Interoperable and Efficient Communications for Public Protection and Disaster Relief (PPDR)

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JRC, Ispra, Italy, 10 October 2011

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Interoperable and Efficient Communications for PPDR

- Introduction
- PPDR spectrum needs in Germany (findings for the German BMWi)
  - PPDR spectrum needs in Germany
  - Impact assessment of a PPDR allocation in Germany
  - Recommendations to the German BMWi
- Comparison to developments in the United States
- Concluding remarks

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Introduction: The need for spectrum for PPDR

- Increased demand for PPDR spectrum to support video and high speed data has been widely recognised for many years.
- Measures to solve the problem have moved at glacial speed, largely due the lack of a clear-cut identification and quantification of spectrum needs.
- New PPDR technology could reasonably be expected to be ready for widespread deployment in the 2015-2020 time frame. This implies the need to begin serious planning now.
- Many experts have felt that this need was common to many countries, and lends itself to a (largely) common solution.

Spectrum management and PPDR

- In all cases, it is essential to minimise harmful interference.
- Multiple, overlapping taxonomies for spectrum management.
- Allocation, Assignment, Rules, Enforcement
- Assignment mechanisms:
  - Market mechanisms
  - Command and control
  - Technical means (including licence-exempt)
- Exclusive use versus collective (shared) use
  - Frequency
  - Time
  - Geography (and/or direction)

Market mechanisms and PPDR

- Market mechanisms have become popular as a means of ensuring that spectrum is made available to those who value it most, and are therefore likely to place it to highest valued use.
- Revenue maximisation *should not be the goal* – governments have conflicted incentives (e.g. creation of artificial scarcity.
- Multiple mechanisms:
  - Auctions to achieve efficient initial allocation.
  - Secondary markets to correct errors in the auction, and to adjust to changes in markets and technology over time.
- Have shown themselves to be efficient in providing for the needs of mobile network operators.
- May not generate efficient allocation where a bidder community is fragmented and incurs high transaction costs aggregating demand.

Dynamic spectrum access and PPDR

- Collective use could be implemented in static or dynamic ways.
- For PPDR, the difference between peak load and normal load can be quite extreme; thus, dynamic approaches are quite promising.
- At the same time, PPDR functions are crucial to safety or life and property; thus, there is no scope for untested experimentation in operational systems.
- When will dynamic solutions be mature enough for serious, operational PPDR use?

Dynamic spectrum access and PPDR

- *Dynamic Frequency Selection (DFS)* represents a form of spectrum sharing with radars – a basic form of Cognitive Radio (CR).
- At some level, DFS has been successful; however, changes over time in the characteristics of the radar systems have necessitated changes in the means of detecting (and avoiding) them.
- Those changes were not easy to distribute to end-user equipment.
- Today, Software Defined Radio (SDR) (e.g. ensuring that end-user equipment can be upgraded over the air link) could provide a solution for such requirements.

- Before dynamic systems can be deployed for operational PPDR, they will need to be extremely reliable and maintainable.

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- Relevance of spectrum sharing concepts to PPDR
- Concluding remarks

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Origins of this work

- Much of this presentation is based on work our team performed for the German Federal Ministry of Economics and Technology (BMWi).
- Team included:
  - J. Scott Marcus (WIK-Consult GmbH)
  - John Burns and Val Jervis (Aegis)
  - Prof Dr Peter Vary (RWTH Aachen)
  - Reinhard Wählen
- Any opinions expressed are my own, not necessarily those of the German government.

