The third dimension of Public Protection and Disaster Relief

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Setting the scene

A key requirement of organisations and authorities responsible for Public Protection and Disaster Relief (PPDR) is a reliable communication amongst the persons on-site and towards the rescue coordination centre. The solutions in place today in most geographies often do not satisfy the needs of the rescue teams. The major issues are the limitation to voice and narrow-band data, and the fragmented market leading to incompatibilities between systems used by different organisations.

In many countries PPDR organisations consider, or have started to implement cellular networks based on 3GPP standards (notably LTE), as a broadband complement to their existing networks. Partially this is considered as an overlay of a best-effort broadband network (notably LTE) over a highly reliable narrowband system (TETRA or similar), but eventually the LTE network can replace the outdated narrowband systems altogether.

In order to contain the otherwise exorbitant cost to roll out a country-wide network, many countries fall back mostly on existing commercial networks with added PPDR features and priority/pre-emption mechanism. Coverage extension to areas with low population density is sponsored by the government, as this would not be economic for the network operators.

In exchange for providing the service to the government, the service provider of the chosen commercial network gets free access to additional spectrum and a recurrent service fee.

Enhancing the third dimension

A solution as described above can cover the needs for terrestrial service, but does not extend to the third dimension. Terrestrial LTE networks do not provide sufficient coverage for helicopters and other aerial vehicles like drones a few hundred meters above ground. Presently, only VHF voice and very narrowband data is available.

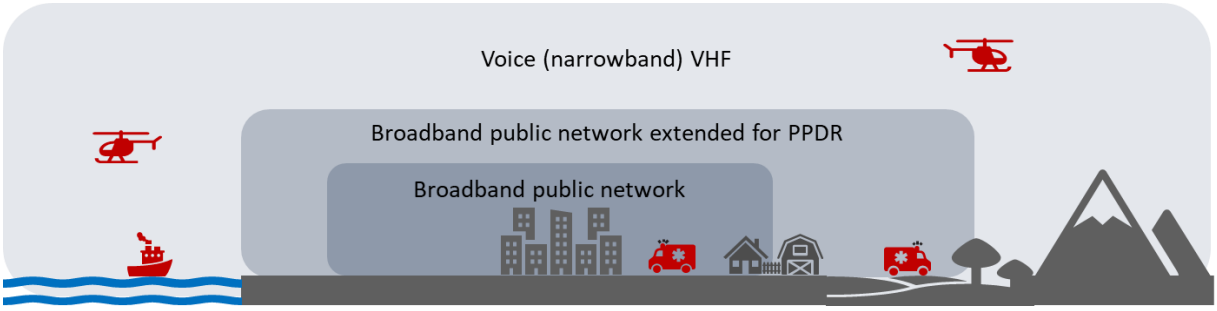


Figure 1: PPDR situation today

Adding broadband capabilities for airborne PPDR operations offers a plethora of new use cases as for example (but not exhaustive) for

Relief organisations – increase survival rate and optimize resource utilization:

Use unmanned airborne surveillance (drones) with real-time video streaming to locate victims of floods and earthquakes and prioritize rescue operation depending on the local situation. Allow informed decision by rescue coordination centre, based on video from body-cams of rescue team. High-performance and low-latency backhaul from flying base station drones provides broadband Wi-Fi or cellular coverage for disaster area.

Combat pandemic – reduce time to herd immunity with controlled vaccination distribution:

Central temperature control of sensitive vaccines (for example COVID-19 vaccines) during air transport via Air-to-Ground connectivity, avoids deterioration, and inoculation of defective vaccine. Air transport of sensitive vaccines can be re-scheduled on-the-fly depending on vaccination facility situation.

Remote/flying ambulance – increase survival rate and reduce secondary damage:

Two-way transmission of patient records and data, transmission of telemetry data like 12-Lead ECG, upload of images to specialist for remote consultations, allow hospital to prepare for the urgent cases.

Police – efficient police operations and increased security for officers on the ground

Police airborne surveillance and coordination with tactical data sharing, situational awareness, high resolution video and thermal imaging.

Aerial firefighting – reduce wasted flights and faster fire extinguished

Tracking of airborne assets, situational awareness – location of other aircraft, fire, coordination with ground team, transmitting operating data, location of drops and amount of water dropped

Maritime – less pollution and less crime

Coastal maritime surveillance, monitoring shipping, oil spill monitoring, anti-smuggling

Technology enablers

Basically, two technologies can provide broadband connectivity to airborne vehicles: Satellites and Air-to-Ground (also referred to Direct Air-to-Ground).

Satellite connectivity is hardly used for PPDR, as the cost is usually too high for PPDR organisations and the airborne satellite equipment is too large and too heavy for helicopters, if really broadband connectivity is required (small narrow-band systems for helicopters and small aircraft exist). Also, the excessive latency of satellite connectivity is hard to tolerate for PPDR purposes.

This leaves Air-to-Ground to provide reliable, broadband low-latency connectivity.

