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AN OPTIMIZED 'SYSTEM APPROACH' DEPLOYING 5G TECHNOLOGIES FOR MOBILE SHOOTING OF TV SPORT EVENTS

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ABSTRACT

The evolution of 4G / 5G technologies is continuously improving network capabilities and expanding service scenarios: this represents an interesting opportunity for broadcasters in shaping the future media landscape. Indeed, it paves the way to promising solutions in different sectors, including the shooting of live TV events on the move. Specifically, new horizons are outlined in the framework of both content production and contribution by means of cooperative deployment options, based on a close synergy between broadcast and mobile technologies. This proves to be particularly interesting in challenging scenarios where the opportunities offered by the deployment interoperability allows cost savings to be achieved while exploiting network resources on a best-efficient basis. To this end, the present paper aims to critically investigate some 'hybrid' deployment models: depending on the circumstances, seamless switching is implemented between the contributions from the 'traditional solutions' so far adopted and those coming from the 4G / 5G network.

INTRODUCTION

Mobile shooting of live TV events has always represented an important pillar for media companies, as it includes a large variety of strategically impacting contests. Such live events range from the most common sport competitions such as *cycling or skiing races*, running matches (like *marathons)*, sailing events (*regattas*), up to very popular 'city events' concerning, for example, *political celebrations* (i.e. presidential elections), religious ceremonies and so on. Conventionally, for each of these events, the deployment of a significant number of radio frequency resources (used by radio cameras, radio microphones, communication systems, long range radio links and so on..) is requested, which need to be efficiently coordinated for the entire duration of the event.

However, recently, promising solutions employing the latest advances in 4G / 5G networks [1], are able to offer high live A/V quality (over IP networks), acceptable latency, low power consumption for portable and mobile, in-vehicle applications. These solutions widely respond to the needs related to shooting live TV events on the move. To this purpose, it becomes interesting to explore how the two technologies can combine, in order to outline solutions that could benefit from the interoperability opportunities. In this respect, the present paper aims at providing a concise description of some reference scenarios for which the proposed hybrid approach is analysed and discussed, both from the technical and the network cost perspectives.

THE 'CONVENTIONAL' (RADIO LINK) SHOOTING SYSTEM

A typical deployment system adopted up to now (schematically illustrated in Figure 1), with reference, for example, to the most important cycling/running events in Italy, requires up to eight motorcycles (Fig.1a) to be equipped with various facilities, including camera units, audio radio links for commentators, geo-localization means, etc. In addition, three helicopters and an airplane are usually employed above the race, two of them for video shooting (Fig.1b), the others as a "bridge" (Fig.1c), relaying the signals coming from the motorcycles to a receiving station (Fig.1d). The latter sends the signals (by means of satellite links) to a mobile production control room situated in an OB van (Fig. 1e) at the finish line where, the signals coming from the motorcycles, helicopters, still cameras (Fig.1f), mobile interview team cameras, and finish-line commentary are properly mixed. Finally, the signal arrives via satellite to the TV Production Center (located in Rome) and hence to the single viewer. The video (shooting) and audio (commentators) motorcycles are usually equipped with complex A/V and transmission/reception devices and multiple antennas each. In addition, each commentator motorcycle sends the commentary voice on the RF helicopter's uplink, while receiving in turn a personalized signal (audio plus director's voice) from the production control room.

