# PPDR-TC

FP7-SEC-313015

*Public Protection and Disaster Relief - Transformation Centre*

# FINAL PUBLISHABLE SUMMARY REPORT


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| **Contract Start Date:** | April 1st, 2013 |
| **Duration:** | 30 months |
| **Project coordinator:** | EXODUS S.A. (Greece) |
| **Partners:** | EXO (GR), ICCS (GR), TCS (FR), RINI (UK), TELE (GR), PLUM (UK), ITTI (PL), TEK (PT), UNIMORE (IT), LRTC (LT) |

**This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 313015**

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## Executive summary

In order to satisfy the increasing demands of future PPDR communications systems there are certain technical and economic barriers to overcome. Requirements for solutions that effectively tackle emergency situations at hand, while efficiently coordinate first responders at operational, strategic and tactical level augment the necessity of evolving the architecture of future PPDR systems. One of the basic aims of these systems will be to pave the way for establishing rapidly deployable broadband infrastructure in the field. To this ground PPDR systems should meet the demands of voice, real-time video and localization of forces together with high speed data transfer for dealing with natural and man-provoked disasters. The basic challenge is the continuous service provisioning, transparently to the end-user and independently of the underlying telecommunication infrastructure.

The major objective of PPDR-TC project is to provide the strategic roadmap towards the full migration path of future PPDR system's evolution satisfying the mid and long-term requirements for the next 10-15 years.

In order to cope with this goal PPDR-TC established a modular study approach with the following building blocks:

- Extensive data gathering from European PPDR organizations to define reference usage scenarios, classify current and future services, while identifying candidate PPDR technologies and architectures.
- Derivation of technical recommendations based on validation of the candidate technologies and architectures so as to achieve uniform communication for public safety agencies (broadband, TETRA, TETRAPOL networks, etc.), offering ubiquitous secure communication over dedicated and commercial networks, while establishing seamless connection to other networks (LTE, 3G, WiMAX, etc.).
- Provide economic recommendations based on validation of the candidate PPDR technologies, according to specific economic factors (NPV, IRR, ROI, etc.) and presenting a cost/benefit analysis to the decision makers.

During the 30-month period of the project execution the project managed to deliver significant results and exhibited a series of important achievements. Numerous public facing documents reporting PPDR communication requirements, scenarios and services together with a compliance matrix that maps them to technology gaps were produced. Furthermore, various software tools to assist the PPDR and the research communities were implemented such as:

a) An on-line database to provide PPDR-related facts and figures within the EU, actively populated by the PPDR community itself.
b) A software toolbox able to help PPDR decision-makers in determining the most suited business model for acquiring, deploying and upgrading a PPDR network, based on technical, functional, economical and organizational requirements.
c) Various network test beds, as well as updated modules for the ns-3 network simulator, all released with Free Software licenses to assist the technical community.

In addition, PPDR-TC project produced a series of techno-economical recommendations, supported by a comprehensive set of simulations and field trials to prepare a transition roadmap from current voice-centred PPDR networks to broadband-capable communication systems. On top of that, to both ensure wider diffusion of project's outcomes and higher impact on the PPDR community, PPDR-TC organized various scientific and end-user workshops that together with a significant number of scientific publications in prestigious international journals and conference proceedings indicate the project's enhanced interaction with both

PPDR and scientific communities. Last but not least PPDR-TC managed to influence current standardization activities by submitting a standardization proposal to 3GPP LTE Public-Safety Work Group.

## Description of the project context and the main objectives

Human-provoked and natural disasters are forcing governments to utilize their Public Protection and Disaster Relief (PPDR) resources more efficiently. The traditional security objectives are changing as new challenges and threats emerge and there is a need for better integration and co-operation with the emergency services at national, European and international levels. Europe is actuating its internal security mechanisms in the context of a framework for increased cooperation between Police, Fire, Rescue, Health and Military. At the moment there is an urgent need for rapidly deployable broadband communication facilities, to meet the increasingly demanding requirements of PPDR users; also, there is an increasing demand for spectrum harmonization for PPDR services (video and high speed data) through a in Europe. The main characteristics identified as particularly desirable for broadband PPDR communications are:

- Interoperability between systems from different vendors and countries that are able to interoperate at some predetermined level without any modifications or special arrangements.
- Economies of scale should support the equipment design layered on top of existing commercial communication networks (WiMAX, LTE, etc.).

The PPDR-Transformation Center vision is to research and provide technical and economical recommendations in order to enhance cross-border coordination, increase potential for interoperability and international cooperation and improve spectrum management and planning. PPDR-TC vision's realization was based on three main elements, namely:

- identification of current PPDR Communications status and requirements for future applications,
- data synthesis and scenarios development,
- technical, economical and organizational analysis of future PPDR Communications development.

The main objectives of PPDR-TC project were:

**1: Gathering of European PPDR facts and figures data.**

A principal goal of the project was to perform an extensive data gathering exercise in order to collect generic information on European PPDR cross sector organisations from different member states. A wide range of information spanning from plain administrative data (Name, type, country, number of personnel, etc.) to events data (number of national and cross-border events, type of events), technologies (communication systems deployed, network size, etc.) and services required (AVL, Video transmission, etc.) could be potentially collected. To facilitate this process, the establishment of a statistical Facts and Figures database that would offer to the connected user advanced functionalities for searching, retrieving and presenting simple set of data or complex statistical information according to the end-user's queries was envisioned.

**2: Definition of PPDR Communications reference usage scenarios and identification of service requirements and future needs in the European context.**

This objective aimed to capture the current status of PPDR services, in particular the interactions between PPDR personnel. The PPDR functionalities that are desirable but not achievable with the current technologies have also been investigated. Both mission critical and non-mission critical situations needed to be addressed with a view to achieving full integration and uniformity. Particular attention has been directed towards:

- Provision of wide area coverage
- Achieving compatibility with current systems such as PMR, TETRA, and TETRAPOL,

- Combining seamless data services and situational awareness,
- Accomplishing high network availability,
- Allowing fall-back operation,
- Ability to operate in non-mission-critical public-protection and disaster-relief situations over dedicated and commercial networks.

**3: Implementation of a detailed study of the reference scenarios with a view to establishing service classification and identifying key technical issues.**

Services needed to be classified on the basis of PPDR user requirements. Technical issues including spectrum availability, PPDR mobile operator capabilities, PPDR traffic growth estimation and developments in technology and standards needed to be investigated. Based on the analysis of the operational needs, the current technological gaps and the identified reference scenarios, the objective of this task were to define a set of PPDR reference services according to the following classification: essential services as required today by the PPDR community due to the fact that they constitute the basis of each PPDR operations (near-term evolution), required services used by PPDR units and identified as efficient to reinforce PPDR operations (mid-term evolution), and future services that would be crucial to take into account (long term evolution).

**4: Identification of candidate PPDR Communications technologies and architectures.**

On the basis of the PPDR user community requirements, system features including interoperability, resilience and security had to be considered in the candidate technology identification. The project had to provide solid foundations for handling mission critical communication requirements, considering issues such as:

- The likely availability of radio spectrum. Spectrum requirements for PPDR operations and the frequency bands that might potentially be available will be factored into the selection of reference architecture options,
- The mobile operator relationship patterns in the PPDR context (i.e. the role that Telco operators, PMR operators, MVNOs might play in the provision of PPDR services and networks),
- The extrapolation, from the current level of use, of the type and volume of traffic, in particular the growth likely to be stimulated by the identified PPDR reference services
- The evolution of current technologies and standards.

Then, the major goal is to analyze current as well as emerging technologies in order to propose options for PPDR reference system architectures on the basis of different parameters including bandwidth requirements, ease of deployment, cross-border operation capability and integration with existing infrastructures.

**5: Development of validation tools for future PPDR Communications.**

To examine the technical performance issues of the candidate technologies/architectures, a suite of validation tools needed to be developed. The validation tools would offer the capability of technical, functional and organisational analysis at different level of detail, by employing decomposition or aggregation approach. On top of that, business-driven solutions for future PPDR systems based on different infrastructures provided by different entities offering services using different tariffs needed to be elaborated. The end-user should have a possibility to select a communication solution that is tailored to its functional and non-functional requirements as well as its budget. The resulting system can be built by the end-user, leased from operator/operators or gained using both approaches. Thus, tools for business analysis based on financial-economical modelling that facilitate the preparation of business models with different levels of collaboration among entities involved in gaining the communication platform were envisioned.

**6: Elaboration of technical recommendations on candidate technologies and architectures.**

Technical recommendations that (a) enable ubiquitous secure communications over dedicated and commercial networks, (b) offer the capability of connection seamlessly to other networks, (c) assure uniform communications for public safety agencies across broadband, TETRA, TETRAPOL networks, (d) provide cross-border solutions and functionalities, and (e) enhance response team abilities in terms of dynamic management, prioritisation and quality needed to be derived.

**7: Provision of economical recommendations on candidate technologies and architectures.**

An investigation into scenarios, where merging of commercial broadband infrastructures with current PPDR Communications systems is realized, needed to be performed. Cost / benefit analysis had to be carried out by ensuring the continuity of services while deploying the new technologies. The implication of cost reduction potential had to be evaluated in the context of economies of scale. Further consideration needed to be given to the impact of deploying a new infrastructure or leasing an existing one.

**8: Provision of a roadmap towards full satisfaction of future PPDR Communications requirements and development of recommendations for PPDR Communications standards for decisions-makers.**

On the basis of the technical and economic recommendations, a roadmap to meet PPDR community requirements during the next 10 – 15 years needed to be elaborated. Two evolution scenarios had to be considered. A mid-term roadmap, considering mainly current PMR system upgrades and interoperability as well as a long-term roadmap that provides options for a migration path towards full satisfaction of PPDR requirements. In addition, recommendations had to be developed to define new standards for PPDR communications systems, services and applications.

## Main S & T results/foregrounds

The project was organized in seven work packages that were responsible to fulfill the aforementioned objectives. The main technical results produced within the project (WP2-6) are highlighted in the following subsections.

### WP2 - Current and Future PPDR Operational Scenarios, Needs and Technological Gaps

WP2 comprised four distinct tasks, namely:

(i) Development of Reference Usage Scenarios

(ii) Identification of PPDR Services and Application Requirements

(iii) Identification of Technology Gaps and

(iv) Establishment of a PPDR Facts and Figures database

In the following sections the results achieved from each of these tasks is described.

#### *Task 2.1: Development of Reference Usage Scenarios*

The objective was to define the typical current and anticipated future operational scenarios faced by PPDR operatives and the related communication needs, including routine "day-to-day" operations, planned major events and unplanned major incidents or disasters. Information was sourced from previous studies, feedback from PPDR stakeholders contacted by the consortium members and additional desk research carried out by the task leaders.

Five distinct communication requirements for PPDR users were identified, namely voice, narrowband data (e.g. for messaging), broadband data (e.g. for images or large files, video and the use of repeater stations to extend coverage or provide air-to-ground communication. Eight high level communication scenarios were also identified, namely:

- A: Between a Central Control Station and Field Personnel at an Incident
- B: Between PPDR Vehicles and an Incident Location or Control Station
- C: Between Individuals at an Incident
- D: Between Different PPDR Entities (e.g. Police, Fire, Ambulance, Volunteers)
- E: Accessing External Data Sources (e.g. Internet)
- F: Communication in Enclosed Spaces (e.g. Tunnels Or Basements)
- G: Communication With Remote Locations (e.g. Mountains or at Sea)
- H: Communication with or between Machines (e.g. Remotely Controlled Vehicles).