Origins of this work

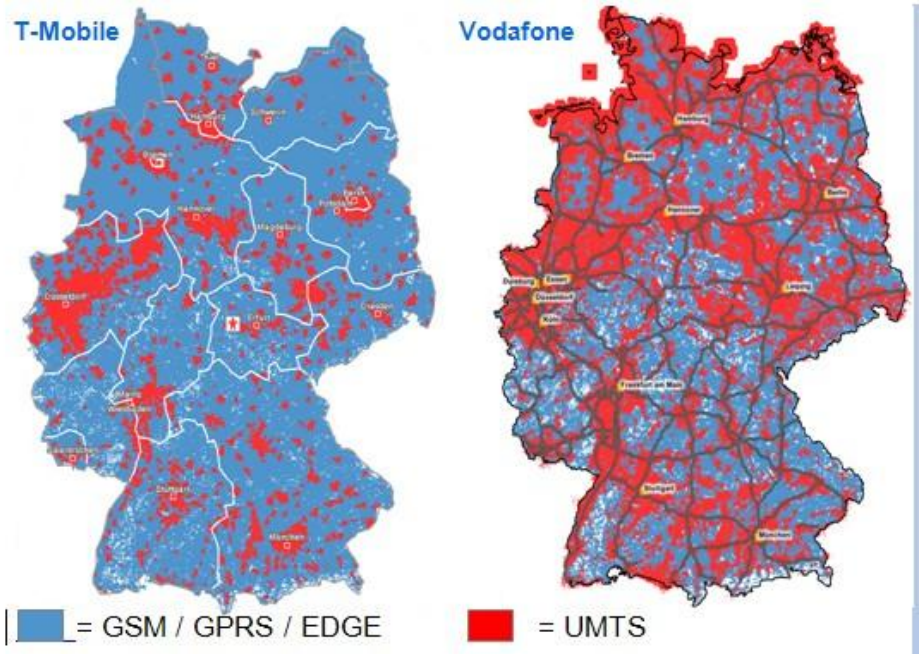
- Requirements of our study for the BMWi included:
  - Translating *functional requirements*, developed in IABG's previous survey of broadband PPDR needs for the German BMI, into detailed *spectrum requirements*.
  - Surveying any estimates of spectrum needs elsewhere in Europe and throughout the world.
  - Identifying candidate spectrum bands or tuning ranges.
  - Assessing costs and benefits.
  - Making recommendations to the BMWi.
  - Making stakeholders (ECC, RSC, Commission, NATO) at European level aware of the results of the study.

Different scenarios, different requirements

- Routine day to day use
  - Road accidents, fires, crimes, and emergency medical
  - How many simultaneous incidents per network cell sector?
  - Deployed network must be able to handle routine needs.
- Sports events and concerts
  - High demand, but predictable.
  - Feasible to deploy a vehicle/command post in advance to relay data using the wired network or an elevated directional antenna.
- Disasters
  - High demand and unpredictable.
  - Feasible to deploy a vehicle with a directional antenna.
- Backhaul, air-ground, satellite capabilities for remote areas.

PPDR requirements for day to day use

- **Must cover all populated areas and the entire road / rail network.**
- **Existing 3G mobile networks fall far short of this requirement.**
- **Requirements for high reliability and robustness.**
- **Commercial networks could, however, complement PPDR networks.**



Coverage of two best serving networks in Germany

Traffic and spectrum demand for day to day use

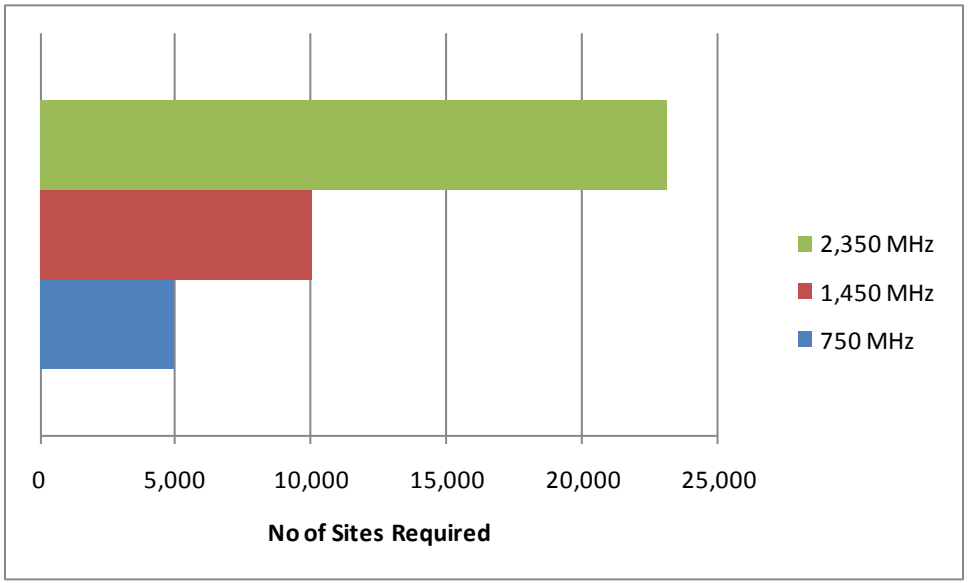
- **The largest driver for spectrum demand will be real time video.**
- **Other data applications (e.g. database / Internet access) are less demanding, because some latency / contention is permissible.**
- **Our estimate based on realistic user requirements and associated data bit rates is 1.2 Mbps downlink and 1.9 Mbps uplink per incident.**
- **Translates to a spectrum demand of 10 MHz for the downlink and 15 MHz for the uplink.**

Addressing Major Incidents

- **We have estimated the following capacity requirement for major incidents:**
  - 50 Mbps uplink and downlink via wide area network (WAN);
  - 50 Mbps total for local, on-site communication needs (LAN).
- **The LAN could be provided by:**
  - 802.11 (Wi-Fi) – may require multiple access points in “mesh” configuration to cover large sites; or
  - LTE repeater station (vehicle mounted base station).
- Maximise capacity through WAN using repeater with directional antenna, or use temporary fixed link.

