Rapidly deployable network for tactical applications:

Aerial Base Station with Opportunistic Links for Unattended and Temporary Events ABSOLUTE example

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***Abstract*— Hybrid Aerial and Terrestrial Communication systems have recently emerged for Public Safety Communications and tactical applications due to their fast deployment and large coverage capabilities. A key question is the choice of the communication payload depending on the Aerial platform being deployed. Indeed, this payload depends on several factors including the aerial platform size, the payload weight as well as coverage and capacity requirements. This article analyses different options and presents the work which is ongoing in ABSOLUTE (Aerial Base Station with Opportunistic Links for Unattended and Temporary Events) European project. It first summarizes the outputs of the user requirements as developed in ABSOLUTE. Then it presents different aerial platforms and associated payload for a rapidly deployable tactical network. Afterwards it presents the hybrid aerial and terrestrial communication system as developed in the project. Finally it presents research topics and remaining challenges.**

Keywords—Aerial platform; LTE-A; tactical communications

I. Introduction

Hybrid aerial and terrestrial Networks have recently emerged for Public Safety and Military communications. Indeed, there is a need to rapidly deploy a network being able to provide a large coverage of several tens of kms while providing high capacity for each user. While in the past research was focusing High Altitude Platforms (HAP) operating at high altitudes, in the recent years, many types of Low Altitude Platforms (LAP) have been investigated in order to operate between several hundred or few thousands meters. These platforms are more easily to deploy and can be used in tactical environments.

The choice of the communication payload for the aerial platform is still under study and should be able to provide high network capacity while having an optimized weight as well as optimized power consumption.

Therefore, this paper investigates a rapidly deployable mobile network architecture based on a 3GPP LTE-A communication payload. The main goal of this work is to demonstrate that the high-capacity, low-latency and coverage capabilities of 3GPP LTE-A solutions can be adapted for rapidly deployable broadband aerial platforms. Several configurations are discussed in III and the final system architecture as being studied in ABSOLUTE is described in IV.

II. user requirements

An External Advisory Board is part of ABSOLUTE project. This board is composed of public safety organizations such as the Ministry of Defense in Spain, the Gendarmerie in France, the Federal Agency of Technical Relief (HTW) in Germany, the Australian Fire and Emergency Service Authorities Council and the Romanian Inspectorate for Emergency Situations. EAB role is to provide guidance in order to insure that project’s outputs will meet real end user needs. EAB produces user requirements that are the basis for ABSOLUTE system development.

From the first EAB outputs, it appears that although organizations are quite different, generic scenarios and communications needs appeared.

From the first estimates, the number of involved staff in an incident area is generally between 10 and 50 and could be event up to 100. If we go away from the central zone, the number of involved staff could be more than 100. These numbers vary with the nature of the incidents but it appeared also clearly that the incident scene could be in different places. In case of terrorist attacks multiple simultaneous targets could be involved in order to dilute the responder’s resources. The envisaged final system should so take into account multiple incident areas.

With regard to the communication needs, voice remains the priority but there is a demand for new services including video live streaming, geo-location or browser access. These services demand more and more communications resources.

For this reason, LTE technology (from release 8 and above) is a good candidate in order to provide high data rate. Indeed, in release 8 Peak data rate are up to 300 Mb/s in Downlink and 75 Mb/s in Uplink and in release 10 peak data rate are up to 1 Gb/s for Downlink and up to 500 Mb/s for Uplink. Furthermore, the access protocol being without

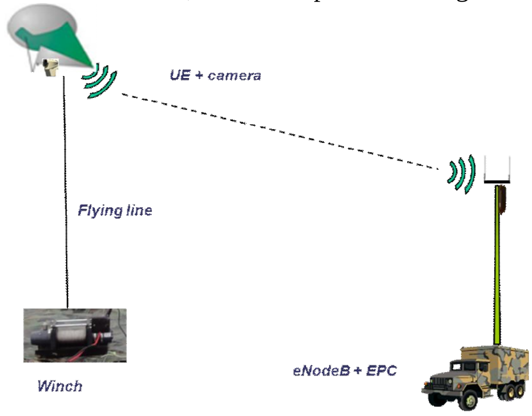

Fig. 1. UE and camera embededed in the aerial platform

contention, it allows to cope with a large number of users. However, some services such as group communications and direct device to device links are of much importance for public safety and military Communications. These new functionalities are under study in ETSI (add reference) and should be included in 3GPP release 12.