In all, 22 stakeholder responses were received and used in the analysis of usage scenarios. In addition, eight specific major incident / event scenario case studies were undertaken, each based on a real-life incident or event.

The analysis uncovered deficiencies in existing PPDR communication capabilities in several areas, including:

- Inadequate network coverage
- Lack of Interoperability (both at the technology and working protocol level)
- Insufficient resilience (e.g. unreliable power supplies or non-rugged terminals)
- Excessive reliance on public networks which are unreliable in crisis situations.

Applications identified as particularly important in the future for supporting PPDR operations included video, other data applications (e.g. breathing apparatus telemetry, vital signs monitoring and access to on-line forms and databases) and location services (e.g. for tracking of personnel, vehicles and other assets). Resilience, flexibility and better interoperability between different agencies and ICT systems were also considered important. Existing PPDR communications were found to vary considerably between EU countries but all suffered deficiencies in coverage, interoperability and/or data capability.

Full details of the outputs of task 2.1 can be found in the public deliverable "PPDR's Current and Future Scenarios", which can be downloaded from the PPDR-TC web site at www.ppdr-tc.eu/userfiles/deliverables/PPDR-TC-D2.1-v2.00_1567038775.pdf.

### *Task 2.2: Identification of PPDR Services and Application Requirements*

The main objective of this task was to identify required PPDR services and applications along with the associated network performance requirements, based on the reference scenarios identified in task 2.1. A total of 45 PPDR applications were identified, based on ECC Report 199, data collected from PPDR end-users and results from other relevant EU projects.

These applications were then classified according to the eight communication scenarios configurations defined in task 2.1 and their requirements identified in terms of the following categories:

- Users of the application;
- Typical coverage area requirements;
- Required network topology;
- Node connectivity models;
- Capacity in terms of type of data and required bandwidth;
- Mobility requirements;
- Interoperability requirements;
- Service availability, reliability and resilience;

- Performance requirements;
- Security;
- Specific voice communication requirements;
- Specific data communication requirements.

Full details of the outputs of task 2.2 can be found in the public deliverable "PPDR's Needs and Requirements", which can be downloaded from the PPDR-TC web site at www.ppdr-tc.eu/userfiles/deliverables/PPDR-TC-D2.2-v2.00_274261689.pdf.

***Task 2.3: Identification of Technology Gaps***

The main objective of this task was to identify technology gaps by comparing the capabilities of existing and potential future PPDR network solutions with the user requirements identified in task 2.2. A total of 18 communication technologies were analysed, including current PPDR technologies (e.g. TETRA, TETRAPOL), current public networks (e.g. GSM, UMTS), potential future technologies (e.g. LTE) and transversal communication concepts (cognitive and software defined radio). The analysis focused on aspects such as relevant industry players, status of technology standards, technical details and strengths/weaknesses for PPDR applications.

Based on this analysis, the technological capabilities of the PPDR technologies were mapped against the users' requirements identified in Task 2.2, in the form of a compliance matrix which can be downloaded from the PPDR-TC web site at www.ppdr-tc.eu/userfiles/deliverables/PPDR-TC-D2.4-v1.00_1996711392.pdf. A detailed description of the technology gaps identified from the compliance matrix was also generated and can be found in the public deliverable "PPDR's Technological Gaps", downloadable from the PPDR-TC website at www.ppdr-tc.eu/userfiles/deliverables/PPDR-TC-D2.3-v2.00_1492260373.pdf.

***Task 2.4: Establishment of a PPDR Facts and Figures database***

The objective of this task was to develop an on-line database to provide facts and figures relating to PPDR activities, networks and technologies within the EU. The database is now fully operational and can be accessed through a sub-domain of the PPDR-TC web site at http://db.ppdr-tc.eu/.

The architecture is client-server providing a front-end with advanced capabilities of searching and retrieving data as well as a back-end mainly offering storage of data and mechanisms for data correlation. Access rights with different levels of authorization were identified focusing on two distinct system roles, namely.

i) Administrator/ Contributor with Read/Write/Modify/Add new entries privileges

ii) User with Read Only and Search rights

The database uses open source technologies starting from MySQL RDBMS and in the front-end a PHP based CMS. For the data entry part, information has been extracted from the questionnaire and the data collection campaign performed in the first months of the project, as well as open source data that can be aggregated and batch imported to the database.

To make the database more attractive to the end-users, additional content and functionality has been added, including:

i) Added tooltip functionality (popup text) on selected fields to provide explanatory notes to better clarify field contents

ii) Added page for download of the free-of-charge and free-to-use "Financial-Economic Basic Tool" which is a business-oriented tool that can deliver a series of efficiency indices for different scenarios of acquiring a PPDR system (developed within the activities of WP4)

iii) Contact point information on each entry (i.e. contact person name, email, telephone, address)
iv) Inclusion of new technical fields related to the supported services and owned systems, e.g. network specific information such as number of base stations.
v) Updated user interface, extended statistics figures and extended search filters and results based on technologies and services used

**WP3 - Existing and Emerging PPDR Services and Architectures**

In summary, the WP3 investigated reference services (Task 3.1 PPDR Reference Services), analysis of radio spectrum requirements (Task 3.2 Analysis of Radio Spectrum Requirements) and system architecture evolution option (Task 3.3 Options for PPDR Reference Architecture and Services) of PPDR communication systems. The outcome of Task 3.1 was a valuable classification of services for PPDR end-users. The outcomes of Task 3.2 provide a detailed analysis of the PPDR radio spectrum. These outcomes were the basis for the definition of PPDR system architectures expressed on Task 3.3. The results of this WP3 were used as an input for PPDR-TC business models and simulation scenarios regarding PPDR reference services, PPDR analysis of requirements and PPDR architectural options.

***Task 3.1 PPDR Reference Services***

The main objective of Task 3.1 PPDR Reference Services was to define a set of reference services that are valuable for PPDR agencies, given their needs and requirements, as well as the current technological availability.

In order to define the PPDR reference services, it was considered PPDR operational scenarios from Task 2.1, PPDR requirements from Task 2.2 and the outcome of the analysis of PPDR network solutions and technologies from Task 2.3. It was also based on other relevant documentation such as the ECC FM49 Report 199.

Task 3.1 produced the definition and classification of a set of 31 reference services that include PPDR voice, narrowband data, broadband data and video, as well as transversal services for the extension of capabilities and challenging services enabled by the next generation of technologies.

Parameters such as the technological maturity, applicable scenarios and service timeframe were used to analyse and classify services. Each service was also placed in a classification scale of potential interest that ranges from near-term evolution, mid-term evolution to long-term evolution.

As final result of this task, the following table summarises the services that have been analysed and their classification in accordance with the analysis.

| Service | Classification |
|---|---|
| Push-to-talk | Near-term evolution |
| Private call | Near-term evolution |
| Emergency/priority call | Near-term evolution |
| Call retention/busy queuing | Near-term evolution |
| Direct mode operation | Near-term evolution |
| Ambience listening | Near-term evolution |
| Voice over the public switched telephone network | Near-term evolution |
| Area selection/dynamic group number assignment | Near-term evolution |
| Messaging and notifications | Near-term evolution |
| Low resolution photos | Near-term evolution |

| Service | Classification |
|---|---|
| Location-based information | Near-term evolution |
| Extension of coverage | Near-term evolution |
| Extension of availability | Near-term evolution |
| Security tools | Near-term evolution |
| Group call | Mid-term evolution |
| Automatic telemetrics | Mid-term evolution |
| Mobile workspace applications (narrowband) | Mid-term evolution |
| Access to internal databases (narrowband) | Mid-term evolution |
| Access to external sources (narrowband) | Mid-term evolution |
| Rapid file transfer | Mid-term evolution |
| High resolution photos | Mid-term evolution |
| Mapping with geographic information system layers | Mid-term evolution |
| Mobile workspace applications (broadband) | Mid-term evolution |
| Access to internal databases (broadband) | Mid-term evolution |
| Access to external sources (broadband) | Mid-term evolution |
| Video transmission | Mid-term evolution |
| Video file transfer | Mid-term evolution |
| Video call | Mid-term evolution |
| Proximity services | Mid-term evolution |
| Augmented reality | Mid-term evolution |
| Remote operations | Long-term evolution |

**Table 1: Summary of the services classification activity**

The main conclusion drawn from this analysis work was that the value or interest to introduce a certain communications service into a PPDR system is not solely determined by the needs and requirements manifested by potential end-users of such a service, being also constrained by:

- The availability of mature network technologies and terminals, able to support the service in a cost-efficient manner;
- The applicable regulations and standards which, among other issues, may limit the RF spectrum that can be allocated for the service or network.

### *Task 3.2 Analysis of Radio Spectrum Requirements*

Task 3.2 activities were related with radio spectrum requirements analysis. It was performed an analysis of the radio spectrum currently utilised by PPDR agencies around the world and the projected future needs for radio spectrum to support new enhanced services such as broadband data and video in the future, based on a variety of publicly available sources and additional internal analysis. Spectrum requirements for wide area mobile networks, local area networks, direct mode operation (DMO), air to ground (A2G) communications, satellite communications and network backhaul were addressed.

Currently the only fully harmonised dedicated PPDR spectrum in Europe is the 380 – 400 MHz band, the lower 2x5 MHz of which is used to support digital trunked radio networks, mostly based on the European TETRA standard. Specific sub-bands within this range are identified for A2G and DMO. Other bands used today on a national basis include the VHF and UHF professional mobile radio bands (80 MHz, 160 MHz and 410-470 MHz, however much of this use is expected eventually to migrate to TETRA in the 380-400 MHz band.

Spectrum has been identified by CEPT for broadband PPDR communication in the 5 GHz range, but only a few EU countries have adopted this to date, mostly in the 5150-5250 MHz band. This spectrum is shared with commercial Wi-Fi systems but PPDR users are permitted to deploy higher powers in the band, enabling significantly longer operating range. Eight EU countries are known to have existing broadband PPDR allocations in either the 2 GHz, 2.3 GHz or 3.5 GHz bands. These are typically used for terrestrial or A2G video links.

Satellite communication is sometimes used by the PPDR community, to connect to remote locations or for disaster relief operations. These generally use established generic satellite frequency bands, such as Ku-band for very small aperture terminals (VSATs) or transportable earth stations, and L-band for mobile satellite services such as Inmarsat. In the future Ka-band systems, which offer much greater bandwidth, may play an increasing role in providing backhaul or temporary communication links. There are specific bands at 406 MHz and 1.5 GHz reserved internationally for emergency satellite communications, but use of these bands is not restricted to the PPDR community. Satellite radio navigation services such as GPS also play an important role for PPDR users.

Currently most PPDR backhaul is provided by microwave links in various non-exclusive frequency bands, typically in the 450 MHz or 1400 MHz range for narrow band links and in higher bands (above 3 GHz) for broadband links.