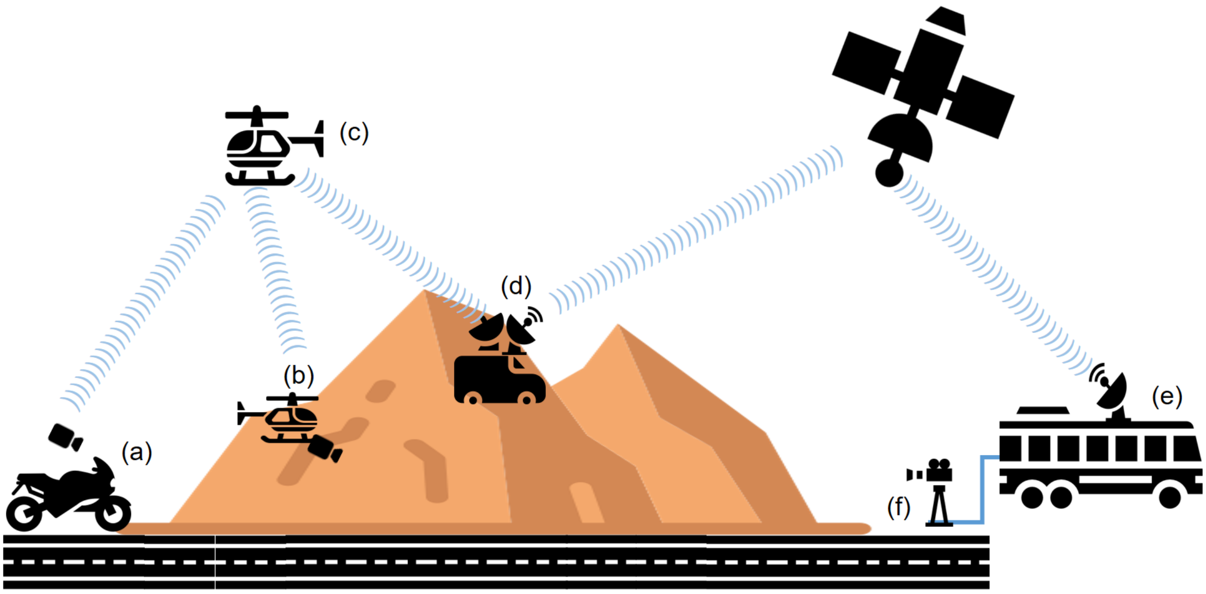

Figure 1 – Traditional shooting system.

Although the system described above has proven to achieve very high reliability and performance, in the case of special events it could be quite complex and expensive. Indeed, it would require the presence of an aircraft's lifting to set up a radio link and a vehicle acting as receiving gateway (for the case of racing events) or the deployment of complex radio-link networks (for the case of big events such as, for example, regattas). At the same time, as briefly stated in the introduction, latest developments in 4G/5G technologies prove interesting key solutions that could be adapted for such circumstances.

A SOLUTION BASED ON '4G/5G BACKPACKS'

In recent years, the growing enhancements of 4G/5G network capabilities have also provided tangible benefits in the field of production and contribution of TV events. In fact, innovative technological features that exploit the capillarity and high-capacity of the network infrastructures, such as highly customizable and versatile 4G/5G-enabled camera backpacks, are well suited to satisfy the needs regarding the shooting of sporting events and more. At present, 4G/5G backpacks solutions available on the market that offer interesting capabilities for delivering video contributions in HD or 4K and are widely adopted both for in motion and pedestrian shooting events. In a conventional scenario, as shown in Fig.2, the shooting camera is connected to the 4G/5G backpack (Fig.2a) which, in turn, contains one or more SIMs (that, in principle, could come from different network operators) for the connection to the mobile infrastructure (Fig.2g). Generally, up to eight modems, each of them equipped with antennas and SIM cards, are integrated in a typical backpack. From the control room (Fig.2e), an equipment properly configured for reception of data streams, is connected to a public IP network. Currently, for live TV production events, the control room can be connected to the public network (internet) accessible via cable (fiber or Ethernet networks) as in Fig.2f, or via satellite connections (for example by means of KA-SAT systems). Nowadays, they are successfully used in urban contexts where a more reliable network infrastructure can be used. However, such solutions could suffer from some drawbacks in scenarios where the mobile network could not guarantee a satisfactory coverage.