Optimal Frequency Ranges for WAN and LAN requirements

- **WAN requires contiguous FDD spectrum below 1 GHz to optimise coverage and minimise the number of sites. Also facilitates building penetration.**



- **LAN can use higher frequencies – could use multiple bands to maximise capacity and coverage.**

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Implications as regards frequency bands

- Spectrum needs under 1 GHz represent a quite significant challenge.
  - 10 MHz are needed for the downlink and 15 MHz for the uplink.
  - For a detailed review of the relevant bands, see the presentation of Patrick Donohue (ANFR) at the Mainz workshop, March 2010.
  - There is no obvious, painless way to obtain that much spectrum under 1 GHz; however, the need is real.
  - Complex negotiations are likely to be required among multiple stakeholders.
- Spectrum needs above 1 GHz appear to be less problematic.

Characteristics of frequency bands (> 1 GHz)

Band (MHz)	Technical characteristics and international allocation status
1452-1479	Favourable propagation compared to higher bands. Spectrum already used for mobile broadband in Japan. Harmonised allocation for T-DAB, but not currently used (spectrum auctioned on service neutral basis in UK).
1980–2010/ 2170-2200	IMT Mobile Satellite bands, can also be used by ground stations. Now licensed to satellite operators, but future deployment uncertain.
2025–2110/ 2200 -2290	Space operations allocation. High density mobile networks prohibited but may be scope for limited public safety use. Might provide national solution in some countries.
2300–2400	Already used for mobile broadband in some countries. Part of band already used in Germany for public safety video links. Suitable for air to ground use
3400–3600	Already widely licensed for wireless access in Europe. Internationally allocated for broadband mobile. Some existing national use for PS air to ground links. Might provide a national solution in some countries.
4940-4990	Already identified for PS use and aligns with the US PS band, but currently used by military in Germany and several other countries.
5150-5250	Already identified for PS use. Available throughout Europe. Shared with commercial WLANs, but limited to indoor use and lower power.

Assessing costs and benefits

- *Impact Assessment* is a standard methodology used by the European Commission to evaluate costs and benefits of proposed policy initiatives.
- Impact Assessment provides a structured way of examining who is impacted by a change, and how, and to what extent.
- Under the Review package adopted in 2009, the Commission must use Impact Assessment to justify any harmonised bands.
- Impact assessment routinely includes options reflecting:
  - No change to whatever is currently in place
  - No intervention
- We have followed the European Commission's Impact Assessment guidelines (2009) in developing a Germany-specific evaluation.

Exclusive, or shared? Commercial, or private?

- Our focus in that exercise was on exclusive assignments.
- PPDR networks tend to require coverage and reliability that are not available with commercial networks; however, interoperability with commercial services (e.g. LTE) for less critical applications and/or for additional capacity is highly desirable.
- Sharing on a pre-emptible basis could be considered; however:
  - Experience with the “D Block” auctions in the U.S. suggests that the commercial value of encumbered spectrum is low.
  - Experience with DFS suggests challenges in ensuring that pre-emption continues to work reliably over time.
  - We felt that it was a bit too early for such a solution.

Policy options

Options for the impact assessment
Option 1: No change
• No additional spectrum allocations for PPDR at European level • No additional spectrum allocations for PPDR at national level • Continued use of spectrum in 380-400 MHz range for TETRA/TETRAPOL
Option 2: “Let a thousand flowers bloom”
• No additional spectrum allocations for PPDR at European level • European countries allocate sufficient additional spectrum for PPDR according to their individual needs • Continued use of spectrum in 380-400 MHz range for TETRA/TETRAPOL
Option 3: Harmonised solution solely in bands or tuning ranges below 1 GHz
• National augmentation of harmonised bands permitted within predefined tuning ranges • Continued use of spectrum in 380-400 MHz range (not necessarily contiguous with the new bands) for TETRA/TETRAPOL
Option 4: Harmonised solution in one or more bands or tuning ranges below 1 GHz, plus one or more bands or tuning ranges above 1 GHz
• Lower bands or tuning ranges to meet requirements for coverage and building penetration • Upper bands or tuning ranges to satisfy requirements for capacity / surges • National augmentation of harmonised bands permitted within predefined tuning ranges • Continued use of spectrum in 380-400 MHz range (not necessarily contiguous with the new bands) for TETRA/TETRAPOL

Impacts relative to option 1 (“no change”)

- An improvement in the overall effectiveness of PPDR response, with probable reductions in lives and property lost, reduced risk to PPDR personnel, and concomitant improvements in social cohesion in the aftermath of any major catastrophes.
- An opportunity cost in the spectrum allocated to PPDR use that is not used for some other constructive purpose.
- Re-farming costs associated with relocating whatever applications are currently using the newly allocated spectrum to other spectrum bands, assuming that their function is still required.
- Increased/decreased cost of PPDR network operation.