III. Low altitude platforms and associated payload

Tactical communications network should be operational in less than 1.5 hour and should work in an autonomous way. This requires a fast and reliable launching of the aerial platform to the optimum altitude, in all likely weather conditions within one hour. Furthermore the aerial platform should remain stable in all wind conditions and the platform must stay in one place for extended periods. For this reason a specific platform has been chosen in ABSOLUTE project. The chosen design of lighter-than-air platform is called a Helikite®, which is presently serving with the US Army in Afghanistan for surveillance purposes. Helikites combine a helium balloon and a kite into one stable aerodynamic unit. Wind that pushes normal aerostat balloons downwards instead pushes Helikites up. This means that even small Helikites can steadily carry radio, or camera payloads, plus antennas to useful altitudes in difficult weather conditions. The Helikite stays in one place unless the wind changes direction which is advantageous for radio-relay. The Aerial Platform should also be easy to recover and only one or two operating personnel will be required.

The ABSOLUTE project initially determined that the largest LAP platform would be a 34m3 “Desert Star Helikite”. However, one of the project objectives is to find the best compromise between the optimum aerial platform size for tactical communications and the payload weight.

Different volumes are available for the Helikites platforms and the best compromise has to be found depending on the different applications.

As illustrated in figure 1, for surveillance applications, only a UE and a camera needs to be put in the aerial platform.

For some tactical applications when there is a need to have large network coverage, there is a need to have a functional eNodeB on the aerial platform. Due to the separation of the Base Band (BB) and the RF in LTE configurations, it is possible to only have the RF part on the aerial platform. The Radio Remote Head (RRH) is so embedded on the aerial platform and is connected to the Base Band part thanks to an

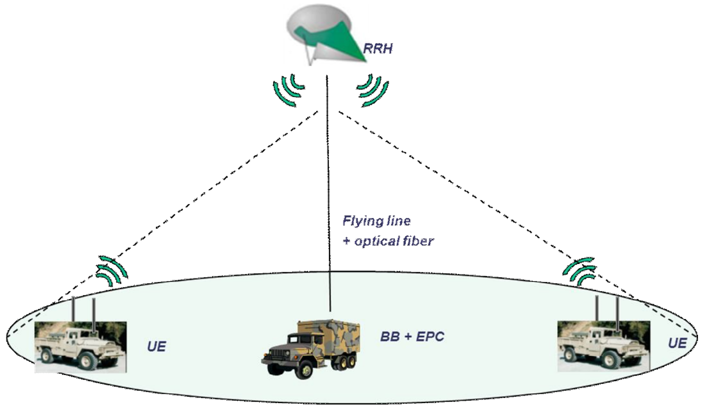

Fig. 2. LTE Radio Remote Head embedded in the aerial platform

optical fiber. A 15m3 seems a suitable size for this configuration (figure 2).

For tactical communications, the network should work in a stand-alone mode. For this reason, the Evolved Packet Core (EPC) should be available on the site and should not be in a remote location. This stand-alone EPC can have reduced functionalities as the number of users is limited.

Aerial platform could be used on the ground as illustrated above but they can also be used for maritime applications. Uniquely for small aerostats, Helikites can be reliably flown from small boats or ships, as illustrated in Figure 3. They can be used either for surveillance or to provide a large network coverage from the shore to the sea.

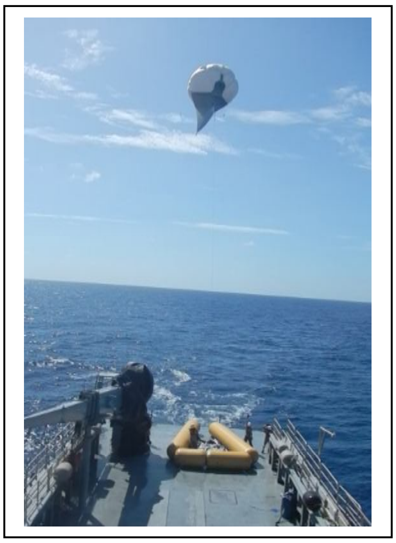

Fig. 3. Aerial platfrom for maritime applications

IV.

V. hybrid aerial and terrestrial system architecture

ABSOLUTE project will demonstrate the high capacity, low-latency and coverage capabilities of LTE-A (Long Term Evolution - Advanced) solutions adapted for broadband emergency communications within disaster relief scenarios through flexible 4G base stations embedded on aerial platforms allowing to provide a large network coverage in a short time.

ABSOLUTE objectives will be achieved through the opportunistic combination of aerial, terrestrial and satellite communication links with the aim to maximize network availability and allow a rapid and incremental network deployment for Public Safety applications.