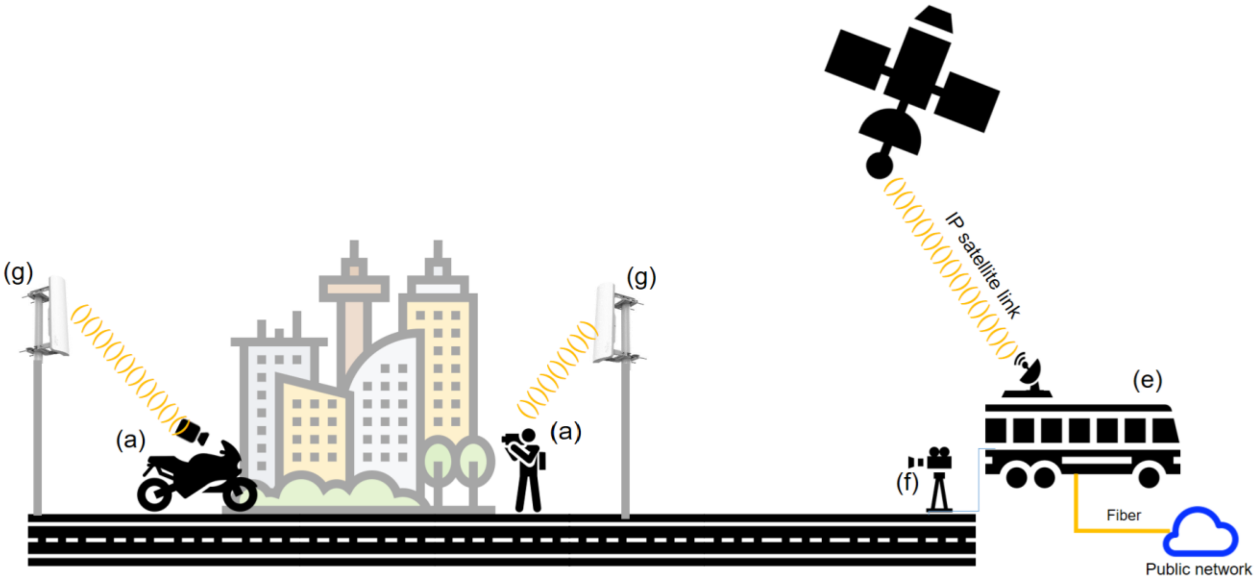

Figure 2 – 4G/5G backpacks based deployment scenario

USE CASES

As previously reported in the introduction, mobile shooting of live TV events includes a great variety of use cases: the adoption of one or the other of the aforementioned technological solutions strictly depends on the critical issues dictated by the respective reference scenario. For example, for the most popular events such as cycling competitions and marathons (Figure 3, top left and right, respectively), tens of kilometres are usually expected to be covered during the whole race, including routes in rural areas characterized by reduced capillarity of the 4G / 5G network. Instead, for the case of regattas (Figure 3, bottom right), due to the peculiarities of the scenario, a huge amount of time would be required to setup the equipment necessary to cover the entire route with radio link-based systems. Critical issues could emerge also for events (see Figure 3, bottom left) with a limited or well-defined perimeter (for example, celebrations concerning the election of the President of the Republic, religious ceremonies, big events like Expo or events in which a stable coverage of the political area of Rome is required). In such situations having a limited perimeter, it would be possible to use only the coverage of the mobile network. However high reliability is required which could be compromised by the risk of network overloading due to the large number of users in that area.

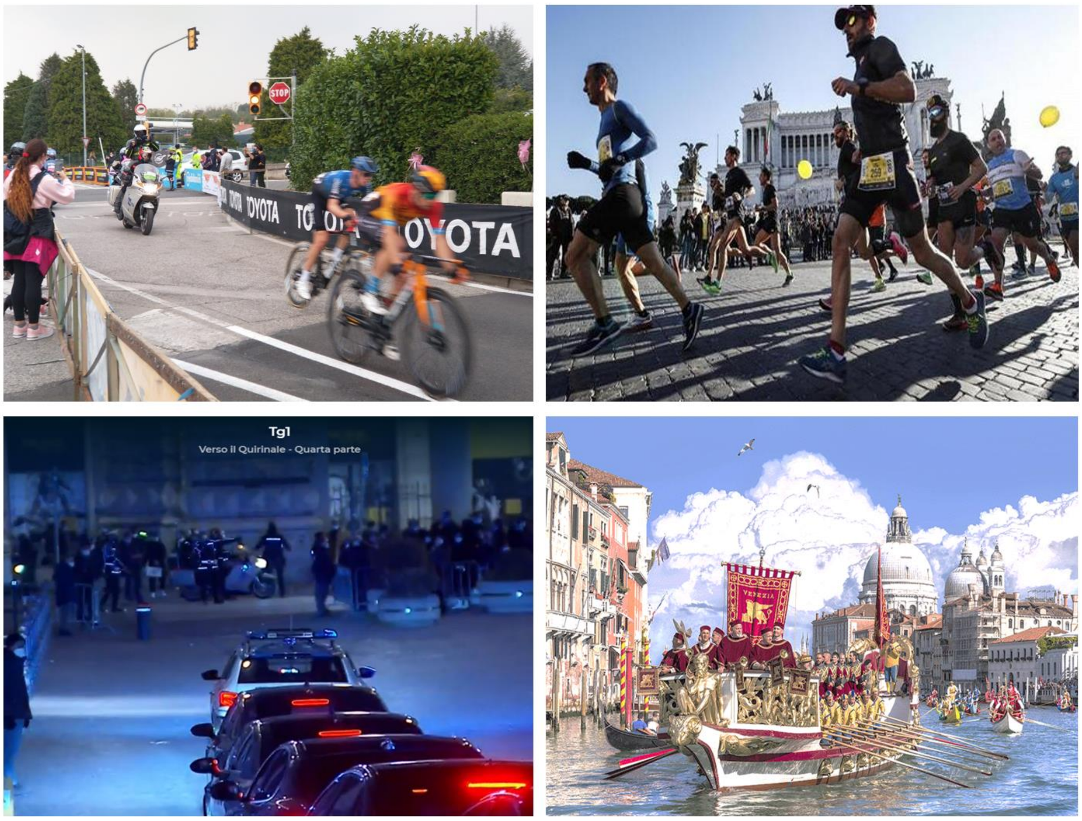

Figure 3 – Use cases: cycling race (top left), marathon (top right), Presidential Elections (bottom left), regattas (bottom right).