Air-to-Ground is based on an overlay LTE network dedicated to aircraft, designed and implemented to serve the airspace with specific antennas and specific parameter and algorithm. As the connection between ground and aircraft is mainly line-of-sight, the range is much higher as for normal LTE networks. Up to 150 km cell ranges are proven, also making this network suitable to cover the ocean up to 150 km offshore.

Sharing the burden

For many PPDR organisations, an own country-wide Air-to-Ground network is not affordable.

Luckily, similar to sharing a commercial LTE network on the ground for PPDR purposes, the PPDR component of an Air-to-Ground solution can be shared with an Air-to-Ground network for commercial aircraft.

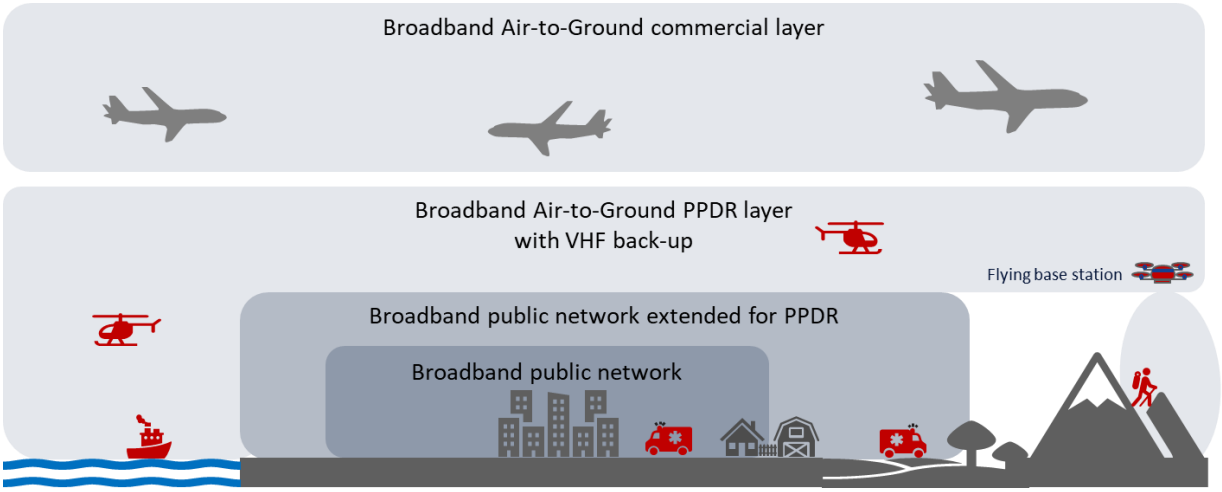


Figure 2: Broadband PPDR in three dimensions

A potential scheme could be to allocate the license and spectrum to an In-flight Connectivity Provider (IFC) for free or for a nominal fee in exchange for the obligation to cover not only the flight path of commercial airlines, but also defined disaster-prone areas. Running expenses of the IFC provider would be settled by a recurring fee.

During normal times, the spectrum can be fully used for commercial airline service. In case of a disaster event, the capacity around the affected area would be pre-empted for PPDR use.

This allows the most effective use of spectrum and allows the PPDR organisation to cover the third dimension within a reasonable budget.

Air-to-Ground for PPDR applications

Usually, the major aim of an Air-to-Ground solution for PPDR is to cover helicopters as part of a larger scope encompassing terrestrial, aviation and maritime operations. It now becomes more common to also include drones into the mission. Investigated, and of high interest for PPDR organisations, are base stations carried by drones to provide local Wi-Fi or cellular coverage using Air-to-Ground as backhaul. Less often other type of aircraft shall be covered, which are mainly slower aircraft operating at lower altitudes. One typical example are firefighting planes.

Usually, the solution has to operate on the ground and in the air up to heights of about 3000 meter / 10,000 ft.

The Air-to-Ground solution in the context of PPDR is not seen as a standalone component, but as a part of a comprehensive set of tools including terrestrial radio, mission control, operation centres encompassed within the wider emergency service network (ESN) whereby everything is managed by complex processes and organisations.

Complementing commercial Air-to-Ground for PPDR

The reader might be familiar with Air-to-Ground for In-Flight Connectivity of commercial aircraft as deployed in the European Aviation Network (EAN)[1]. Air-to-Ground as deployed for PPDR requires to consider, in addition to the cruising altitude of commercial aircraft[2], the lower airspace from a few hundred meters up to 3,000 meters above ground.

This lower layer is more sensitive to topographical obstacles and may require a higher number of sites as compared to pure commercial IFC service. Otherwise, the solution is identical.