Benefits of newly available applications

- The improvement in the overall effectiveness of PPDR response benefits everyone.
  - To the extent that it means that better protection is delivered for no greater cost, this generates benefits to all, whether they are victims or not.
  - It also benefits PPDR workers, whose personal safety may be enhanced.
- It is simplest to think of these benefits net of the costs of deploying and operating the networks and applications that produce them.
- Small differences in the band chosen have little effect on these benefits. Thus, the benefits of making new high speed applications available are largely independent of which user relinquishes spectrum to make it available to PPDR.

Benefits of better crime deterrence

- Suppose *arguendo* that improved technology can enhance law enforcement at a given cost. If so, a relatively small number of crimes deterred could justify a substantial expenditure in support of that technology.

Table 1. Cost estimates per offense for five index offenses (2008 US dollars).

Offense	Victim costs	Justice costs	Offender productivity	Subtotal	WTP	Total
Murder	4,712,769	307,355	143,432	5,163,556	12,089,100	17,252,656
Rape	138,310	8503	4610	151,423	297,109	448,532
Armed robbery	29,711	15,060	4098	48,869	286,864	335,733
Aggravated assault	37,907	13,831	6557	58,295	87,084	145,379
Burglary	2049	2356	1025	5430	35,858	41,288

Source: “Murder by the Numbers”, Matt DeLisi et al., Iowa State University, 2010

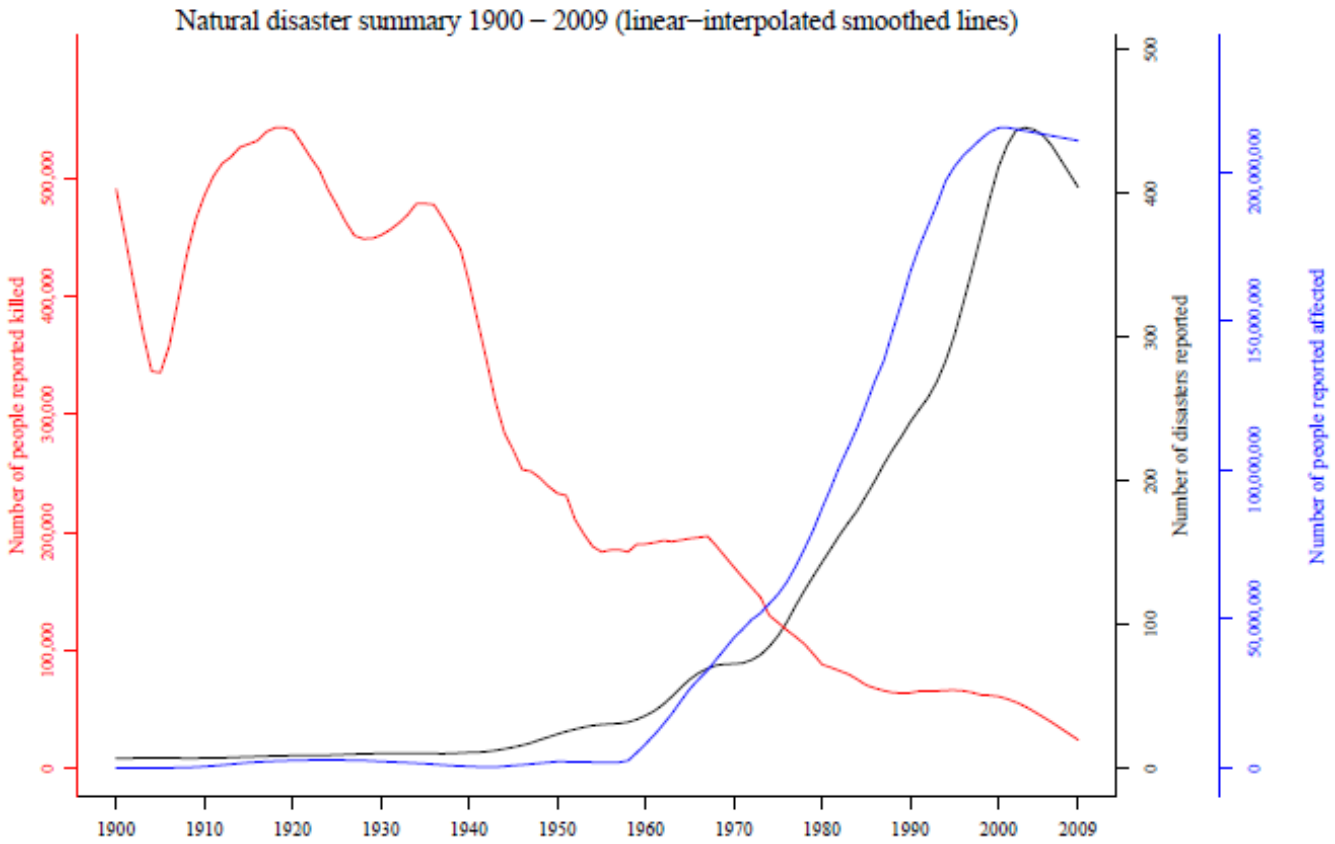
Benefits for special events

- Might there be room for improvement?
- Der Spiegel: “Firemen and police officers on duty in Duisburg on Saturday said they had had problems with their analog radios. Communication between officers had been difficult at best, and at times impossible. Was there a communications breakdown? Did the officers at the entrances to the tunnel not know that people were being crushed on the ramp? So far no one wants to comment on these questions. The radios ‘are in some cases so old that you can't even get spare parts for them,’ said … a member of the police federation for the state of North Rhine-Westphalia, where Duisburg is located. Officers repeatedly get in dead spots where they are out of range and can't be reached in emergencies. ‘Often officers take their private mobile because it's the only way to stay in touch,’ … But the mobile phone network collapsed on Saturday, so that wouldn't have helped either.”

Der Spiegel, “Analysis of the Love Parade Tragedy: The Facts Behind the Duisburg Disaster”, 28 July 2010, http://www.spiegel.de/international/germany/0,1518,708876,00.html

Benefits for disaster relief

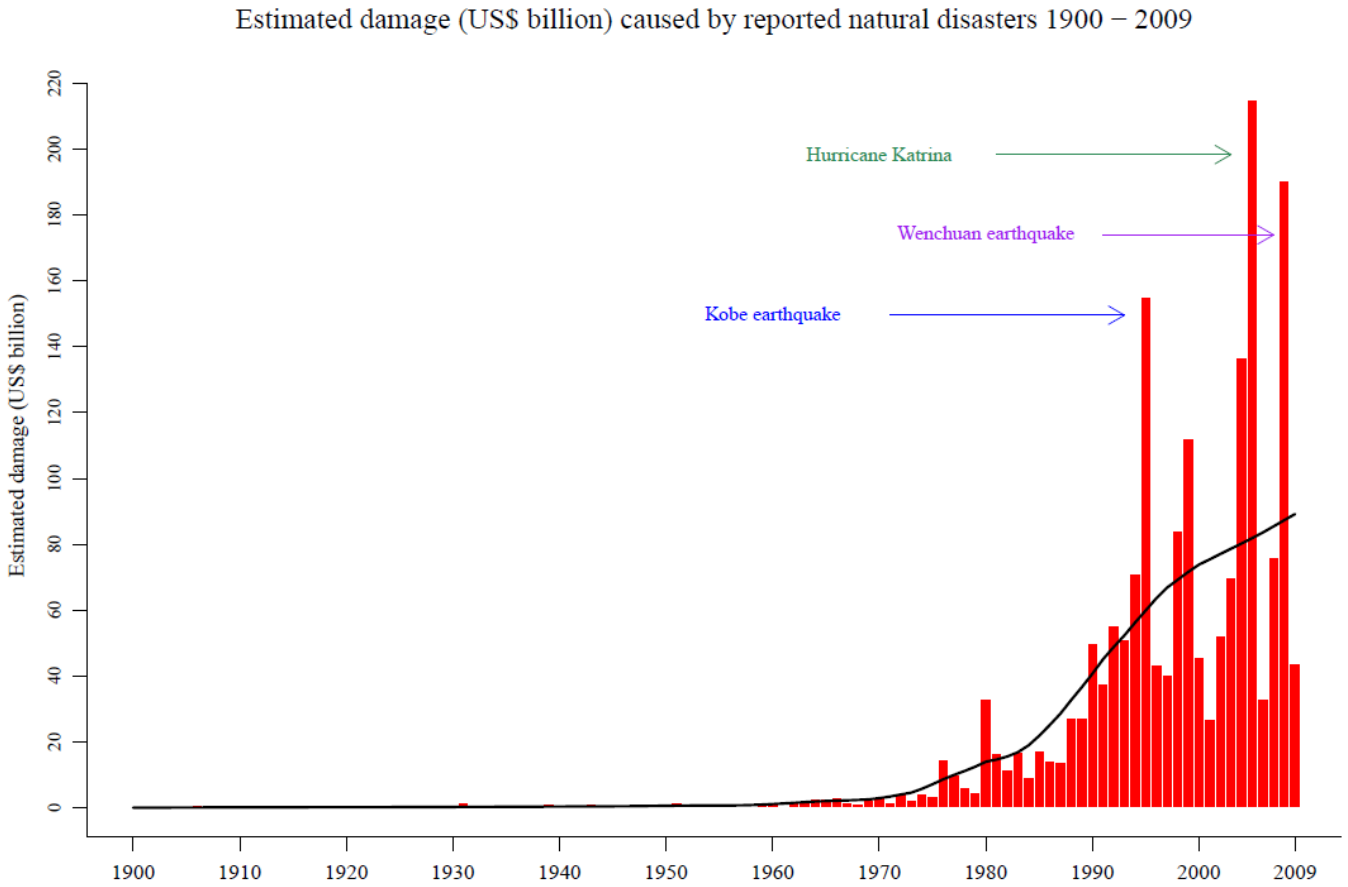
- We are witnessing a huge increase in the number of natural disasters reported, and people affected, but a decline in the number of deaths.