PROPOSED 'HYBRID' SOLUTION

In order to overcome the critical issues of the use cases mentioned above, some hybrid deployment models are proposed: depending on the circumstances, *seamless switching* is implemented between the contributions of the traditional system and those coming from the 4G/5G network. The proposed scenario, concerning the possibility of passing from one system to another as needed, is implemented in Figure 4.

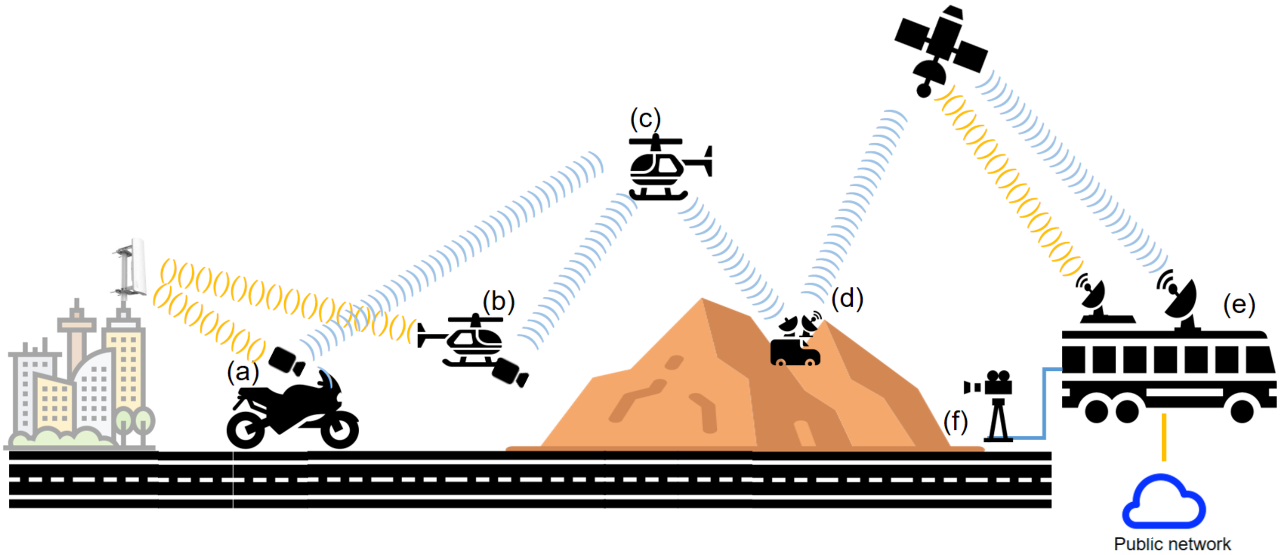

Figure 4 – Hybrid deployment scenario

This solution proves to be very interesting in situations where the cooperative use of the two options would allow for an optimization of resources as well as a cost reduction of the network infrastructure to be deployed. This option could be particularly useful in mixed scenarios, such as sports competitions (i.e. cycling races) where the conventional (radio link) shooting system would potentially guarantee better coverage compared to a 4G/5G network-based solution for the most part of the route that takes place mainly in mountain (or in general rural/suburban) areas. Instead, for the remaining part of the competition occurring in urban areas, the 4G/5G "backpack" solution, leveraging the possibility to guarantee good 4G / 5G network coverage, would avoid the deployment of huge (traditional) system resources. In this case, the combined use of the traditional system and 4G / 5G backpacks would allow an increase to the reliability of the system: opting for backpacks in the first part of the competition (with less critical routes..) would save the set-up of the radio link and the consequent costs associated with aircraft's lifting. In case of regattas and marathons, given the (typical) short range and fixed path of the whole event, the expected coverage could eventually be tested in the preceeding days: this would allow the use of a 4G/5G solution for the whole race and integrate it with fixed camera units (without the deployment of a radio-link helicopter) in most popular and spectacular road sections of the routes. Instead, for events located in defined areas (as reported above for the case, for example, of events concerning the election of the President of the Republic), the hybrid approach would allow the use of traditional radio-links in the most strategic or overcrowded spaces (where the risk of mobile network congestion could lead to critical failures.), while completing the rest of the coverage with the 4G / 5G network-based systems.