A. *ABSOLUTE overall system architecture*

The overall network architecture is outlined in figure 4. Scalable network coverage and capacity as well as a resilient, flexible and secure infrastructure are essential prerequisites for ABSOLUTE architecture The design rationale behind this target architecture relates to the intention to impact on the public safety communications landscape and to contribute to a faster adoption of a ubiquitous, multi-purpose wireless broadband technology for mission critical deployments.

The system architecture is therefore segmented into distinct, but tightly interconnected network sections:

- An aerial segment, which mainly consists of LAPs, lifting communication payloads (named Aerial eNBs (AeNBs)).
- A terrestrial segment made of Portable Land Mobile Unit (PLMU) and advanced multi-service professional terminals for first responders, named Multimode User Equipments (MM-UEs).
- A satellite backhaul for connection with the headquarters.

The rest of this section details the related key subsystems of this architecture.

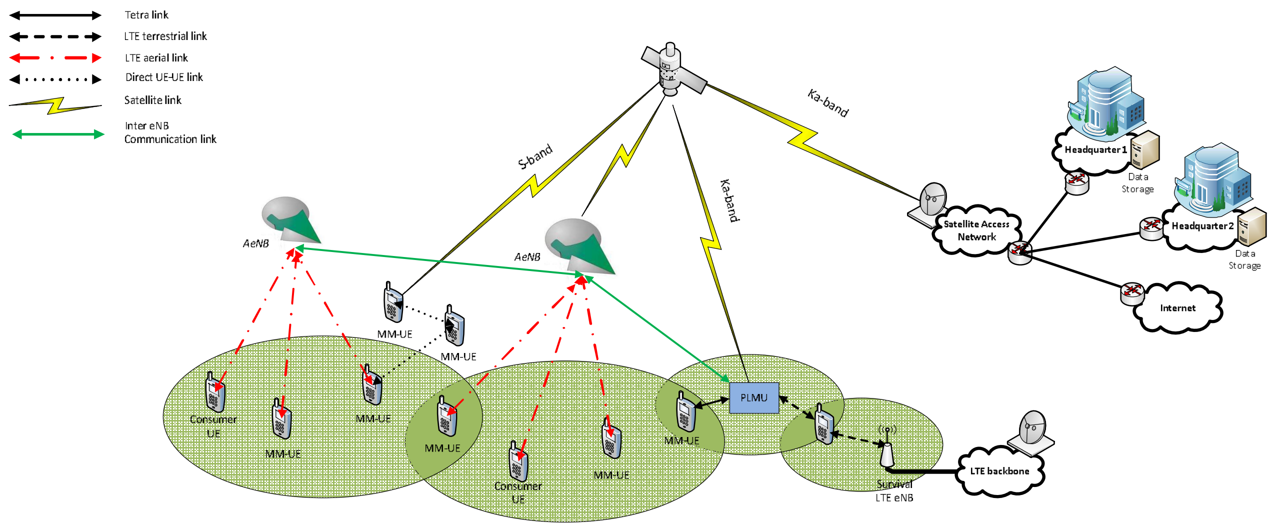

Fig. 4. ABSOLUTE system architecture

B. *ABSOLUTE sub-systems description*

1) *Aerial eNodeB*

As stated in the previous section, different communications platforms can be embedded in the aerial platform depending on its size and the applications. The goal of ABSOLUTE is to rapidly provide a 4G network with a large coverage.

For this, two solutions are envisaged:

- The first solution is to use a 34 m3 aerial platform and to have a full eNodeB embedded in this platform. However, the 34m3 platform needs a non-negligible amount of helium (several big helium bottles) and the time to inflate the platform is not negligible.

- The second one is to use a 10 m3 and to have only the Radio Remote Head embedded in the aerial platform.

This configuration needs an optical fibre that can be on the winch with the flying line.

2) PLMU (Portable Land Mobile Unit)

The LAP platforms are expected to provide coverage to very large regions. However, since it is transported in a truck, together with its helium bottles, some disaster-affected regions may prove unreachable. Further, for some specific terrains, the system availability cannot be always guaranteed solely by the LAP deployments. Such coverage gaps can be covered by a portable land unit hosting additional communication systems. This unit must be man-portable and ruggedized to facilitate its deployment in harsh terrains and host a self-sufficient communications platform. The PLMU designed as part of the ABSOLUTE architecture is a standalone and self-sufficient communications platform. The PLMU includes a WLAN access point, a Terrestrial eNodeB (TeNB), an IP router and a Ka band satellite modem, as well as a computer for centralized control of the various subsystems. Similarly to the LAP, the PLMU provides wireless communications in the location of deployment, interconnecting local users across technologies through the IP router. However, in addition to the LAP, remote communications are provided through a satellite link.