Source: EM–DAT: The OFDA/CRED International Disaster Database

Benefits for disaster relief

- Property damage, however, has increased enormously.



Source: EM−DAT: The OFDA/CRED International Disaster Database

Benefits for disaster relief

- Europe is less impacted by natural disasters than other regions, but damages of $13 billion US per year are still substantial.
- Germany represents about a sixth of European population, and about a fifth of European GDP, so one could expect about € 1.5 billion of damage per year caused by natural disasters.
- Improvements in response effectiveness could have a substantial impact.

Damages (2009 US$ bn)	Africa	Americas	Asia	Europe	Oceania	Global
Climatological 2009	0.00	1.23	0.06	0.12	1.30	**2.71**
Avg. 2000-08	*0.05*	*2.36*	*3.47*	*3.15*	*0.36*	***9.39***
Geophysical 2009	0.00	0.30	3.10	2.50	0.16	**6.06**
Avg. 2000-08	*0.73*	*0.72*	*17.90*	*0.31*	*0.00*	***19.67***
Hydrological 2009	0.15	1.33	5.23	0.97	0.19	**7.88**
Avg. 2000-08	*0.37*	*2.99*	*9.05*	*7.01*	*0.52*	***19.94***
Meteorological 2009	0.02	10.37	7.53	6.65	0.07	**24.64**
Avg. 2000-08	*0.08*	*39.93*	*10.30*	*3.01*	*0.31*	***53.63***
Total 2009	**0.17**	**13.23**	**15.91**	**10.24**	**1.73**	**41.28**
Avg. 2000-08	***1.23***	***45.99***	***40.72***	***13.49***	***1.19***	***102.63***

Source: CRED, Annual Disaster Statistical Review 2009

Benefits for disaster relief

- Germany is subject to significant hazards. Some of these have widespread impact, others are more localised.
  - 2007: Storm; 11 dead
  - Aug-2003: Extreme temperature; 9,355 dead
  - 7-Jun-2003: Storm; 10 dead
  - 11-Aug-2002: Flood; 27 dead
  - 26-Oct-2002: Storm; 11 dead
  - 1999: Storm; 15 dead
  - 1998: ICE train accident in Eschede; 101 dead
  - 1997: Oder flood; damage EUR 327.4 million, 2,300 evacuated
  - 1988: Aircraft crash at Ramstein air display; 70 dead, more than 400 injured
  - 1987: Tanker explosion at Herborn: 5 dead, 38 injured
  - 1986: Fire at Sandoz in Basel; heavy pollution of the river Rhine (DE/CH)
    1962: Tidal wave and flooding in Hamburg; 400 dead, more than 100,000 people affected, 50 dyke bursts

See http://ec.europa.eu/echo/civil_protection/civil/vademecum/de/2-de-6.html.

Benefits for disaster relief

- A number of European countries, including Poland, Germany, Austria, the Czech Republic, Hungary, Slovakia, Serbia and the Ukraine experienced serious flooding in May, June and August of 2010. Dozens of people died, tens of thousands were evacuated, and billions of euro in damages were incurred.
- “Among the individual EU member states who have so far sent rescuers and equipment [to Poland] are France, Germany, the Baltic nations of Lithuania, Latvia and Estonia, and Poland’s neighbour the Czech Republic, which has also been hit by floods.” (RTE, 21 May 2010)
- Clearly, international assistance could be far more effective if communication capabilities were fully interoperable.

Spectrum opportunity costs

- The value of the 800 MHz spectrum is a reasonably good proxy, in our view, for the opportunity cost of allocating spectrum under 1 GHz to PPDR broadband use in Germany.
- With that in mind, we use € 60 million per MHz as an estimate of the opportunity cost of allocating spectrum under 1 GHz to PPDR, and € 2 million per MHz as an estimate of the opportunity cost of allocating spectrum over 1 GHz to PPDR.