LABORATORY TESTS

With reference to the above discussed solution, two main scenarios (labelled as *testbed 1* and *testbed 2*, reported in Figure 5 and 6, respectively) have been envisaged to be potentially interesting for laboratory tests.

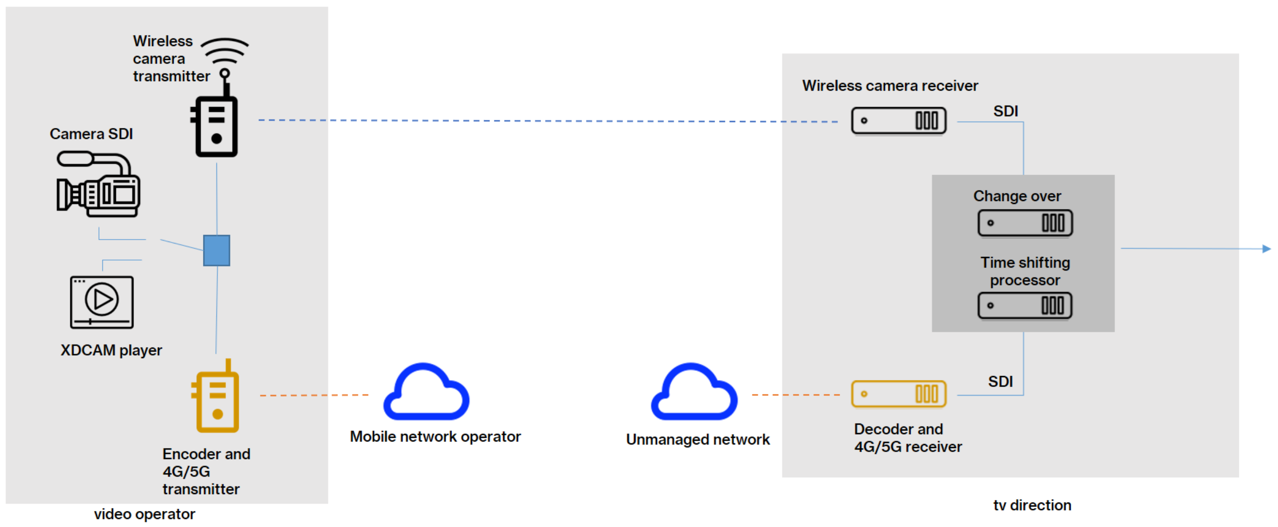

Figure 5– System architecture for testbed 1

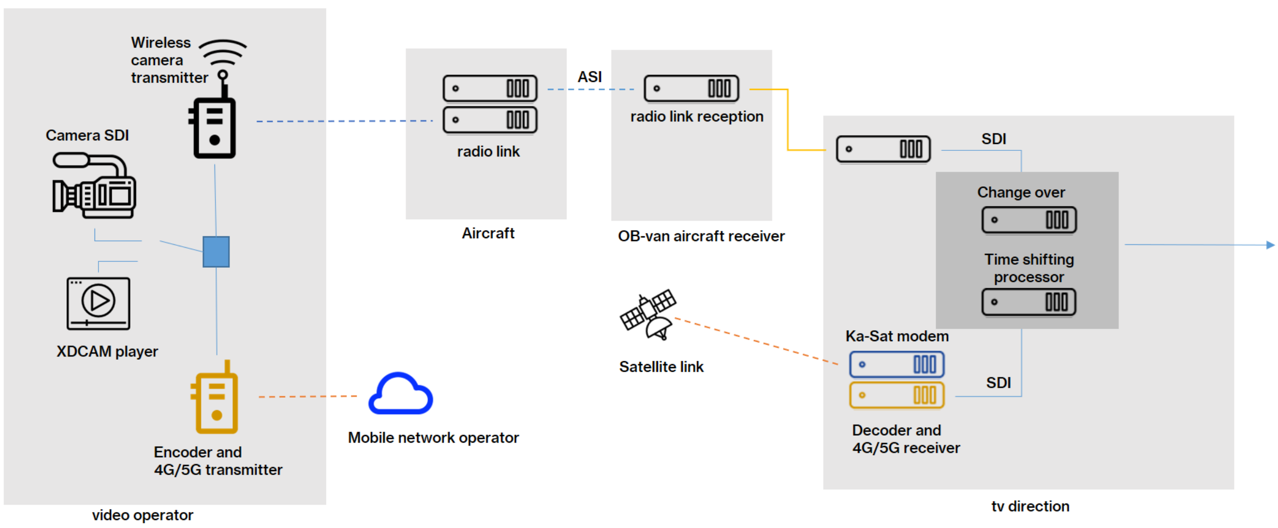

Figure 6 – System architecture for testbed 2

The main scope for both scenarios is to test the synchronization accuracy of the two received video streams and appropriate QoE metrics, such as video quality, achievable bit rate and end-to-end delay. The video operator is equipped with a camera connected to two devices (the “traditional” wireless camera transmitter and 4G/5G backpack) via SDI video interface. With reference to Figure 5, the chain labelled with the blue line is referred only to the radio link network while the one in orange indicates the connections on the public (unmanaged) mobile network operator. At the end of the whole chain, a time shifting processor is placed in order to synchronize the two video streams. Eventually, a changeover can be set to automatically switch on a secondary video stream in case of a potential failure of the preferred one. The set-up reported in Figure 6 has been improved in order to represent situations in which the OB van control room is placed in a complex and challenging environment like mountain areas. In these circumstances, the reception of the IP signal is provided by satellite connections (for instance, Ka-Sat systems), as reported in Figure 6. It should be noted that all the devices usually employed in the traditional (radio link) shooting system (as described in the first paragraph) have been included in the chain.

Video quality test

In the preliminary phase of the tests, a set of measurements on the effective latency of the two proposed scenarios were carried out using a reference time - coded video (Fig.7).

Figure 7 – Synchronization tests: two inputs (top and bottom left) and the two synchronized outputs (top and bottom right)

With the obtained data and using a time shifting processor, a set of end-to-end delay compensation tests were performed. It was found that the backpack adopted for the measurements can reach a glass-to-glass (G2G) delay between 800ms and 10s. Specifically, with reference to testbed 1, in a subsequent testing session, it was decided to keep 800ms as ‘representative’ delay. The camera’s encoding latencies range from 10ms to 760ms but only some values are permitted. Adding the decoding delay, a G2G latency of 1080ms is achieved. Table 1 shows the values of the achievable latencies, bit rates and delays for tests referred to the scenario reported in Figure 5.