Shared or dedicated spectrum

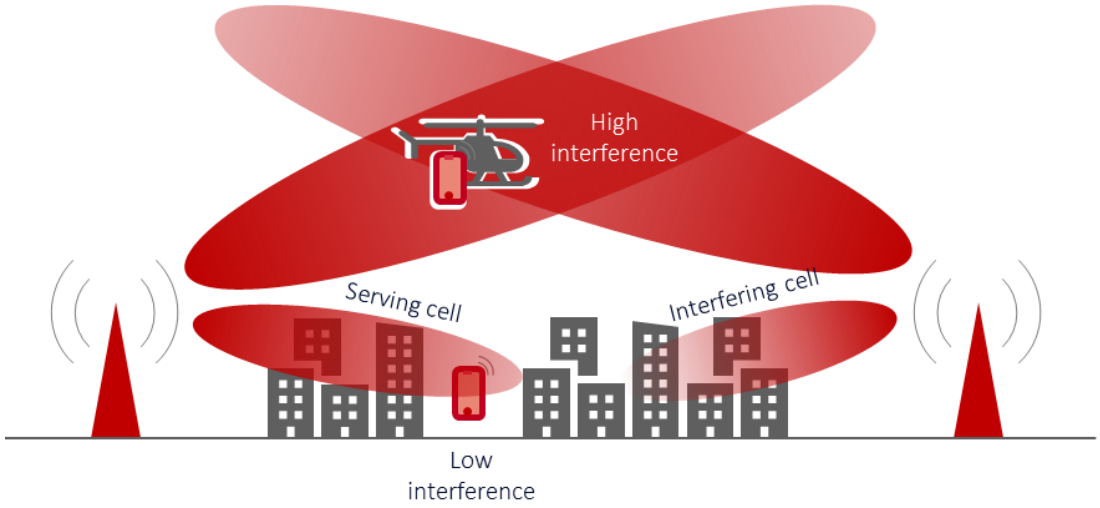
Communication systems for PPDR comprise two components:

- Communication on ground
- Communication in the air

Generally, public safety authorities own their own spectrum, but the available bandwidth is limited.

The question is whether to assign one common band to both ground and air communication, or to split the band and assign part of the band for each component.

From radio planning perspective, the challenge is the different propagation for ground communication (obstacles like buildings and hills, foliage, etc.) and air communication (predominantly free line-of-sight).



Modern communication solutions like LTE and 5G depend on tight frequency reuse to obtain maximum capacity leading to the need to tackle interference between base stations, and between user equipment.

Sophisticated features for interference management are included in the standards as for example Inter-Cell Interference Coordination (ICIC), MIMO and space diversity. Unfortunately, the properties and

[1] https://www.europeanaviationnetwork.com/en/index.html

[2] Commercial aircraft are flying up to 45,000 ft (13,700 m), general aviation up to 51,000 ft (15,500 m) above sea level.

characteristics of these features depend on the propagation conditions, so it is difficult to optimize these features simultaneously for both terrestrial and aerial propagation environments.

Therefore, in all cases known of by the author of this document, the spectrum is split into two parts, one dedicated to ground and one dedicated to air.

What can SkyFive provide for PPDR

The individual components of a typical Air-to-Ground solution for PPDR purposes are available off-the-shelf:

- Base stations for LTE and 5G can be provided by Nokia
- Ruggedized user terminals (smartphones) and aircraft communications system are available off-the-shelf
- Antenna can be sourced from Nokia

What can't be found elsewhere are the unique three-dimensional radio network planning capabilities, end-to-end solution expertise of SkyFive and in-depth experience of integration and operation of Air-to-ground networks based on the experience gained by supporting the EAN network in Europe.

In order to support SLA requirements, SkyFive provides a specific link supervision and analytic solution permanently supervising the connection between the airborne device and the ground network.

SkyFive can provide vendor-agnostic consulting, solution engineering, project management and life cycle management for 4G and 5G Air-to-Ground solutions regardless of the use case and application.

Also a specifically customized and pre-integrated LTE and 5G core network can be provided by SkyFive allowing to introduce Air-to-Ground in a short time and with a minimum of complexity.

Conclusion

Governmental PPDR authorities as well as private and non-governmental organisations require reliable and mobile communication solutions with much more bandwidth as available by classical analogue and trunked radio. This capability is required not only on ground, but in the air as well.

Air-to-Ground on basis of LTE is a proven and cost-efficient answer to this request. Upcoming 5G technology further enhances performance and allows access to new spectrum significantly increasing deliverable capacity at low latency with high reliability.

SkyFive can help in selecting the appropriate technology and design, plan and realize the project in a vendor-agnostic way.

Acronyms	Definition
3DNP	Three-Dimensional Network Planning
3GPP	3rd Generation Partnership Project
4G	4th Generation 3GPP network, also referred to as LTE
5G	5th Generation of mobile communications
A2G	Air-to-ground (sometimes in literature also abbreviated with “ATG”)
AR	Augmented Reality
DA2G	Direct Air-to-Ground, synonymous to A2G
EAN	European Aviation Network
ESN	Emergency Service Network
ICIC	Inter-Cell Interference Coordination
IFC	In-Flight Connectivity
IoT	Internet of Things
LOS	Line Of Sight
LTE	Long-Term Evolution (see 4G)
Mbps	Mega Bits Per Second
MIMO	Multiple-Input and Multiple-Output
NLOS	Non Line Of Sight
OBE	On-Board terminal Equipment
PPDR	Public Protection and Disaster Relief
RF	Radio Frequency
RPA	Remotely Piloted Aircraft
SLA	Service Level Agreement
TETRA	Terrestrial Trunked Radio
UAV	Unmanned Aerial Vehicles