Band	Price per MHz for Germany
800 MHz	€59.607.917
1.800 MHz	€2.087.100
2.000 MHz	€8.790.025
2.600 MHz paired	€1.841.457
2.600 MHz unpaired	€1.730.360

Spectrum refarming costs

- For the six reference cases that we have analysed, we find that the cost of clearing a band was in the range of € 0,001 to € 0,05 per MHz/POP.
- Expressing the cost in terms of MHz/POP enables us to factor it up or down appropriately for larger or smaller bands, and for larger or smaller countries.

Country	Year(s)	Band	Spectrum quantity in MHz	Transferred from	Relocation Cost in 000€	Population Affected in 000	Cost MHz/POP
US	2007-2010	1710 MHz	45	12 Fed Agencies & DoD	€737,288	301,290	€0.05438
FR	2001	1800 MHz	150	Defence	€7,000	59,476	€0.00078
FR	2001	2 GHz	140	Defence & FT	€38,000	59,476	€0.00456
FR	2001	2.4 GHz	83.5	Defence	€8,000	59,476	€0.00161
FR	2002-2010	DTT	320	Analogue broadcast	€57,000	61,181	€0.00291
FR	2001	PMR446	0.1	SNCF & RRs	€120	59,476	€0.02018

Sources: NTIA, ANFR and WIK estimates

Network operation costs

- Incremental costs for parallel operation of two PPDR networks are likely in the near term.
- Broadband PPDR networks will in the longer term absorb the functions of the current TETRA/Tetrapol networks, as TETRA evolves to become a service over future broadband PPDR networks.
- Once that occurs, the cost of operation of a single integrated PPDR network that carries voice, data and video is likely to be no greater than that of the current TETRA network. The new network will be based on more advanced and more efficient technology.

Harmonised, or country-specific?

- Advantages include:
  - a broader manufacturing base and increased volume of equipment resulting in economies of scale and expanded equipment availability;
  - enhanced cross-border coordination;
  - increased potential for interoperability, with increased possibilities for international assistance; and possibly
  - improved spectrum management and planning.
- Disadvantages include:
  - Reduced ability to customise spectrum allocations to meet national circumstances (Mitigated by the use of tuning ranges?); and
  - Risk of inappropriate allocation in the absence of a market test.

Comparing the options

- It is customary to compare options among a number of dimensions, including:
  - **effectiveness** – the extent to which options achieve the objectives of the proposal.
  - **efficiency** – the extent to which objectives can be achieved for a given level of resources/at least cost (cost-effectiveness).
  - **coherence** – the extent to which options are coherent with the overarching policy objectives, and the extent to which they might have undesirable economic, social, or environmental consequences.

Comparing the options

- In comparison with Option 4, Option 1 is less expensive to the extent that it avoids the following costs:
  - An opportunity cost of €60 million per MHz times 25 MHz below 1 GHz, plus €2 million times 27 MHz, for a total opportunity cost of €1,554 million.
  - A refarming cost of not more than €160 million.
  - Incremental network operation costs for a limited number of years that, in comparison to the opportunity costs, are small enough to ignore.
  - In round numbers, Option 4 is superior to Option 1 if it generates at least €1.714 million in net savings over the life of the system, which is surely at least thirty years.

Comparing the options

- In reality, the cost can be justified by any combination of:
  - property loss avoided,
  - lives saved,
  - crimes deterred,
  - gains in operational efficiency, and
  - avoidance of injury or loss of life on the part of PPDR personnel.
- In a simplistic static calculation, over a thirty year lifetime, the net savings must exceed €57 million per year.
- This is a modest threshold that will, for reasons already noted, easily be exceeded by the gains associated with new PPDR capabilities.

Comparing the options

Criterion	Option 1: No change	Option 2: Let a thousand flowers bloom	Option 3: Harmonised solution below 1 GHz	Option 4: Harmonised solution below 1 GHz and above 1 GHz
Effectiveness	Low. In the absence of additional spectrum, new applications that depend on video and high speed data cannot be deployed.	Moderate. New applications can be deployed, but cross border interoperability is not assured, nor the ability to loan PPDR forces to other countries.	High. New applications can be deployed, cross border interoperability is assured, and PPDR forces from one country can be fully effective operating in another.	High. New applications can be deployed, cross border interoperability is assured, and PPDR forces from one country can be fully effective operating in another.
Efficiency	Low. This is the lowest cost option, but it fails to achieve the quite substantial benefits that new PPDR technology potentially offer.	Low. Achieves the benefits of new PPDR applications, but fails to achieve economies of scale or scope. Certain costs are low, but the overall relationship of costs to benefits is poor.	High. Achieves all benefits but opportunity costs may be excessive.	Highest. Achieves all benefits, and has lower opportunity and re-farming costs than Option 3.
Coherence	Low, in the sense that it fails to promote security, counter-terrorism, or law enforcement.	Moderate, in the sense that it promotes security, counter-terrorism, and law enforcement, but not in a way that enhances international cooperation.	High, in the sense that it promotes security, counter-terrorism, and law enforcement in ways that enhance international cooperation.	High, in the sense that it promotes security, counter-terrorism, and law enforcement in ways that enhance international cooperation.