Beyond Europe, the 800 MHz band (806-824 and 851-869 MHz) is often used, sometimes alongside spectrum in the 400 MHz range (380 - 470 MHz). In North America 2x10 MHz of spectrum has been allocated in the 700 MHz range (former TV broadcast spectrum) to broadband public safety services but the configuration of this spectrum is not compatible with other parts of the world (including Europe).

There is a strong global consensus that additional spectrum is required to support future broadband PPDR services and studies within both CEPT and the ITU have indicated that this should ideally comprise 2x10 MHz in a frequency band below 1 GHz, to provide the necessary coverage and capacity. The favoured frequency band is 700 MHz (694-790 MHz), which is currently allocated to broadcasting but expected to be re-farmed for mobile use in the next few years. This reflects the current situation in North America, but will require a different band configuration due to the historic differences in mobile and broadcast frequency allocations in the Americas and other parts of the world. In Europe consideration is being given to using the lower portion of the 700 MHz band (698-703 and 753-758 MHz) as a dedicated PPDR allocation, which would also enable access when needed to the adjacent band (703-733 and 758-788 MHz), which is likely to be mainly used by commercial mobile operators.

Higher frequency spectrum will also be required to support localised high traffic demand at major incidents, but the existing identified spectrum around 5 GHz should be capable of supporting this. In addition, spectrum is also likely to be required for specialised applications such as broadband A2G and DMO communications. Because A2G communication generally involves a line of sight transmission path, higher frequencies may be used and currently the favoured frequencies appear to be in the 2.3 GHz and 3.5 GHz ranges. However, in the future these frequencies may be increasingly in demand for commercial cellular activities.

As far as possible PPDR terminals should be capable of operating on both dedicated PPDR network infrastructure where it exists and on commercial networks, to provide users with maximum flexibility. Use of cross-sector technologies like LTE or Wi-Fi in frequency bands that lie either within or adjacent to existing commercial bands should help to facilitate such interoperability.

The table below summarises the most likely future spectrum resources for broadband PPDR services in Europe at the time of writing, based on publicly available literature and discussions within regulatory entities, notably CEPT and ITU-R:

| Application | Preferred band(s) | Comments | References |
|---|---|---|---|
| Wide area cellular network | 700 MHz (698-733/ 758-803 MHz) | 2x10 MHz required but equipment should tune over full band to facilitate interoperability with commercial networks. Lower 2x5 MHz has been mooted as a harmonised PPDR band | CEPT document FM49(13) 085 Annex 1,<br>ITU-R document 5A/265 |
| Local area / ad-hoc networks | 4940-4990 MHz and 5150-5250 MHz | Higher band is shared with commercial Wi-Fi. May also be used to support direct mode operation | CEPT ECC Recommendation (08)04 |
| Air to ground (A2G) communications | 1900-1920/ 2010-2025 MHz<br>2300-2400 MHz | Based on current utilisation in some countries and on-going CEPT considerations | CEPT ECC, National Regulatory Authorities |

**Table 2: Likely preferred bands for future PPDR deployment in Europe (as of May 2014)**

### *Task 3.3 Options for PPDR Reference Architecture and Services*

Based on the identified set of reference services and the classification developed in PPDR-TC Task 3.1, the Task 3.3 addressed three main topics:

- High Level System Requirements for future broadband PPDR networks;
- Operational scenarios to be used as a basis for simulations;
- Architecture models for PPDR network deployment.

Technologies that match market needs and deliver the right technical capabilities are a critical building block in creating successful national and international communication systems. As one of the result of PPDR-TC Task 2.3 Identification of technology gaps, it is clear that 3GPP LTE is a strong candidate for future broadband PPDR networks. Over the coming years 3GPP will be working with the commercial cellular and PPDR community to develop enhancements to apply LTE to PPDR and commercial critical communication scenarios. PPDR-TC project advocates that potential requirements for future broadband PPDR networks are vast and an exhaustive list would consist in a composition of:

- Current PPDR system requirements (e.g. TETRA, TETRAPOL, PMR services);
- Commercial Broadband network currently available in consumer market (3G, 4G LTE, Wifi, Satcoms).

The technical work to produce enhancements to the 3GPP LTE standard to support PPDR applications is already taking place in 3GPP from LTE Release R12 and beyond. Cooperation has been established between 3GPP and other groups such as ETSI TC TETRA, TCCA and US National Institute of Standards and Technology (NIST) to ensure broad representation of the public safety community.

PPDR consortium decided to focus on the following **High-Level system requirements**: node connectivity, out-of-coverage, interoperability, mobility, network sharing, roaming and resiliency requirements. These topics were carefully chosen because they are the main enablers for the applications and services identified in WP2

and earlier tasks of WP3. The evolution of current technologies and standards, being a key element of the PPDR-TC project, links with current standardisation work items.

Three different types of events considered were 1) day to day operations, 2) large planned events and 3) large unplanned event/disasters. For each event type, it was provided setups for hypothetical scenarios where the services, technologies, actions, actors and deployment areas were identified.

Attributes combined with the technical properties identified on a technology basis will constitute the main input to be provided for the investigation of the overall performance of PPDR services behaviour and of traffic growth evolutions that will be performed via the simulations studies in WP5.

Mobile operators relationship patterns in the PPDR context provided a set of reference architecture options for future PPDR networks. The potential role of PPDR operators, MVNOs or even Commercial Operators in the provision of PPDR services and networks are provided. Five architecture options were considered:

- Option 1: Keep TETRA/TETRAPOL only
- Option 2: PPDR MVNO only for Data
- Option 3: Shared Radio Access Network
- Option 4: Dedicated, Private Radio Access Network
- Option 5: Commercial Operator for voice and data services

Moreover, for each of the architecture option considered, a first technical analysis was provided taking into account the likely availability and nature of the spectrum available. Simulation investigations to be performed in PPDR-TC project WP5 and impact of the individual architecture options on the simulation scenarios were also analysed.

**WP4 - Business Models, Economical Analysis and Tools for Decision-Makers**

The aims of the Work Package 4 of the PPDR-TC project were four-fold:

1) identification of business models of gaining a PPDR system;
2) elaborating use-cases and scenarios that lead to creating new system, upgrading existing system with new services, migrating from old system to new one, etc.;
3) development of spread sheets for financial-economic analysis;
4) implementation of calculations for modelling of use-cases and scenarios as a set of software tools (toolbox) allowing a selection of the system and taking a few decision levels into account (i.e. technical, functional, economic and organisational areas).

To achieve these goals, the work was organised in three subsequent Tasks:

- Task 4.1: Identification of business models
- Task 4.2: Technical, financial, economic and organisational analysis
- Task 4.3: Analysis tools for decision makers

In Task 4.1 several business models with sub-models presenting different approaches to set up a PPDR system were identified. The elements used to construct business models reflect the broad range of options analysed in the project, including a range of actors as well as value and cash flows, though the dominant view is supposed to be that of a PPDR service organisation. Three general models have been identified with respect to owning and operating entities; three sub-models of system acquiring, three sub-models of system building, four sub-models of financing, and two sub-models of operations. Drawing conclusions from various studies

reported in last years, PPDR-TC project claims that in practice 'business models' general alternatives available for implementation of critical communications broadband services are the following:

a) **User Owned – User Operated (UO-UO)**: Building, ownership & operation of the network(s) by the end-user agency (or agencies) themselves.
b) **User Owned – Commercial Operated (UO-CO):** Build & ownership of the network(s) by the end-user agency (or agencies). Operation of the network(s) by a commercial provider of outsourced managed network services.
c) **Commercial Owner – Commercial Operated (CO-CO):** User agencies subscribe for services provided by a commercial network owner / operator.

An illustration of the considered acquiring models is provided in Figure, and models are tagged (red labels in Figure ) with respect to the general Ownership/Operation models listed above.

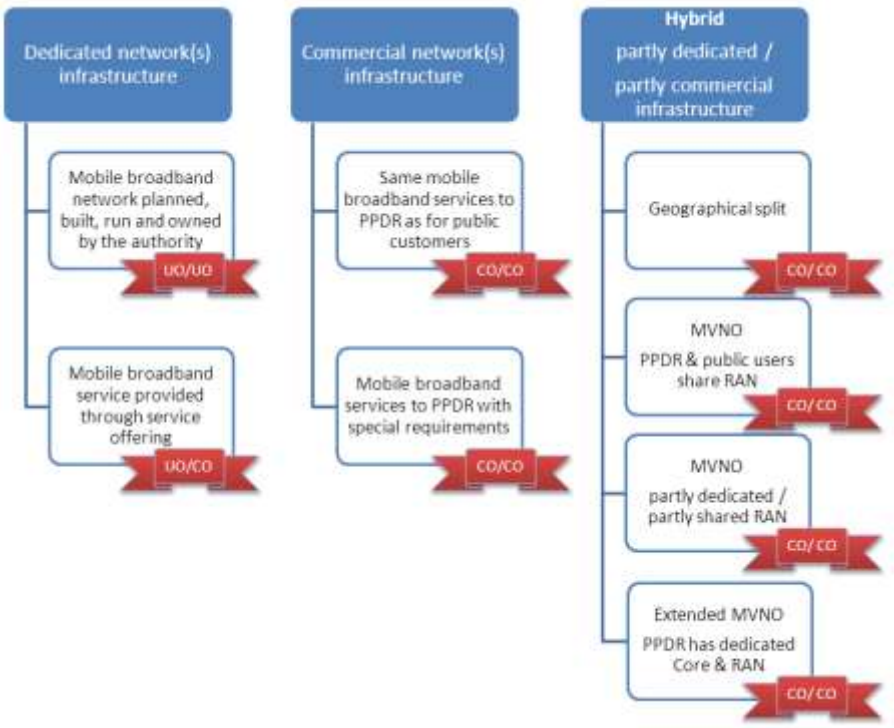


**Figure 1. Models overview for PPDR system acquisition**

In this Task, the identified models were also illustrated with current national network deployment us e-cases. Each use-case was described and then put into perspective with the business model they implement. Member countries all have different needs regarding PPDR systems deployments. Analysis of the legacy national use-cases highlights that the predominant model in the past for PPDR agencies was to own and operate their network. Due to high Total Cost of Ownership, but also thanks to new tools available to fund future broadband networks, this paradigm is shifting to innovative "hybrid approaches" in which a combination of a dedicated network for PPDR critical communications and a commercial network for non-critical and broadband transmissions managed by a MVNO can be considered. Full details of the outputs of Task 4.1 can be found in the public deliverable "Business Models", which can be downloaded from the PPDR-TC web site at http://www.ppdr-tc.eu/userfiles/deliverables/PPDR-TC_D4%201-v2.00_904892321.pdf.

In Task 4.2, taking into consideration business models identified in Task 4.1, a spreadsheet workbook application was developed. The workbook consists of a number of worksheets that make it possible to compare technical, financial and economic parameters of different PPDR systems vs. investments, costs and

potential income (if a system is planned to be operated commercially), with a set of efficiency indicators automatically calculated. The tool employs a range of business formulas and indices for comparing efficiency of alternative scenarios for a variety of PPDR systems. It also provides analysis of organisational aspects. A user interface allows for modifying parameters of the implemented models and presenting the analysis results graphically.