	Radio-link	4G/5G backpack
Bitrate	10 Mbps	10 Mbps
Latency	G2G – 1080ms	G2G – 800ms
Delay	280ms - (7frames)	0

Table 1 – Tested parameters for testbed 1

With reference to testbed 2, the main difference in terms of delay is given by the adoption of a Ka-Sat system as the only data reception source. In this case, an interesting test was performed for the evaluation of the minimum latency between backpack and radio camera. By setting the backpack with the minimum allowed latency (800ms as in the previous tests), the video connection is established but the perceived video quality is very poor and the bitrate is much lower than the set value. Hence, it was decided to set up a G2G time delay of about 3s on the backpack which is then compensated by the time shift processor. The results from tests referred to testbed 2 are summarized in Table 2.

	Radio-link	4G/5G backpack
Bitrate	10 Mbps	10 Mbps
Latency	G2G – 1080ms	G2G – 3000ms
Delay	0	1920ms (48 frames)

Table 2 – Tested parameters for testbed 2

RF interference tests

In the devised operating situation, the 4G/5G backpack and the radio camera would be located very close to each-other. Concerns about possible RF interference led us to test some worst-case configurations. The radio camera is a transmit-only device, therefore the possible victim is the receiving section of the 4G/5G backpack. The latter has several modems, each equipped with its own embedded antenna. The distance between the radio camera transmitting antenna and the backpack antenna(s) can be as little as 10cm or so. The intended interference tests are not easy to perform due to the fact that the 4G/5G link can adopt different, adaptive, power levels and ModCods, both in downlink and uplink, depending on the RF link distance and quality. This is beyond our control, and could be an unknown variable in the experiment. To work around the problem, a bench setup has been devised in which the 4G/5G network signal is accessed by a good quality external antenna located outside the window, and individual RF attenuators are inserted in both radio camera signal path and 4G/5G antenna signal path, before an RF power combiner. Figure 8 shows the whole chain used for tests.