Comparing the options

- Option 4 best balances effectiveness, efficiency and coherence.
- It is clearly superior to the current (“no change”) situation.

Option 4: Harmonised solution in one or more bands or tuning ranges below 1 GHz, plus one or more bands or tuning ranges above 1 GHz
• Lower bands or tuning ranges to meet requirements for coverage and building penetration • Upper bands or tuning ranges to satisfy requirements for capacity / surges • National augmentation of harmonised bands permitted within predefined tuning ranges • Continued use of spectrum in 380-400 MHz range (not necessarily contiguous with the new bands) for TETRA/TETRAPOL

Recommendations to the German BMWi

- German government policy should advocate:
  - a harmonised allocation with two sub-bands below 1 GHz: one of 15 MHz (uplink) and one of 10 MHz (downlink).
  - additional harmonised allocations above 1 GHz for local use for disasters, sporting events, and concerts.
  - a 15 MHz harmonised air to ground allocation above 1 GHz.
  - an integrated view toward the use of satellite, primarily for areas that are hard to reach with terrestrial networks.
- German government policy should promote development and use of standards that enable seamless interoperability.
- The German government should coordinate closely with a wide range of relevant stakeholders.

Technological requirements

- Our focus was spectrum, not technology.
- Whatever technological standards are chosen, we would note that the following characteristics are highly desirable, if not absolutely essential:
  - **Full interoperability:** Systems from different vendors, or procured for different European countries, should be able to interoperate at some predetermined level without any modifications or special arrangements.
  - **Economies of scale:** If technically feasible, equipment should be designed such that PPDR-specific capability is layered on top of an existing technology such as LTE or WiMAX (or 802.11 for wireless LAN PPDR). Doing so potentially enables the equipment to benefit from mass market economies of scale (e.g. in chipsets), and possibly to interoperate with commercial networks (perhaps with reduced functionality).

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Developments in the United States

- The United States attempted to provide a spectrum band pre-emptible by PPDR as part of its “D Block” auction.
- The US FCC sought to “… award a nationwide 10 MHz commercial licence in the Upper 700 MHz … Block to the winning bidder once it has entered into a Commission-approved Network Sharing Agreement … with the [corporate entity established by the FCC to manage emergency services rights of access to the spectrum]. … Under the Partnership, [emergency services] will have priority access to the commercial spectrum in times of emergency, and the commercial licensee will have pre-emptible, secondary access to the public safety broadband spectrum. Providing for shared infrastructure will help achieve significant cost efficiencies while maximizing public safety’s access to interoperable broadband spectrum.”

Developments in the United States

- Unfortunately, this approach failed.
- Private bidders did not have sufficient interest in the pre-emptible spectrum. Bids failed to reach the FCC's reserve price.
- Reasons?
  - One possible interpretation is that the commercial value of a band that can be pre-empted by PPDR in an emergency is not very great.
  - In addition, the detailed arrangements for this band introduced enormous uncertainties for bidders that likely also reduced its effective commercial value.
  - The relative balance of these two factors is difficult to assess.

More recent developments in the United States

- "Nationwide, Broadband, Interoperable Public Safety Network" Order and NPRM released 25 January 2011
  - Seeks to establish public safety spectrum in the 700 MHz band
  - Requires "… that all networks deployed in the 700 MHz public safety broadband spectrum adopt LTE, specifically at least 3GPP Standard E-UTRA Release 8 …"
- This is not inconsistent with our recommendation to the BMWi to adopt interoperable technical standards.
  - Our terms of reference did not include choice of technology.
  - However, our modelling assumptions are based on LTE.
- There is still no spectrum for broadband interoperable PPDR!

Concluding remarks

- The spectrum management process seems to moving forward.
  - The European Commission convened a High Level Meeting of military and public safety experts on 31 March 2011.
  - The Commission‘s expanded authority through the 2009 revisions to the regulatory framework may prove helpful.
  - Work proceeds in parallel through Project Team FM49, which will “work on radio spectrum issues concerning PPDR applications and scenarios, in particular concerning the broadband high speed communications as requested by PPDR organisations.”
- A parallel technology effort is equally essential.
- Innovative technology such as CR appears to be extremely promising in the somewhat longer term.

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