The business oriented tool entitled "model_PPDR_TC" delivers a series of efficiency indicators that can be used from decision makers to simulate different scenarios of acquiring a PPDR system. The approach used to develop the workbook was based on the following basic axes:

- **A Bottom-up analysis** delivering a set of financial-economic factors for assessment of business efficiency of a model.
- **A Top-down analysis** adjusting the value of parameters (e.g. size of system, a number of terminal, a number of base stations, a number of years of investment) for assumed maximum expenses

Four categories of parameters including technical, financial, economic and organizational were identified for developing the workbook.

- Technical
  - Services and applications defined and classified in Work Packages 2 and 3 of the PPDR-TC project
  - Technologies satisfying the different services and applications identified in Work Package 2
- Financial
  - investments CAPEX and
  - operational costs OPEX
- Economical
  - advantages in case of system ownership by the end user that can offer in the cash flow of the entity
- Organizational
  - expenditures to acquire and operate/manage/maintain the system are allocated into three roles: PPDR agency as infrastructure owner, PPDR agency as system operator and PPDR agency as user

The developed worksheets were validated as for their proper operation in two different ways. The first one was based on existing cases of PPDR systems and facts used from local and/or national level. The second one was based on a "green field" scenario, a hypothetical case of a PPDR entity willing to acquire a system covering specific needs and requirements. In the second case the scenario included the following elements:

- A PPDR agency wants to acquire a new PPDR system defining the desired set of applications and services
- All the different acquisition models and sub-models from Task 4.1 are tested in this common basis

Through the model_PPDR_TC tool strengths and weaknesses of its different sub-models are listed in the basis of a trade-off between needs and funds under the different parameters.

As an example of use, three use-case groups were presented. First, eight different business models identified in Task 4.1 were analyzed by the tool and presented numerically and graphically. Then, five national PPDR network systems were compared and analysed. Finally, five scenarios of implementing a dispatching service for a large energy company were analysed. Full description of the tool and the results obtained for the use cases and scenarios described above can be found in the public deliverable "Technical, financial, economic

and organisational analysis", which can be downloaded from the PPDR-TC web site at http://www.ppdr-tc.eu/userfiles/deliverables/PPDR-TC_D4.2_v1.00_1264281003.pdf.

The objective of Task 4.3 was to enhance the tool of Task 4.2 towards a set of tools (toolbox) that offers to a user (decision-maker) the possibility of performing comprehensive multi-domain analysis that takes into account telecommunication techniques, communication services, financing and business models, and economic expectations. The toolbox uses the spreadsheet workbook "model_PPDR_TC (developed in Task 4.2) as a core (main) application that invokes new components for enhanced functionality. The new components that were developed are related to radio network planning and dimensioning, multi-criteria decision analysis and graphical presentation of organizational aspects. To offer improved and more comprehensive analysis, the toolbox employs two recognized software tools: an RF Signal Propagation, Loss, And Terrain analysis tool – SPLAT! and a software environment for statistical computing and graphics – *R*. The generic structure of the toolbox is depicted in Fig. 2.

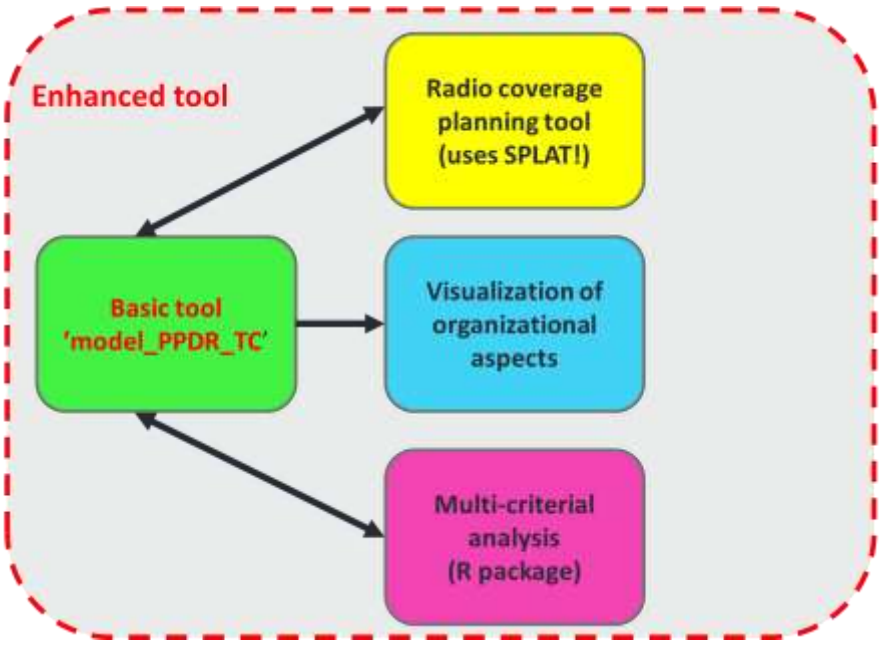


**Figure 2. Generic structure of the toolbox**

By means of the toolbox multi-domain analyses were performed for the cases of two EU countries: France and Poland. In the studies, various technologies and business models were considered. In the first case, comparison of two models of acquisition of a nation-wide dispatcher system for a PPDR organization in the area of France was carried out. The first scenario involved the construction of a new LTE network, exclusively owned and managed by PPDR organization own resources. The second scenario was based on communication services leased from an external operator that has the nation-wide LTE infrastructure. In the case of Poland, both planned networks are hybrid ones as they both involve the construction of own TETRA sub-network and the acquisition of a broadband LTE sub-network. For the LTE sub-network e the same scenarios as for France were investigated. Full description of the toolbox and the results of the multi-domain analyses obtained for the scenarios described above can be found in the public deliverable "Tools of technical, financial, economic and organisational analysis", which can be downloaded from the PPDR-TC web site at http://www.ppdr-tc.eu/userfiles/deliverables/D4%203_v1.00_final_1694012576.pdf.

### WP5 - Validation Tools Chain for PPDR Systems Evolutions

The PPDR-TC project core objective is the definition of an interoperable, secure and resilient voice and data communications architecture, tailored specifically to the needs of the PPDR community. It aims at delivering

the cornerstone for future mission critical communication systems. Although PPDR-TC addresses mission-critical situations, it also takes into consideration the requirements for situations commonly designated as non-mission critical. The analysis of these two very different types of situations is performed using a single framework, which has been devised and thoroughly documented in several documents in the scope of this project. The PPDR framework was mostly driven by the PPDR community end user requirements, which have been captured and analysed in the early stages of the project. From a communication systems point of view, the main outcome of the requirements analysis tasks was that the PPDR operational scenarios could be classified into three distinct categories:

- The routine operations, also commonly designated as the "Day-To-Day" operations;
- The large and planned event operations, that include large events such the visit of a country high-representative or a large scale social event such as the final of the European Champions League, amongst many other examples that fall into this category;
- And finally, the large although unplanned operations; as an example of an event that falls into this category we include what it is commonly designated as natural catastrophes, among other types of examples not necessarily originated by natural causes.

PPDR-TC project has already characterised each of the previous scenarios and established potential communication architectures to address not only the current needs of the PPDR end user community, but also some gaps that the current communication system are not able to deliver. The latter not only concerns interoperability, security and resilience of the communication infrastructures, but also the need to account for innovative operational procedures based in the exchange of digital information (e.g. sending an image, performing a video-call).

The PPDR-TC research community then proposed to perform a set of simulations, tests and field trials to gather the evidence necessary to identify the pros and cons of each architectural approach researched in the project. This brings us to the current scope of Work Package 5:

'To capture the core results of the simulations, tests and field trial activities performed under the scope of the PPDR-TC project, to support a set of recommendations directly derived from the different architectural options studied in the scope of this project'.

To summarise, Work Package 5 presents and discusses, from a performance perspective the results of the end-to-end simulations for end user services as well as the results of the undertaken field-trials. However, the result analysis also took into account aspects such as the network resilience, interoperability and overall deployment strategies. More specifically, WP 5 aimed at organizing and documenting the evidence that the objectives of the activities carried out within the PPDR-TC project have been successfully achieved. The following are the objectives for the WP5 activities that were achieved:

- Investigation and analysis of the System Boundaries and Equipment
- Investigation and analysis of the "Global" network architecture of PPDR-TC with respect to the PPDR scenarios
- Simulations into PPDR-TC Simulator of the whole network architecture including core network – incident network and team / personal area network interconnections based on defined PPDR scenarios
- Performance analysis of end-to-end services (achievable QoS, latency, jitter, throughput) for the different PPDR scenarios through network simulations

- Assessment of the proposed architecture and identification of candidate solutions with respect to the PPDR user needs and requirements

Within each operation scenario devised in Work Package 5, several communication paths were considered as having good potential to fulfil the communication needs of the PPDR end users. To assess the performance of these communication paths, simulation models were designed to be (as much as possible) representative of each operational scenario. In addition, all simulations models also considered the utilisation of three principal types of applications, identified as the most important for PPDR end user operations: VoIP applications, video streaming and web based application. Furthermore, the simulation models also considered that the utilisation of the network resources would occur with different levels of background traffic. Results have been computed for several levels of background traffic ranging from 10% to 50%.

This work package also assessed the performance of some available technologies using field trails. Field trials using a broadband IP based MESH network have been performed under a scenario that falls into the "Planned" or "Unplanned/Disaster" PPDR-TC scenario categories. The field trials using this technology demonstrated that ad-hoc MESH networks deliver good performance with reduced deployment costs, especially in harsh terrain conditions like mountains or tunnels. However, for "Day-To-Day" operations the results presented, provide strong evidence that better alternatives are available.

To ensure that the architectural options, considered by the PPDR-TC research community, are compatible with other research efforts, several EU projects were studied, namely the Hit-Gate, ISITEP and GERYON projects that mainly address the important problem of connecting existing first responder communication systems.

The final area investigated in Work Package 5 was deployment, spectrum, and interface flexibility without the need for SDR. The flexibility of SDR was considered in periods 2 and 3 for realistic terminals/ radios. The conclusion from this, was that pursuit and e-greedy are based on a learning algorithm; they therefore need time to learn the most appropriate parameters. Once trained, their performance is often on par or even better than the experimental optimal value strategy represented by Fixed-best. Another advantage is that even when those strategies are trained, they continue to explore the solution space, being able to cope with the non-stationarity of the contact process that rules the opportunistic diffusion.

The principal overall conclusions of the tasks reported in Work Package 5 were collected in the form of recommendations to the PPDR end-user community. These recommendations then provided input to further work carried out in the scope of work package 6.

The main recommendation for "Day-To-Day" operations addressed the utilisation of the LTE based technologies. However, because the standardization work on LTE technologies is still ongoing, that recommendation is only be applicable on mid to long term basis. Other technologies such UMTS and WiMAX although not as flexible as LTE, may provide the performance levels required by the PPDR end users in the short term.

For the "Planned" operations and "Disaster" scenarios, the recommendations were not so obvious because the undertaken simulations showed that the requirements for these scenarios are too demanding for achieving good QoS for all three types of applications. Nevertheless, focusing on the VoIP services alone, we reached to the conclusion that LTE (with SATCOM backhaul) or WIMAX are good approaches for scenarios with a number of users below 600. For other services, namely video streaming, broadband IP based MESH networks showed good performance, so is probably a better choice for this type of applications in "Planned"/"Disaster" scenarios.