Furthermore and despite its independence from the LAP, the PLMU also can also play an integrating routing role within the larger system architecture. This is achieved by providing remote connectivity to the systems on board of the LAP. Due to payload weight constraints, the LAP hosts no satellite modem and thus, it cannot provide remote connectivity to the users beneath. This lack of connectivity is solved by the satellite modem in the PLMU, which backhauls traffic between the LAP and the PLMU through means such as cabling (through the Helikite tether), WLAN or even optical radio links. Such solutions avoid the need for instantiation of satellite modems on the LAP, which is challenging than relaying the LAP traffic to the ground-based PLMU.

3) MM-UE (Multi-Mode User equipment)

The Multi-Mode User equipment is composed of different interconnected radios.

It includes a LTE User equipment for the communication with the aerial eNodeB.For Public Safety applications the MM-UE includes a TETRA radio and for Military applications the MM-UE could include legacy radios. These radios are should inter-operate together but are not necessarily in the same casings.

In the immediate aftermath of a disaster, it is of paramount importance for rescue teams to forward to headquarters early reports on the situation on the field. Such information may provide the number and status of the victims, damaged areas, as well as the situation of the team itself, and typically leads to a number of short messages. In order to effectively serve this critical traffic in the absence of a telecommunication network, rescue personnel can resort on a narrowband S-band geostationary satellite link. Towards this aim, the ABSOLUTE system integrates in the MM-UE a communication link based on the newly ETSI standardized S-band Mobile Interactive Multimedia (S-MIM, [6]) protocol, which allows end-users to transmit small messages over satellite at low data rate (in the order of 15 kbit/s). Entailing a reduced satellite terminal complexity, this standard benefits from the wide satellite coverage and represents an undeniable solution in the early phase of the ABSOLUTE architecture deployment when aerial eNBs is not yet available. Forward link information from the headquarters is received using the Digital Video Broadcasting - Satellites services to Handhelds standard (DVB-SH, [9]), enabling two-way connectivity and dramatically increasing system reactivity and effectiveness. More exhaustive insights on the S-MIM protocol specifications can be found in [7] and [8].

4) Satellite backhaul

The role played by the geostationary satellite within the ABSOLUTE architecture goes beyond the S-band connectivity offered to MM-UEs at early phases, embracing broadband backhaul functionalities. By means of a Ka band satellite payload, both terrestrial and, when equipped with the necessary communication module, aerial eNBs can resort to upstream- and downstream- flows in the order of 5 and 20 Mbit/s, respectively. The advantage brought by satellite backhauling to a rapidly deployable network in tactic scenarios is multifold. In the first place, such a component complements the architecture by enabling ubiquitous and reliable broadband connectivity with the headquarters to teams on the ground. Moreover, effective policies can be devised to allow a seamless integration with survivor or trusted terrestrial infrastructure when available. In this way, traffic can be opportunistically forwarded through the less congested or more reliable route, so to cope with traffic peaks and unforeseen disruptions of terrestrial backhaul. Finally, the availability of a dedicated satellite link enables the design of routing strategies based on traffic classification and prioritization, triggering more flexibility in terms of QoS that can be offered to ground users as well as allowing the exchange of sensitive information bypassing untrusted infrastructures.

VI. remaining challenges

A. Energy consumption

Supplying mobile power supply to a LAP involves lifting weight to altitude. Radios and transmitters require power but they also operate far better at high altitude. There is a balance to be struck between high power and high altitude. It was decided that the use of lithium batteries was a better overall radio-relay solution than bringing power up the flying line via heavy copper cables. Especially if the LAP is very quick and easy to launch and recover, therefore enabling a single daily battery change to occur within a few minutes.

B. Antennas

Antenna design, configuration and placement on the Low Altitude Platform (LAP) is important. Antenna gain optimization will allow relatively weak radio signals from mobile phones to be picked up from many miles away. Better transmission from the LAP allows for reduced power requirement, greater range and longer endurance. The Helikite LAP used in this project allows the antenna to stay at the correct attitude whatever the weather or altitude. Helikites can carry antennas of considerable size and of many shapes if required. It is therefore possible to reliably test various antennas at different altitudes to determine the most suitable type.

VII. conclusions

TO BE FILLED

Acknowledgment

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