optimal]

The following graphics provide a visual representation of some KPI evaluations, illustrating the performance metrics recorded during the UC7 experiment. These charts highlight key aspects such as the RTT latency and the upstream and downstream speed.

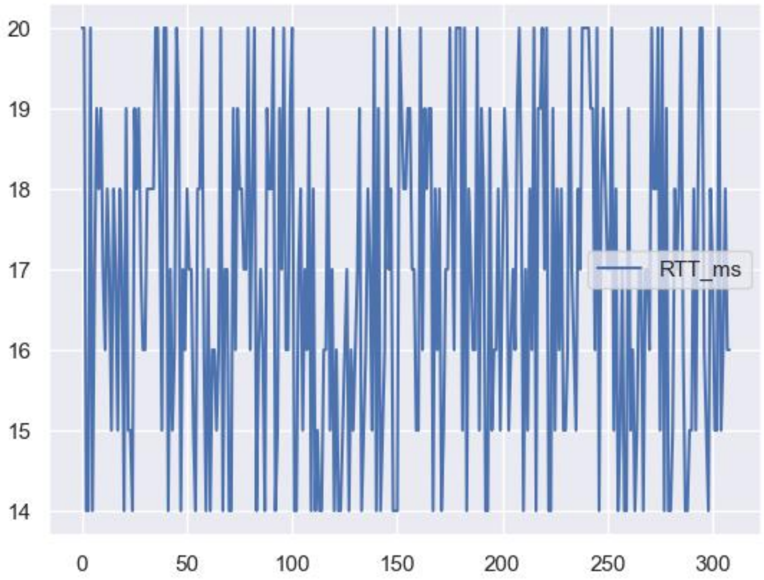

Figure 3: UC7 in HHI: RTT Latency (ms)

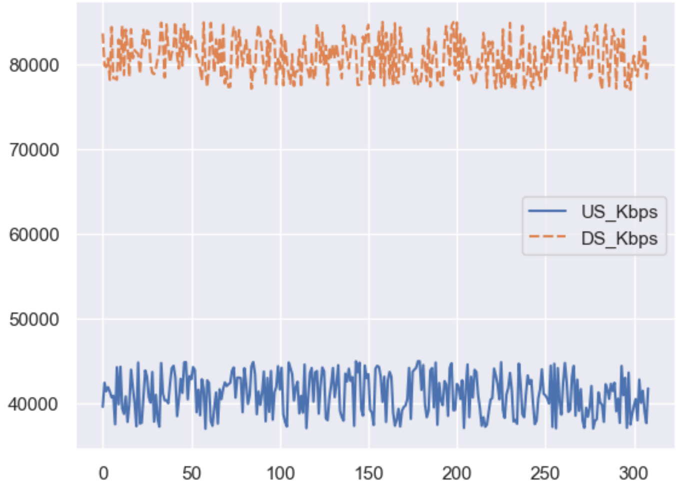

Figure 4 : UC7 in HHI: Upstream and Downstream speed (Kbps)

Overall evaluation

The numerical results of the UC7 experiment were generally positive and aligned with expectations. The "time to detect" and "time to present" KPIs demonstrated rapid response times, 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. Specifically:

- **Time to Detect (UC 7.1):** The measured detection times of 117ms, were significantly faster than traditional systems, showcasing the efficiency of the AR integration.
- **Time to Present (UC 7.2):** The total presentation times of 717ms were well within the acceptable range, ensuring that critical AR information is promptly available to field operators.
- **E2E Latency (UC 7.3):** The achieved latencies of 13ms indicated minimal delay, essential for effective real-time communication and coordination.
- **Video Transmission Data Rate (UC 7.4):** The high negotiated upload speeds of 45Mbps 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.

For the use case as tested in the HHI testbed, it is relevant to notice that an additional workload is required for the upstream link, in order to support the transmission of an extra video streaming channel coming from the drone, included into the equipment set. The video streaming has been accounted for the maximum bandwidth the drone is capable to produce, which can be stated at a maximum of 20Mbps when operating in 4K resolution at 30fps. This bandwidth has been added to the videocall maximum bandwidth (5Mbps), to validate the operating environment conditions in the worst possible use case.

Overall, the 5G network had a profound impact on the application's performance. 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.

Moving forward, the successful outcomes of this experiment suggest that continued research and development in 5G-enabled AR technology could lead to broader adoption in various practical scenarios. The findings highlight the transformative potential of 5G in enhancing the capabilities of PPDR operations, paving the way for more advanced, efficient, and reliable solutions in the field.

HHI platform conclusion

SC2 vividly demonstrates the transformative potential of 5G networks. Cutting-edge technologies like massive MIMO, Beamforming, and expanded bandwidth up to 100 MHz facilitate near-real-time data connectivity, offering crucial advantages for PPDR professionals, such as firefighters and police. In this era of advanced tools, like drones and AR/VR smart glasses equipped with ML and AI capabilities, PPDR teams can swiftly assess situations and devise effective strategies. Real-time transmission of critical information to mission control streamlines strategy formulation and response to life-threatening scenarios. SC2 exemplifies this by simulating scenarios in a controlled environment, leveraging the HHI testbed to showcase how 5G, particularly in UC3, UC6, and UC7, enhances PPDR operations. The recorded KPIs underscore the significant advancements and benefits that 5G's New Radio technology offers to the PPDR community.)

Conclusions

The experiments performed can be summarized as in the following breakdown:

- Hardware Configurations and Issues
    - The utilization of specific hardware configurations, such as Android tablets and custom AR visors, was essential in the testbed setups.
    - 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.