More specifically, the following recommendations were documented:

**RECOMMENDATION 1**

LTE AS A ROUTINE OPERATIONS COMMUNICATION SYSTEM

LTE is recommended as the future de-facto Wireless Technology for PPDR communications in "Day-to-Day" routine operations.

As clearly demonstrated by the results of the simulations performed in the scope of this activity, LTE is perhaps the most promising Wireless Technology to address the majority of PPDR communication requirements. Furthermore, the PPDR topic is now being addressed in the main standardization bodies, such as ITU and 3GPP, which is a clear sign that in a near future the LTE technology will be a strong competitor to other systems which are now currently in use, such as TETRA. There are even some systems based on LTE available but they are based on proprietary solutions.

**RECOMMENDATION 2**

RESILIENCE CAPABILITIES OF DEPLOYABLE AD-HOC LTE NETWORKS

These recommendations apply to *major planned event* and *unplanned event* scenarios.

Usually, infrastructure-based systems are not redundant and, in general, they are vulnerable to disasters and subsequent incidents. Unfortunately, the same may hold for ad-hoc networks that are deployed in the mission area.

The following is PPDR-TC proposal to improve resilience capabilities of deployable ad-hoc LTE networks:

- Usage of MultiPath TCP for the reliable delivery of data, instead of the more common single-flow TCP variants.
- Dynamic, ad-hoc and remote (e.g. PPDR mission headquarters) reaction to anomalous network events through Software-Defined Networking.
- Architectural choices and architecture layout able to implement redundancy.

**RECOMMENDATION 3**

IMPROVEMENT OF END-TO-END PERFORMANCE OF NETWORKS COMPOSED BY LTE BASE STATIONS BACKHAULED BY SATELLITE CHANNELS

These recommendations mainly apply to *unplanned event* scenarios.

The usage of satellites as backhaul mediums implies that QoS may be strongly affected by TCP, known to perform badly when employed on links with high propagation delay.

We propose the following to improve the end-to-end performance of networks composed by LTE base stations backhauled by satellite channels:

- Usage of TCP variants optimised for high Bandwidth-Delay Product links, like TCP Cubic or TCP HighSpeed
- Perform a centralised control of the network resources through specific tools (ECN, GWA, C2ML+, PINK).
- As last resort, employ PEP-like solutions.

For better resilience it is recommended that all truck-based mobile command and control centres should be equipped with a backup satellite link.

**RECOMMENDATION 4**

USAGE OF WI-FI NETWORKS

Wi-Fi networks, although quite common and easy to deploy may not provide the necessary flexibility to address the PPDR-TC end user requirements, namely under scenarios with a large number of users.

As presented, if the number of users is kept low (below 20), the performance may be adequate.

**RECOMMENDATION 5**

USE OF WIMAX NETWORKS

WiMAX networks are not as common as Wi-Fi networks but may outperform the Wi-Fi networks in bandwidth and also coverage. So their utilisation is recommended as a mechanism for backhaul connectivity.

Wi-Fi-WiMAX does not cope very well with scenarios with a large number of users. However, if the number of users is below 50, this network may delivers better performances than solutions based in LTE and SATCOM.

**RECOMMENDATION 6**

USE OF MESH NETWORK

The utilisation of broadband IP based MESH networks is recommended for situations where communication infrastructure is not available, terrain does not facilitate the deployment of communication infrastructures and the number of users is below 20. Furthermore, its usage is also recommended for operations under tunnels or for providing communication in vehicle convoys.

### WP6 - Recommendations for Future PPDR Systems Evolution and Standardisation

Based on inputs from WP4 and WP5, PPDR-TC consortium elaborated recommendations for different levels of decision-makers, including national member state procurement administrations, CEOs of industrial companies, ministries, operators, regulators, emergency services, and standardization bodies. Task T6.1 aimed at gathering all potential recommendations in the technical-economical domain identified thanks to outputs from WP4, and WP5, while Task T6.2 focuses on the transition roadmap from current PPDR networks to next generation (infrastructure, funding model, narrowband-broadband transition). Finally, T6.3 focused on the identification of standardisation opportunities and reporting on PPDR-TC impact on standardisation bodies. At the end of WP6, an interactive web application has been developed in order to illustrate the PPDR-TC transition roadmap and present the results to the targeted audience (end-users, industries, procurements, etc …).

#### *Task 6.1: Analysis of technical/economical recommendations for future PPDR systems*

This task T6.1 aimed at gathering all potential recommendations in the technical-economical domain expressing the necessary guidelines for the future PPDR systems. The task started on month M18 and produced its first results during the 2nd reporting period.

During the third reporting period, and now that full results from WP4, and WP5 are available, consolidated recommendations were emitted and presented in Deliverable D6.1. Each recommendation is developed in Deliverable D6.1 thanks to the following parameters:

- **Context of the recommendation**: describes where and in which use-case scenario it is considered relevant

- **Motivations for the recommendation**: provides a rationale behind the recommendation. Typically the recommendations address a specific issue not yet addressed by State-of-The-Art, or an issue partially resolved but considered too far from optimal
- **Propositions**: technical or economical proposal to solve the aforementioned issue
- **Target:** to which entity or entities the recommendation is addressed. If a standardization body is targeted, a specific working group is identified
- **Timeline:** whether the recommendation relates to the short-term, mid-term, or long-term
- (Optional) **Economic:** impact of the recommendation on TCO, CAPEX and OPEX from the procurement/operator perspective. Only presented when applicable.
- (Optional) **Cross-references to other recommendations**

The following table summarise the key recommendations introduced thanks to Task T6.1.

| Code | Recommendation title | Targeted organisations | Timeline for implementation |
|---|---|---|---|
| **WTC1** | Wireless technologies combination for PPDR communications | National Regulators; procurement groups | Short to medium-term |
| **WTC2** | Usage of a single wireless technology for PPDR communications | National Regulators; Standardization Bodies; industries; PPDR agencies | Medium to long-term |
| **WTC3** | Deployment of Mobile Ad hoc Networks technologies for high demand PPDR communications | National Regulators; procurement groups | Short to medium-term |
| **EP1** | Hybrid MNO/MVNO business models | PPDR agencies (national and regional levels); MNOs with deployed LTE networks | Short-term |
| **EP2** | Recommendation EP2: MVNO business models | National Regulators; MNOs with deployed LTE networks | Short to long-term |
| **EP3** | Differentiated Quality of Service (QoS) for PPDR users using commercial networks | PPDR agencies | Short-term |
| **EP4** | Coexistence with existing networks | PPDR agencies | Short to long-term |
| **EP5** | Other Economic & procurements recommendations | PPDR agencies | Specific to PPDR needs |
| **SR1** | PPDR spectrum allocation based on “flexible harmonization” | National Regulators / Procurement groups. | Short to medium-term |

| Code | Recommendation title | Targeted organisations | Timeline for implementation |
|---|---|---|---|
| **SR2** | Identify harmonised frequencies for Device-to-Device and Air to Ground Communication | National Regulators / CEPT. | Short to medium-term |
| **TC1** | Rapidly deployable resilient MESH networks | Network operators; PPDR procurement groups; System integrators; Vendors | Short to medium-term |
| **TC2** | Rapidly deployable WiMAX networks | PPDR procurement groups; system integrators | Short-term |
| **TC3** | Resilience capabilities of deployable ad-hoc LTE networks | Network operators; system integrators | Mid-term |
| **TC4** | Resilience capabilities of deployable ad-hoc LTE networks (Transport Protocols) | Network operators; system integrators | Short-term |
| **TC5** | Resilience capabilities of deployable ad-hoc LTE networks (SDN) | Network operators; system integrators | Short to mid-term |
| **TC6** | Improvement of end-to-end performance of network composed of LTE base stations with Satcom backhaul | Network operators; system integrators | Mid to long-term |
| **TC7** | Recommendation TC7: Joint Device-to-Device (D2D)/Multicast for Push-to-Data services in LTE | PPDR network manufacturers, System integrator, PPDR system operators | Short to mid-term |
| **TC8** | Recommendation TC8: Mobile Cellular Ad-hoc LTE | Standardization body targeted: 3GPP Isolate E-UTRAN work item (IOPS); PPDR system integrators | Mid-term |

**Table 3: Key recommendations**

### *Task 6.2: Roadmap for migration path towards full compliance to PPDR requirements*

Task T6.2 associated D6.2 deliverable aimed at presenting the roadmap for migration path towards full compliance of PPDR requirements using outcomes from PPDR-TC WP2, WP3, WP4, WP5 and WP6.1. The resulting roadmap presented in Deliverable D6.2 provides the end users with a summary of the potential technologies available in relation to capacity & coverage, funding, investment cycle conditions, expiry dates of existing commercial agreements and operational and technical requirements. In order to reach a final stage where broadband networks fully replace existing PPDR communication technology, the PPDR communities need to undertake a set of steps to allow a consolidated evolution that will not compromise their operational capability and, very importantly, with reduced economical risk. The PPDR-TC research community refers to these steps as the "**roadmap towards the adoption of a broadband PPDR communication network**". A future broadband network would not only comply with the current PPDR

capabilities but would also support broadband services (e.g. real-time video streaming), which are becoming important catalysts of the PPDR operations efficiency and effectiveness.

The PPDR-TC researchers' vision for the short term (5 years from now) considers the use of the LTE services to accommodate broadband services. The medium term vision depends on the establishment of an LTE standard for mission critical voice communication over LTE. Therefore, in the medium term 10 years from now, the existing TETRA system will be close to their end of life and their operation is ensured, not by refurbished TETRA technology, but rather by the adoption of LTE based solutions which are capable to interoperate with existing TETRA infrastructure. Finally, the long term vision, i.e. the scenario envisaged in 15 years from now, assumes that the LTE mission critical capabilities is now a mature technology and has surpassed the rigorous scrutiny of the end user daily utilisation for all possible scenarios, over the most remote regions. By then LTE has slowly but reliably replaced TETRA technology as TETRA systems naturally became obsolete and incapable of delivering the prominent need for broadband services.

Deliverable D6.2 presents a description on the major milestones of the proposed roadmap to be undertaken by the PPDR-TC community to reach a full-fledged broadband PPDR network: **initiation phase, transition phase, LTE rollout**. Then it is presented a discussion on the recommended business models for the implementation of a broadband PPDR network: **PPDR owned network, MNOs LTE networks, MVNO**. Additionally, the consortium also provides recommended solutions for other operational scenarios that require a punctual re-enforcement of existing wireless capabilities. Finally, a list of **risks and pitfalls** is elaborated that may impact the implementation of the general guidelines. A number of Country specific case studies have been included in the appendices of D6.2.

During the execution of the task, it was clear that individual countries and PPDR agencies will have specific limitations directly affecting the path they choose to meet the needs of their broadband requirements. This level of analysis will assist end users to make a better informed decision over the short, medium and long term. The identified options for migration roadmaps are illustrated thanks to a web-application.