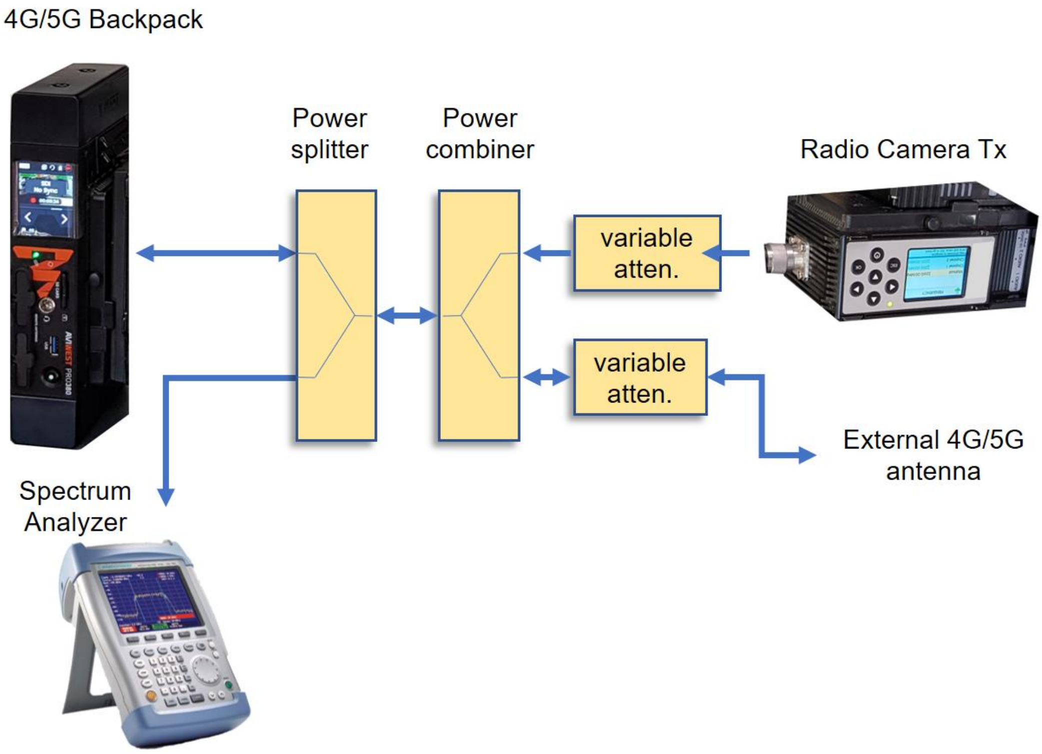

Figure 8 – The measurement set-up

We have tested a worst-case situation in which the backpack is operated in an area where only a single frequency band is covered. The operating frequency band adopted in the test is B01 (uplink 1920-1980, downlink 2110-2170) according to [2-4].
The radio camera operating frequency can be set before its use, in the range allowed for this kind of service. We have chosen the frequency 2100MHz, being the channel closer to B01 downlink band (Fig.9). In this condition, inserting attenuation large enough on 4G/5G signal path in order to emulate fairly large distance from base station, with 200mW (23dBm) radio camera RF output power, simulating 20dB coupling between interfering antenna and victim antenna, the reception of the downlink was in facts put out of service, resulting in total link loss. In this condition, the out of band emission of the 2100MHz radio camera at 2112.5MHz victim frequency, integrated in 5MHz bandwidth, results in about -51dB below the main signal, or -54dBm power. In general, the problem depends on the out –of-band emission of the radio camera, and on the susceptibility of the receiver in presence of strong signals. Although both parameters depend on the specific equipment used, the problem is structural. The purpose of these tests was to simply verify a worst-case scenario nevertheless demonstrating that the backpack and the radio camera can be used simultaneously at close range.

As already mentioned, the above operating conditions are representative of the worst case. In practical situations, the link margin could be probably less critical and different

4G/5G bands will be available, thus enabling the capability of the system to skip the interfered band. Of course, it is in any case a good choice to avoid radio camera channels too close to the downlink bands.