**Web-application: illustration of the migration path to broadband PPDR**

In order to visualize and, hence, allowing for better and easier understanding of the PPDR-TC generic migration path to broadband PPDR communications networks, a web-based application has been developed. The application presents in a graphical form a roadmap for development of PPDR communications systems based on the evolution scenario depicted in the figure below. It introduces three dimensions of the roadmap for upgrade of PPDR networks towards broadband.

The first dimension introduces mobility vs. capacity. It is shown for different technologies including TETRA, UMTS, HSPA, and LTE/LTE-Advanced. The demand for higher speed services will limit the number of users that can be supported. As can be seen, for all technologies except for TETRA, increased users' mobility limits the instant throughput. The instant throughput also depends on the distance of the mobile from the base station.

The second dimension adds timeline and an important factor influencing evolution path, i.e. standardization of LTE to support critical communications through relevant services – Group Communication and Mission Critical PTT ones. It shows also the first step on the roadmap –setting up of a PPDR organization as a MVNO based on many 4G hosts. Moreover, own TETRA/TETRAPOL networks can remain in use and 3G/4G broadband services can still be provided by CMNOs as it is currently common situation.

The last dimension introduces on the timeline a span related to gradual release of frequency bands for PPDR mobile communications within the digital divident. As the bands become available to PPDR organizations, the second and the third step in the migration path can appear. In the second step PPDR organization

becomes MVNO/MNO with partly shared/partly dedicated commercial/own RAN networks. Finally, in the third step PPDR becomes MNO with dedicated radio channels in both commercial and own RAN networks.

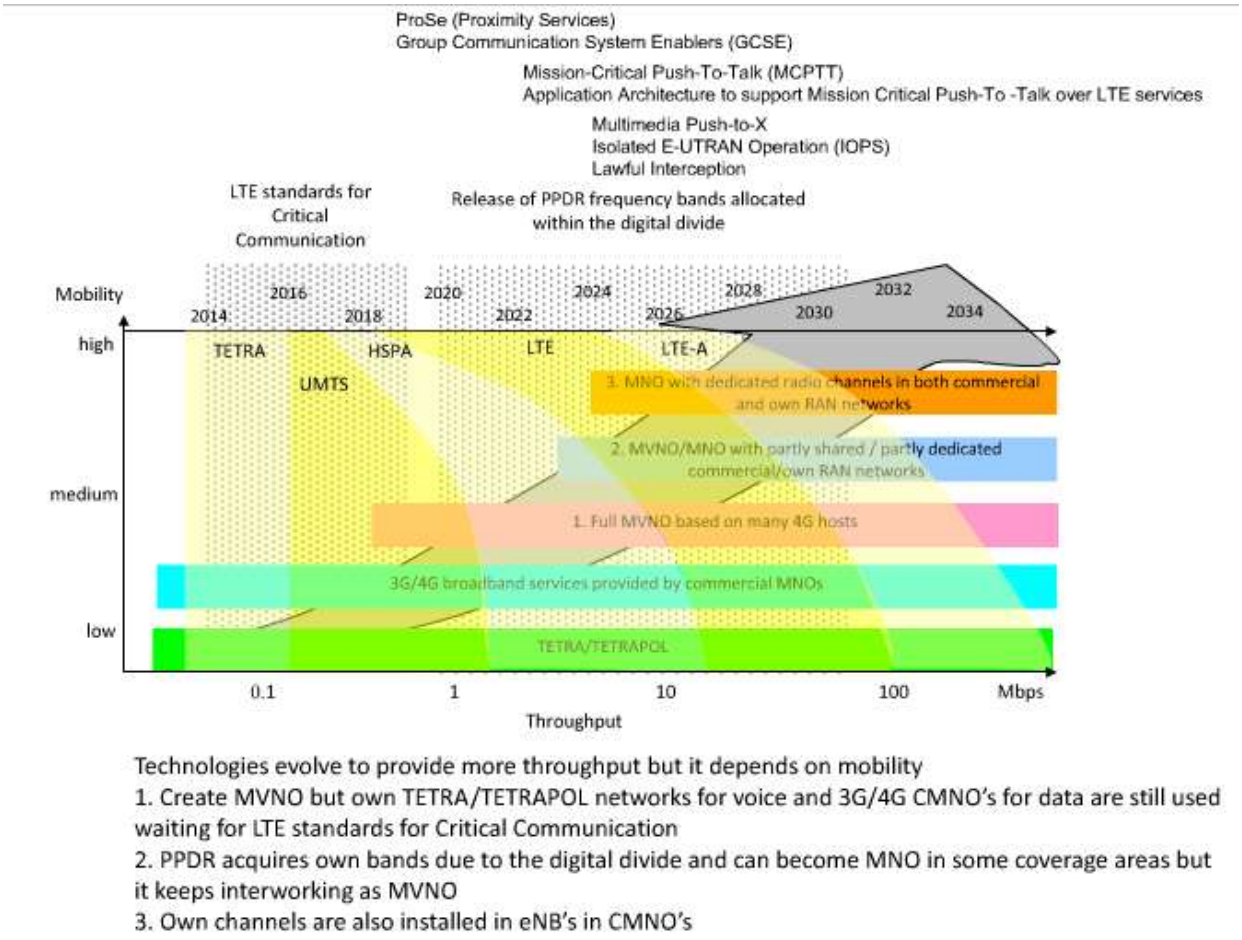


**Figure 3. Illustration of the migration path to broadband PPDR**

An effort has been made aiming at presenting the roadmap in a simplified, yet clear and intuitive manner to allow the user/stakeholder acquiring good vision of what is expected in the future for PPDR systems, and concludes the work performed by the PPDR-TC consortium in task T6.2.

### *Task 6.3: Recommendations for PPDR standards and European decisions-makers*

The work performed in this task T6.3 aimed at:

1. Identifying the standardization bodies, national regulators and stakeholders which can be interested in PPDR-TC recommendations

2. Prepare technical contributions resulting from PPDR-TC project to impact on-going standardization efforts related to PPDR broadband communication networks and applications

Standardization bodies can use recommendations in order to create or support standards. The next table summarizes the PPDR-TC recommendations assignment based on the profile of the standardization bodies and their internal workinggroups. The recommendations can be addressed to the contacts of the responsible of the standard organization sub group targeting possible meetings of the correspondent organization.

| | WTC | TC | EP | SR |
|---|---|---|---|---|
| ITU / ITU-R | | | | |
| SG5 WP5A | ✓ | ✓ | | ✓ |
| SG5 WP5D | ✓ | ✓ | | |
| CEPT | | | | |
| FM-49 | | | | ✓ |
| SE-7 | | | | ✓ |
| ECC-PT1 | | | ✓ | ✓ |
| ETSI | | | | |
| BRAN | ✓ | ✓ | | |
| CABLE | | | | |
| EMTEL | | | ✓ | |
| ERM | | | | ✓ |
| RSS WG4 | ✓ | ✓ | | ✓ |
| SES WG SatEC | | ✓ | | |
| TCCE | ✓ | | ✓ | |
| 3GPP | | | | |
| TSG-SA6 | ✓ | ✓ | ✓ | ✓ |
| EU RSC | | | | |
| RSC | | | ✓ | ✓ |
| OMA | | | | |
| OMA PoC | ✓ | ✓ | ✓ | ✓ |

**Table 4: PPDR-TC recommendations' assignment to standardization bodies (Wireless technology compliance recommendations (WTC), PPDR network technical characteristics recommendations (TC), Economic & procurements recommendations (EP), Spectrum recommendations (SR))**

High-priority was given to impact 3GPP as it was considered to be the most active body related to the topics covered by PPDR-TC project, especially #SA6 Working-Group. At least 2 people from the standardisation team of TCS (TCS is a contributing member of 3GPP) attended 3GPP SA6 meetings proposing studies or contributions in order to help the definition of Mission Critical Push to Talk (MCPTT). During the first 3GPP #SA6 meeting that occurred in the beginning of 2015, the work was focused on Technical Specification TS 22.179: Mission Critical Push to Talk (MCPTT), Release 13, stage 1, document providing the service requirements for operation of the MCPTT service. MCPTT makes use of capabilities included in Group Communications System Enablers for LTE (GCSE_LTE) and Proximity Services (ProSe), with additional requirements specific to the MCPTT service. The work performed in PPDR-TC WP2 and WP3 has been exploited in order to push relevant use-cases and requirements inside the document.

## PPDR-TC anticipated impact

The project is anticipated to significantly impact the Critical Communications domain, and society in general, in various ways as illustrated below.

1. **Reaching the European PPDR community and reinforcing the awareness and the involvement of PPDR end-users**

The PPDR-TC project aims at increasing the efficiency of communications infrastructure by the enhancement of new communication technologies in order to achieve interoperable, secure and resilient communication, tailored specifically for the future needs of the PPDR community. Following this vision, the integration and participation of end-users, with specific knowledge in public safety issues, played a key role in the development of PPDRs, while making the project's goals more concrete.

The PPDR-TC project was committed to link at the European level with stakeholders interested or directly involved in PPDR. The project consortium planned to achieve a strong PPDR community awareness and involvement through the following initiatives:

- The enhancement of consultancy group of the project by the involvement of many PPDR stakeholders.
- Disseminating the project results to The Public Safety Communications Forum Europe (PSC-E)
- The participation in specialized PPDR working groups, fora, presentations and publications of white-papers targeted at key-focus groups involved in PPDR, outlining PPDR-TC analysis of future PPDR systems, communications and services evolutions.

Towards this goal the project has achieved significant advances by:

- Exploiting a large pool of involved end-user organizations (33 Organizations participated in requirements elicitation, workshops, questionnaires, deliverables reviewing)
- Participation in various end-user driven events (PSCE meeting, RCEG meeting, European Civil Protection Forum)
- Organization of 2 end-user driven workshops with the participation of more than 18 different organizations

**2. Impact on current and future PPDR standardisation**

The PPDR-TC consortium planned to provide additional feedback to the already existing European standards in order to achieve the following goals:

- To ensure communication systems interoperability
- To ensure broadband connectivity
- To ensure a common PPDR reference
- To provide neutral and independent platform of all interested partners
- To give the research outputs a wider transparency, visibility and availability

Towards these goals, high-priority was given to impact 3GPP as it was considered to be the most active body related to the topics covered by the PPDR-TC project, especially #SA6 Working-Group. At least 2 people from the standardization team of TCS (TCS is a contributing member of 3GPP) attended 3GPP SA6 meetings proposing studies or contributions in order to help the definition of Mission Critical Push to Talk (MCPTT).

In addition, the work performed in WP2 and WP3 of the project has been exploited in order to push relevant use-cases and requirements inside the Technical Specification TS 22.179: Mission Critical Push to Talk (MCPTT), Release 13, stage 1 document.

Finally, a number of recommendations were produced by PPDR-TC members, while the relevant standardization bodies and/or policy makers for addressing these recommendations in the future have been already identified (D6.3).

**3. Elaborate, simulate and test new approaches in the domain of techniques, protocols and services that ensure interoperability, integration and interconnection among different professional and public radio systems**

Towards this goal, a number of simulation models and tools were implemented to test new broadband communication approaches that are expected to be used by the scientific and manufacturing communities. In addition, proposals for new architectural models have been elaborated that are expected to help decision

makers to plan for future migration to broadband networks. Combined with very strong dissemination actions performed during the whole duration of the project it is anticipated that this work is sufficiently communicated to relevant stakeholders and can further impact the different approaches that will be followed in future implementations.

## 4. Empowering stakeholders (decision makers, end-users) with tools that facilitate their role

To facilitate the role of various stakeholders (decision makers, end-users), PPDR-TC has developed a set of tools that can further impact the Critical Communications community during and (mainly) after the project ending.

a. Facts and figures Database

PPDR-TC project established a PPDRs Facts and Figures statistical database containing basic data related to PPDRs (e.g., police forces and first responders) covering, at least, the following information fields:

- Name (in English)
- Type (e.g., Police, Fire-brigade, Civil Protection)
- Member state
- Number of people
- Number of people involved in field operations (with wireless communication needs)
- Number of national events
- Number of national cross organization events
- Number of cross border events
- Number of external EU event
- Generic crime statistics figures
- Security indicators and trends (e.g., socio-economic data, unemployment rate)
- Communication scenarios
- Future services and requirements of the end users
- Available PPDR communication solutions
- Linkage of services and requirements with available telecommunication infrastructures
- Technology gaps
- Classification of services and requirements to near, medium and long term evolution
- Contact point information on each entry
- Number of base stations allocated at each technology used per organisation.
- Vendor name(s) used for each technology.
- Type of operation
    - User Owned – User Operated (UO-UO): Building, ownership & operation of the network(s) by the end-user agency (or agencies) themselves.
    - User Owned – Commercial Operated (UO-CO): Build & ownership of the network(s) by the end-user agency (or agencies). Operation of the network(s) by a commercial provider of outsourced managed network services.
    - Commercial Owner – Commercial Operated (CO-CO): User agencies subscribe for services provided by a commercial network owner / operator.)

The database is following a client-server architecture, providing a front-end with advanced capabilities of searching and retrieving data as well as a back-end mainly offering storage of data and mechanisms for data correlation. Access rights with different levels of authorization were identified focusing on three distinct system roles (Simple user, Contributor, Administrator).

The database was comprehensively presented to the participants of the PPDR-TC end-users workshop performed in London on June 2015, while almost one third of the questionnaire prepared for collecting end-users feedback was dedicated to the database. The recommendations collected from the workshop have been taken into account and multiple updates on the database occurred since then.

In addition, the database was also disseminated in multiple other major events (eg Critical Communications World 2015), where access codes were provided to various end-users that visited the PPDR-TC dedicated booth.

To assure the database sustainability, mainly for reasons that have to do with trust of the PPDR organizations to the hosting entity, it is foreseen that the hosting and maintenance of the database will be handed over to another (public) organization, assisting as such the whole PPDR community that will gain access to this valuable source of information.

b. Toolbox for multi-domain analysis

The toolbox for multi-domain analysis in the process of acquiring new PPDR telecommunication systems has been developed within the PPDR-TC project. The toolbox offers to a user (decision maker) the possibility of performing comprehensive analysis that takes into account telecommunication techniques, communication services, financing and business models, as well as economic expectations. Such multi-level analysis will help decision makers to select a PPDR telecommunication system that best fits to their functional and business requirements.

The toolbox provides technical, financial, economic and organisational analysis. It is made up of four components:

- Main application – the spreadsheet workbook "model_PPDR_TC"
- Tool for radio coverage planning
- Tool for multi-criteria decision analysis
- Visualization of organizational aspects of PPDR communication system

The analysis that the main tool "model_PPDR_TC" offers, is carried out on four levels:

- technical – by indicating the functionalities of the system,
- financial,
- economic – through financial-economic analysis,
- organisational – through the allocation of investments and costs associated with the system, which can be segregated into three categories: owner, operator and user.

The tool integrates different levels of analysis on the basis of a trade-off between the end-user's requirements and available funds. Spreadsheet workbook implements *bottom-up* and *top-down* analysis. Bottom-up analysis delivers a set of financial-economic factors for assessment of business efficiency of a model. Top-down analysis adjusts the value of parameters (e.g. size of system, number of terminals, number of base stations, number of years of investment) for assumed maximum expenses. The analysis results are presented as a report for each of the selected configurations of the system that is planned to be acquired by PPDR organizations. The report presents the results in the form of quantitative and qualitative data, shown as tables and charts. The report provides the following information:

- main information about the configuration of the system:
  - system description,
  - size of system (including expected coverage, number of infrastructure components, etc.),
  - system functionalities,

- financial data and aggregated/break-down/efficiency indicators (e.g. TCO[1], CAPEX[2] and OPEX[3] in years, NPV[4], IRR[5]),
- economic data and aggregated/break-down/efficiency indicators (ENPV[6], EIRR[7], B/C[8], DGC[9]),
- results of organisational analysis,
- SWOT analysis.

The tool also allows for a comparison of the results for different configurations of the planned system and the results are presented in comparative tables and charts to allow for benchmarking.

The objective of the radio coverage planning tool (RCP) is to provide the number of base stations for considered system(s) in a given area based on terrain's form and resulting from the radio propagation characteristics. The importance in accurate calculation of the optimal number of base stations required in a given area originates from the fact that this parameter is a significant factor influencing financial indicators and overall cost of acquiring a new wireless communication system. The tool employs popular and recognized in the radio planning community SPLAT! software.

Multi-criteria decision analysis (MCDA) tool deals with multiple criteria that need to be considered in decision-making on acquiring new PPDR communication systems. As an example the following criteria can be listed: OPEX, TCO, threats, frequency band, opportunities and voice services. It is evident that well structuring complex problems and taking into account as much as possible criteria explicitly leads to more informed and better decisions. Therefore, the elaboration of the toolbox's component that performs MCDA is very important for decision-makers as it offers better comparison capabilities through more accurate analyses performed for various competing scenarios. For its development, the MCDA tool employs *R* – a free software environment for statistical computing and graphics.

Visualization of organizational aspects of PPDR communication system(s) allows having a quick and concise overview of the allocations of PPDR agency and, if applicable, other entities into three roles: infrastructure owner, system operator and the end-user, for an investigated scenario. It also presents key financial, economic and technical data and expenditures to acquire and operate/manage/maintain the system obtained from the analysis of a selected acquiring scenario.

The toolbox is available to interested stakeholders under licence agreement with its developer – ITTI Sp. z o.o.

c. Visualization tool for roadmap towards the adoption of a broadband PPDR communication network

The project outcome also includes elaboration of the roadmap for future development of PPDR broadband networks. There are a few dimensions that can be identified in this roadmap. They are as follows:

- evolution of mobile technologies (TETRA, UMTS, HSPA, LTE, LTE-Advanced) along time scale,
- throughput vs. mobility for different technologies,
- time scale for two 3GPP releases that have different levels of suitability for PPDR communication meeting a series of end-users' requirements to provide following services:
    - ProSe (Proximity Services),
    - Group Communication System Enablers (GCSE),
    - Mission-Critical Push-To-Talk (MCPTT),

[1]TCO – Total Cost of Ownership
[2]CAPEX – CAPital EXpenditures
[3] OPEX – OPerating EXpenditures
[4]NPV – Net Present Value
[5]IRR – Internal Rate of Return
[6]ENPV – Economic Net Present Value
[7]EIRR – Economic Internal Rate of Return
[8]B/C – Benefits to Costs ratio
[9]DGC – Dynamic Generation Cost

  - Application Architecture to support Mission Critical Push-To -Talk over LTE services,
  - Multimedia Push-to-X,
  - Isolated E-UTRAN Operation (IOPS),
  - Lawful Interception,
- current status of deployment of existing private and public networks including different technologies (TETRA/TEDS, 3G/4G) and different models (own/leased networks),
- three-stage evolution of broadband PPDR networks based on different business models that comprises:
  - full MVNO based on many 4G hosts,
  - MVNO/MNO with partly shared and partly dedicated commercial and own RAN networks,
  - MNO with dedicated radio channels in both commercial and own RAN networks.

In the consortium's opinion the elaborated roadmap is the most likely path of the evolution which end-users and decision makers can expect in the near future. This migration may be headed into another direction if political (e.g., at EC level) or technical (e.g., within 3GPP) circumstances or opportunities appear. They might also result from national strategies or constraints to balance or at least minimize expenditures, yet keeping in mind that safety and security requirements are of the highest priority.

The roadmap has been delivered as a web diagram available on the PPDR-TC webpage to visualize and disseminate it to interested stakeholders.

**5. New opportunities could be created for private companies operating in the domain of communications and consultancy services in terms of new services-products**

The wide spread of PPDR-TC produced outcomes is foreseen to impact the relevant ecosystem built around the critical communications community. Among the results produced within the project that are publicly available are the elaboration of mission critical communication requirements, the currently existing gaps as well as the roadmap towards the adoption of future PPDR communication technologies. This information can prove to be a decisive factor in the evolution of large industrial vendors and SMEs, in terms of facilitating their strategy towards the development of new relevant products/services.

**6. Economic impact**

PPDR-TC is anticipated to have economic impact as well to the critical communications ecosystem, basically due to the adoption of several projects' outcomes. This will be mainly achieved by improving the decision making process of key actors in this ecosystem. More specifically:

a. Techno-economic tools can facilitate stakeholders in cost-efficient decision making.

b. More focused research and productization is expected towards covering real end-users needs and gaps.

c. A widespread adoption of the facts and figures database can facilitate interaction among different EU PPDR organizations and lead to more informed decisions by decision makers on potential migration of legacy critical communication systems to broadband solutions.

d. Rationalization of public investments on critical communications and respect to tax payers is foreseen.

**7. Scientific impact**

The project is anticipated to also impact the scientific community. This can be achieved basically due to the fact that:

a. PPDR-TC results can be the basis for further research activities on the field of PPDR communication technologies (e.g. future H2020 funded projects, 5G research)

b. The simulation models that have been developed and the numerous publications in peer-reviewed conferences proceedings and journals may boost further technical research in the related domains

**8. Social impact**

Strengthening the decision making process for civil protection organisations may result in future optimisation of their critical communications networks. Broadband Communications and next generation of PPDR services can potentially improve the capability of saving lives especially in cases of major disasters. This may indirectly affect the European citizens in need, since they will potentially be served by PPDR agencies capable to respond in a quicker, more effective, more coordinated and more efficient way.