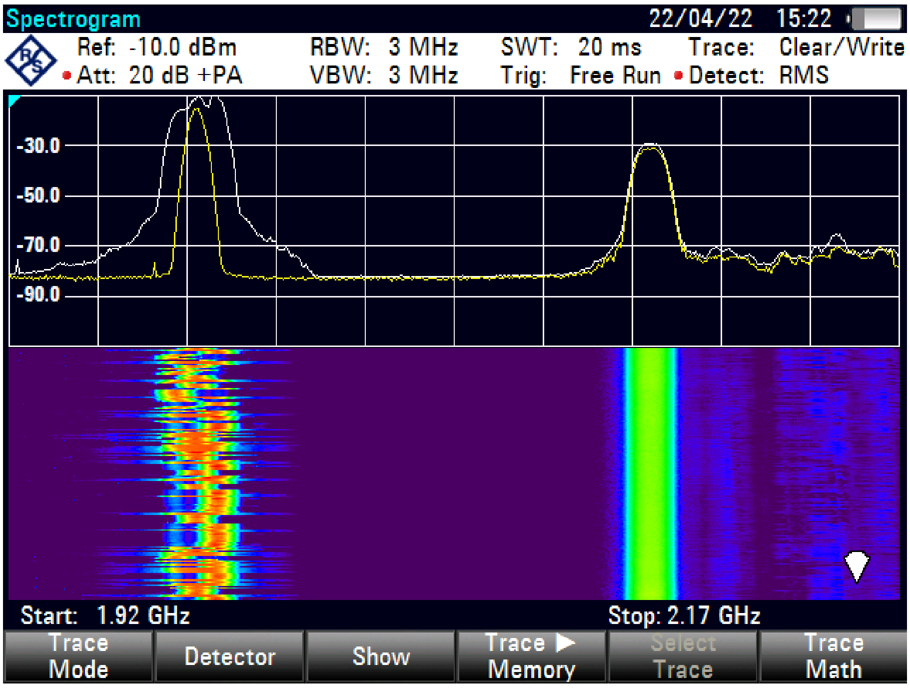

Figure 9 – Spectrum visualization: the envelope (white line) and the instantaneous trace (yellow line). In the right part is visible the downlink signals arriving from the Base Station (2110-2170 MHz).

A ROUGH ASSESSMENT OF THE DEPLOYMENT COSTS FOR THE PROPOSED SCENARIOS

In addition to ensuring coverage optimization for the most critical scenarios, one of the strengths of the proposed hybrid solution concerns the possibility of guaranteeing significant savings in deployment expenses. Assuming, for simplicity, to neglect the Capex's expeditures and to consider only the most onerous and impacting costs associated with Opex, i.e. those relating to the rental of helicopters (cost per minute approximately 30 €), in the case of a bicycle race or marathon (in which, at least, one shooting helicopter and one single bridge aircraft are required), using the traditional radio-link shooting solution would entail a cost of the bridge aircraft for, on average, 4 hours of competition per day. This means that the entire cost would be approximately 240min x 30 € = 7200 €/day. Using a hybrid solution, which would permit to cover, on a best effort basis, the first two hours of the race with 4G/5G (backpacks) solutions, would save about 3600 €/day. Considering that a typical "long-range" cycling competition takes from one to three weeks (considering an average of 5 days of competition per week), the savings of a single competition with hybrid use would be around 18 - 54 k€/racing event. Assuming that in one year, up to ten cycling events occur (events lasting a single day, a few days, a week or more), the cost's savings (on average) could reach up to 100 k€/year.

In the case of regattas, assuming to cover only the start and finish line (where a massive participation is expected), a significant reduction on personnel costs (a rough estimate is around 3-4 person/day) and network deployment needed to cover the whole path, can be achieved.

It should be noted that the solution employing only 4G/5G backpacks has not been taken into account as, at present, the mobile network operators do not allow to reserve a guaranteed bandwidth if not on a best effort basis. At the same time, broadcasters need to ensure a good QoS: in the future the costs associated to the bandwidth reservation could represent the discriminant element to opt for a solution over another.

CONCLUSIONS

In this paper the possibility of implementing a cooperation between the traditional (radio link) shooting systems and the recent technology based on 4G/5G backpacks has been investigated. By means of laboratory measurements, a solution that could benefit from the interoperability opportunities offered by the collaborative approach has been tested. Results proved to be satisfactory in terms of QoE metrics, such as received video quality, achievable bit rate and end-to-end delay. RF interference tests on some worst-case configurations have been carried out in order to verify that in the considered operating situation, the 4G/5G backpack and the radio camera would not disturb each-other.

The advantages arising from the use of the proposed (hybrid) scenario are twofold: on one hand it makes it possible to ensure adequate coverage in challenging scenarios, and on the other hand it may provide significant cost savings compared to the conventional system adopted so far.

In the future, an important improvement will be to use only the 5G network for the production of live images. It will be achievable by giving broadcasters the possibility to easily integrate their own (private) network such as 5G SA in areas where mobile operators could not guarantee a priority service due to their network's overcrowding. This would allow you to have a single device linked to the camera, that was able to connect to both the public network of the mobile operator and to the private network of the broadcaster. In this way it will be possible to achieve the two objectives discussed in this paper: to guarantee a high quality of service by lowering the costs necessary for a complete implementation of the network.

These considerations demonstrate the effectiveness of the proposed solution: its applicability paves the way to promising opportunities in the field of shooting of live TV events on the move.

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