## PPDR-TC Dissemination highlights

All in all, the entire dissemination plan prepared since the project start and strategically updated and followed throughout the project's course is considered fully successful. Not only had the project managed via the strong engagement of the entire consortium to raise awareness across a wide and diverse Consultancy group of stakeholders, but it has attracted attention and most importantly diffused its results, thus enabled knowledge exchange, across a large European – and not only – audience of PPDR related authorities and organisations. This has been achieved through a plethora of dissemination and communication activities carried out by all partners that targeted relevant agencies, industry, research and academic bodies as well as the general public. Such activities are summarized below, under three categories, Stakeholders activities, Awareness actions and Workshops/Conferences, to inform the reader on the dissemination means utilised, their context and major results:

A. Stakeholders activities

1. The PPDR-TC consortium created a large Stakeholders Consultancy Group comprised of 33 members in total. The Group brings the consortium various aspects of expertise and knowledge as their profiles span from typical end users such as civil protection agencies to industrial members, SMEs, spectrum providers and regulators. The activities carried out involving the Group have been a) completion of several questionnaires to shape project's progress and validate results via their feedback, b) participation in 3 PPDR-TC workshops (2 local and 1 Pan-European) to better understand the project and interactively discuss and brainstorm on PPDR communications important topics, c) review of final project's deliverables on recommendations and PPDR roadmap to grasp their views on how results are useful to be presented and their value to relevant organisations and d) offer of major project's results and tools to benefit end users and facilitate their needs.
   As the consortium intends to make all necessary efforts continuing interaction with the end-user community, all relevant stakeholders are warmly invited to contact either the Project Coordinator – Dr. Dimitris Kanakidis (dkan@exus.gr) or the Dissemination Manager – Dr. Angelos Amditis (A.Amditis@iccs.gr) should they wish to obtain project's results and tools, establish links with all or selected consortium partners and mutually exchange their views on PPDR communication status in Europe and worldwide.

B. Awareness Actions

1. Creation and maintenance of the official project website - http://www.ppdr-tc.eu; in which visitors can retrieve all public material generated by the project. Interestingly the reader may retrieve all public deliverables following this link: http://www.ppdr-tc.eu/en/index.php?about=39

2. Production and wide distribution of the project's leaflet to all events in which consortium partners participated. The reader may find the leaflet in the following link: http://www.ppdr-tc.eu/PPDR%20LEAFLET_v15_Hires.pdf .
3. Production and wide distribution of the project's poster to all events in which consortium partners participated. The reader may find the poster in the following link: http://www.ppdr-tc.eu/POSTER_PPDR_TC_A0_FINAL.pdf .
4. Issuing and distribution of 2 Newsletters through the stakeholders' consultancy group and individual partners' contact lists to inform PPDR-TC project followers on consortium's updates. The reader may find the newsletters in the following links: http://www.ppdr-tc.eu/en/singlenews?nid=25 & http://www.ppdr-tc.eu/en/singlenews?nid=28
5. Promotion of the project through EU channels since a project prospectus was included in the EU 2013 & 2014 Security Research Projects Catalogues - http://ec.europa.eu/enterprise/newsroom/cf/itemdetail.cfm?item_id=6296&lang=en
6. Clustering and liaison activities with 10 EU funded security project and standardisation bodies to exchange knowledge diffuse results and push for adoption of PPDR-TC recommendations with respect to future PPDR broadband communication networks. The reader may find all relevant liaison audience in the following link: http://www.ppdr-tc.eu/en/useful-links
7. Promotion and exhibition of the PPDR-TC project facilitating interaction with a large portion of the PPDR end user community globally through participation – inter alia – in 5 prestigious events of high visibility within the PPDR market. These events are a) Security and Policing, Farnborough, UK on March 2015; Counter Terror Exhibition and Conference, London, UK on April 2015; 5th European Civil Protection Forum, Brussels, Belgium on May 2015; 17th Annual Critical Communications World & TETRA World Congress, Barcelona, Spain on May 2015 and European Researchers' Night, Modena, Italy on September 2015. The reader may find all relevant info on the above events as well as on significant events of lesser magnitude in which the PPDR-TC project was promoted, in the following link: http://www.ppdr-tc.eu/en/news

C. Workshops/Conferences

1. Organisation of the PDDR-TC Final End Users Workshop in London on 18th of June attracting 17 different organisations that belong to the end-user community. The scope was to present the key findings of the Consortium and provide an opportunity for PPDR end-users and other stakeholders to discuss their experiences and concerns. In addition to presentations by the project's partners, there were two keynote speakers representing the regulatory and end-user communities. The reader may find more details of the workshop and retrieve all presentations in the following link: http://www.ppdr-tc.eu/en/singlenews?nid=27
2. Organisation of 3 international scientific workshops in the framework of IEEE WiMob 2014, IEEE WiMob 2015 and EuCNC 2015 that strongly promoted the project acknowledging in parallel its significance with respect to the research work conducted by the consortium. In addition, the abovementioned workshops gave the opportunity to closely interact with the global scientific community involved in the PPDR communication networks domain. The reader may find more details of the workshops and retrieve in the following link: http://www.ppdr-tc.eu/en/news
3. Publication of 21 scientific papers in conference proceedings and 5 journal papers (whilst 3 journal papers are currently submitted and under review) to witness strong impact and the importance of the results of the PPDR-TC project within the scientific community.

Even though the project ended the PPDR-TC consortium remains committed to carry on several actions in the successful dissemination, communication and awareness track already established. In this context, the PPDR-TC consortium respecting the EC recommendations that showcase the potentials of project's outcomes shall perform as minimum the following activities in the near and medium term future:

- The PPDR-TC Website - http://www.ppdr-tc.eu/ - will be maintained by EXUS for at least 5 years after the project end envisioning to be the main access point for all interested organizations to acquire part of the work performed within the project. Additionally, a web tool that will allow for easy access of any visitor to the roadmap produced during the project will be attached to the website.
- A white paper will be prepared with main outputs and related steps for implementation (e.g. Recommendations from PPDR-TC to SALUS, EC, next PCP in H2020 WP 2016-2017) for the consideration of PPDR stakeholders at an EU level.
- To handover the Facts and Figures Database to the ENLETS group thus facilitating data exchange and relevant statistics among civil protection and PPDR agencies.
- To keep publishing scientific work performed beyond the project that capitalises on the project's results
- To disseminate the project's results to the consortium (in case of funding) of the project submitted to H2020 – DRS18 call -2015

## PPDR-TC Exploitation plans

PPDR-TC project's primary goal was not to develop new technologies, software platforms or hardware components, integrated into a final product, but rather to study, specify and validate PPDR technologies and architectures, tailored specifically for the needs of the PPDR community as well as to provide technical and economical recommendations and a roadmap towards full satisfaction of future PPDR requirements. Therefore, it is evident that the nature of the project itself was not in favour of producing a unified, integrated exploitable component but rather a series of individual exploitable items. A number of exploitable components have been identified as an outcome of the PPDR-TC project. A summary list is presented in Table 5.

| PPDR-TC Exploitable components | | |
|---|---|---|
| No | Exploitable Component | Partner |
| 1 | New consultancy services and/or further Security related research activities | EXO |
| 2 | The PPDR-TC facts and figures Database | EXO |
| 3 | Accurate knowledge base that includes a set of hypothetical operational scenarios where PPDR scenes have been established | ICCS |
| 4 | Database of extensive analyses of spectrum, data and traffic requirements for the PPDR community | ICCS |
| 5 | Database of the network and radio propagation simulators | ICCS |
| 6 | The LTE Simulator developed by ICCS and relevant NS-3 modules with their respective extensions related to LTE | ICCS |
| 7 | NS-3 modules and respective extensions related to SATCOM | ICCS |
| 8 | The UMTS simulator developed by ICCS and NS-2 modules with their respective extensions related to UMTS | ICCS |
| 9 | Toolbox to support decision makers in the deployment of a broadband network in short- and long-time perspectives. | TCS |
| 10 | Greedy algorithms for mobile attachment procedures. Considered to be introduced in future deployable LTE networks offers of TCS | TCS |
| 11 | Device-to-Device helped multicast strategies | TCS |
| 12 | PodNode-R with variations of R-SD, R-WF | RINI |
| 13 | PodNode-I | RINI |

| PPDR-TC Exploitable components | | |
|---|---|---|
| **No** | **Exploitable Component** | **Partner** |
| 14 | RapidNet | RINI |
| 15 | Network Management System | RINI |
| 16 | PodComm | RINI |
| 17 | Simulation models for performance assessment of future PPDR networks (e.g. UMTS, WiFi, etc.) | TELE |
| 18 | End-to-end services performance evaluation methodology. | TELE |
| 19 | Analysis of radio spectrum requirements and optimal frequency bands for PPDR | AEGI |
| 20 | Modelling of radio spectrum bandwidth requirements for PPDR | AEGI |
| 21 | Estimation of PPDR network infrastructure requirements based on coverage and capacity | AEGI |
| 22 | Analysis of service and application requirements for specific PPDR operational scenarios | AEGI |
| 23 | Toolbox for technical-financial-economic analytical tool for business modelling of broadband network deployment | ITTI |
| 24 | Radio planning tool enhancement to training simulators | ITTI |
| 25 | Analysis and Classification of PPDR services | TEK |
| 26 | Recommendations for Harmonization of PPDR Frequency Spectrum | TEK |
| 27 | Ns3 Simulation of WiFi and MANETs | TEK |
| 28 | PPDR-TC Recommendations | TEK |
| 30 | TCP Cubic [ns-3 module extension] | UNIMORE |
| 31 | TCP High Speed [ns-3 module extension] | UNIMORE |
| 32 | TCP Noordwijk [ns-3 module extension] | UNIMORE |
| 33 | TCP Hybla [ns-3 module extension] | UNIMORE |
| 34 | $C^2$ML: Congestion Control Middleware Layer [ns-3 module] | UNIMORE |
| 35 | DyBRA: Dynamic Bandwidth Reservation Algorithm [ns-3 module extension] | UNIMORE |
| 36 | QRM: Queue Rate Management [ns-3 module extension] | UNIMORE |
| 37 | TCP Window Scaling and Timestamp Options [ns-3 module] | UNIMORE |
| 38 | TEMPEST: Test EnvironMent for Performance Evaluation of the Scheduling of packeTs [Unix-based tool] | UNIMORE |
| 39 | CPMCC: Cyber-Physical Mobile Collaborative Community [MininetTestbed] | UNIMORE |
| 40 | New services based on the PPDR-TC database on the next generation PPDR emergency calls services to end users combined with Location based services via mobile WiMAX or LTE network infrastructure | LRTC |

**Table 5: PPDR-TC list of exploitable components**

These components have been detailed and an exploitation plan including technology and market analysis as well as ownership, targeted audience, distribution channels and SWOT analysis has been performed.

In addition, several measures for the sustainability of the project results have been taken in order to ensure the maximization of the PPDR-TC exploitation impact to the consortium members, the PPDR organizations and the European Union in total. In summary:

- The project will investigate means of handing over the Facts and Figures database to a public organization to assure the database sustainability, mainly for reasons that have to do with trust of the PPDR organizations to the hosting entity.
- The basic version of the Technical-Economic toolbox has been offered free of charge to the appropriate entities of all EU Member States, e.g. to all telecommunications regulatory bodies and other relevant institutions responsible for national PPDR communication network deployments. An extended toolbox will be also available to different parties in a more commercial way.
- The PPDR-TC website will be maintained up and running for at least 5 years after the project ends. This will be the main access point for all interested organizations to acquire part of the work performed within the project and will be used as a point of reference from any consortium partner.
- During Requests for Information THALES business lines will redirect customers towards the PPDR-TC website (www.ppdr-tc.eu) in order for them to better understand what could be the different deployment models for a mobile broadband PPDR network, candidate technologies, estimation for Total Cost of Ownership, and other useful recommendations.
- To support sustainability of project's outcomes it is envisaged that the partners participated in the creation of the PPDR-TC ns-x simulators will submit the totality or pieces of their code to the ns-x official forum, https://www.nsnam.org/.