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System Reference document (SRdoc); Critical Infrastructure Utility Operations requirements for Smart Grid systems, other radio systems, and future radio spectrum access arrangements below 1,5 GHz

Reference

DTR/ERM-562

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dPMR, M2M, PMR, resilience, Smart Grid, TETRA

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Executive summary

The present document builds on ETSI TR 103 401 [i.1]: "Smart Grid Systems and Other Radio Systems suitable for Utility Operations, and their long-term spectrum requirements".

It highlights the general and essential requirements of electricity systems, e.g. identifying that the resilience requirements for Smart Grids are typically significantly more stringent than those for Smart Meters.

It also highlights the future spectrum requirements below 1,5 GHz for mission critical electricity systems, e.g. 18 MHz of spectrum within the VHF, 400 MHz UHF anchor band, and 1,35/1,4 GHz bands.

Introduction

The present document builds on ETSI TR 103 401 [i.1]. It seeks access for spectrum suitable for resilient machine to machine (RM2M) supervision, control, and data acquisition (SCADA) systems, including Wide-area Multi-Point (WiMP), for electricity, gas and water Smart Grids.

Electricity, Gas and water grids are designated as critical national infrastructure [i.2]. The present document builds on the Smart Grids Co-ordination Group Technical Report Reference Architecture for the Smart Grid [i.3] (RASG) in that it highlights that real-time mission critical Smart Grid systems typically need to be resilient, sometimes requiring best practice resilience. Smart Meter systems may form part of a Smart Grid system, but do not generally need to be as resilient as network monitoring and control equipment. This should clarify which of the systems mentioned within the RASG [i.3] may be suitable for Smart Grid systems and which may only be suitable for Smart Meter systems.

1 Scope

The present document considers:

1) the essential functional requirements for existing and future radio systems suitable for controlling critical national infrastructure utility systems; and

2) the long-term spectrum requirements for critical national infrastructure utility systems.

The present document does not include the high data rate microwave link backhaul requirements of the Smart Grids or satellite connectivity. Nor does it include any licence exempt spectrum requirements for Smart Meters or similar Smart systems. Access to those spectrum blocks are not expected to be an issue.

Requirements for Smart Cities or Smart Homes are not within the scope of the present document.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TR 103 401: "Smart Grid Systems and Other Radio Systems suitable for Utility Operations, and their long-term spectrum requirements".

[i.2] CPNI: "Telecommunications Resilience Good Practice Guide", Version 4.

NOTE: Available at https://www.cpni.gov.uk/critical-national-infrastructure-0.

[i.3] CEN-CENELEC-ETSI Smart Grid Coordination Group: "Smart Grid Reference Architecture".

NOTE: Available at http://ec.europa.eu/energy/sites/ener/files/documents/xpert_group1_reference_architecture.pdf.

[i.4] "Treaty on the Functioning of the European Union" (Treaty of Rome).

NOTE: Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:12012E/TXT&from=EN.

[i.5] EUTC Spectrum needs for Utilities EUTC position paper.

NOTE: Available at https://eutc.org/wp-content/uploads/2018/08/EUTC-Spectrum-Position-Paper.pdf.

[i.6] ETSI EN 300 113: "Land Mobile Service; Radio equipment intended for the transmission of data (and/or speech) using constant or non-constant envelope modulation and having an antenna connector; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.7] ETSI EN 300 220: "Short Range Devices (SRD) operating in the frequency range 25 MHz to 1 000 MHz".

[i.8] ETSI EN 302 561: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Land Mobile Service; Radio equipment using constant or non-constant envelope modulation operating in a channel bandwidth of 25 kHz, 50 kHz, 100 kHz or 150 kHz; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.9] ITU-R Radio Regulations Articles RR 5.503 iv.

NOTE: Available at http://handle.itu.int/11.1002/pub/80da2b36-en.

3 Definition of terms, symbols and abbreviations

3.1 Terms

Void.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

GHz	Giga Hertz
kbit/s	Kilo bits per second
kHz	kilo Hertz
MHz	Mega Hertz

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

CCTV	Closed Circuit TeleVision
CDMA	Code Division Multiple Access
DMR	Digital Mobile Radio
dPMR	digital Private Mobile Radio
ETSI	European Telecommunications Standards Institute
EUTC	European Utilities Telecoms Council
FDD	Frequency Division Duplex
ITU	International Telecommunication Union
LTE	Long-Term Evolution
M2M	Machine to Machine
RASG	Reference Architecture for the Smart Grid
RM2M	Resilient Machine to Machine
SCADA	Supervisory Control and Data Acquisition
SMO	Spectrum Management Organization
TDD	Time Division Duplex
TETRA	Terrestrial Trunked Radio
TFEU	Treaty on the Functioning of the European Union
UHF	Ultra-High Frequency
VHF	Very High Frequency

4 Critical Infrastructure Utility Operations

4.0 Introduction

Almost all of Europe's businesses are dependent on the stable supply of electricity to enable them to provide the goods and/or services demanded by Europe's citizens, consumers, and other businesses. Gas provides energy to many consumers and industry either directly for heating or indirectly through the generation of electricity.

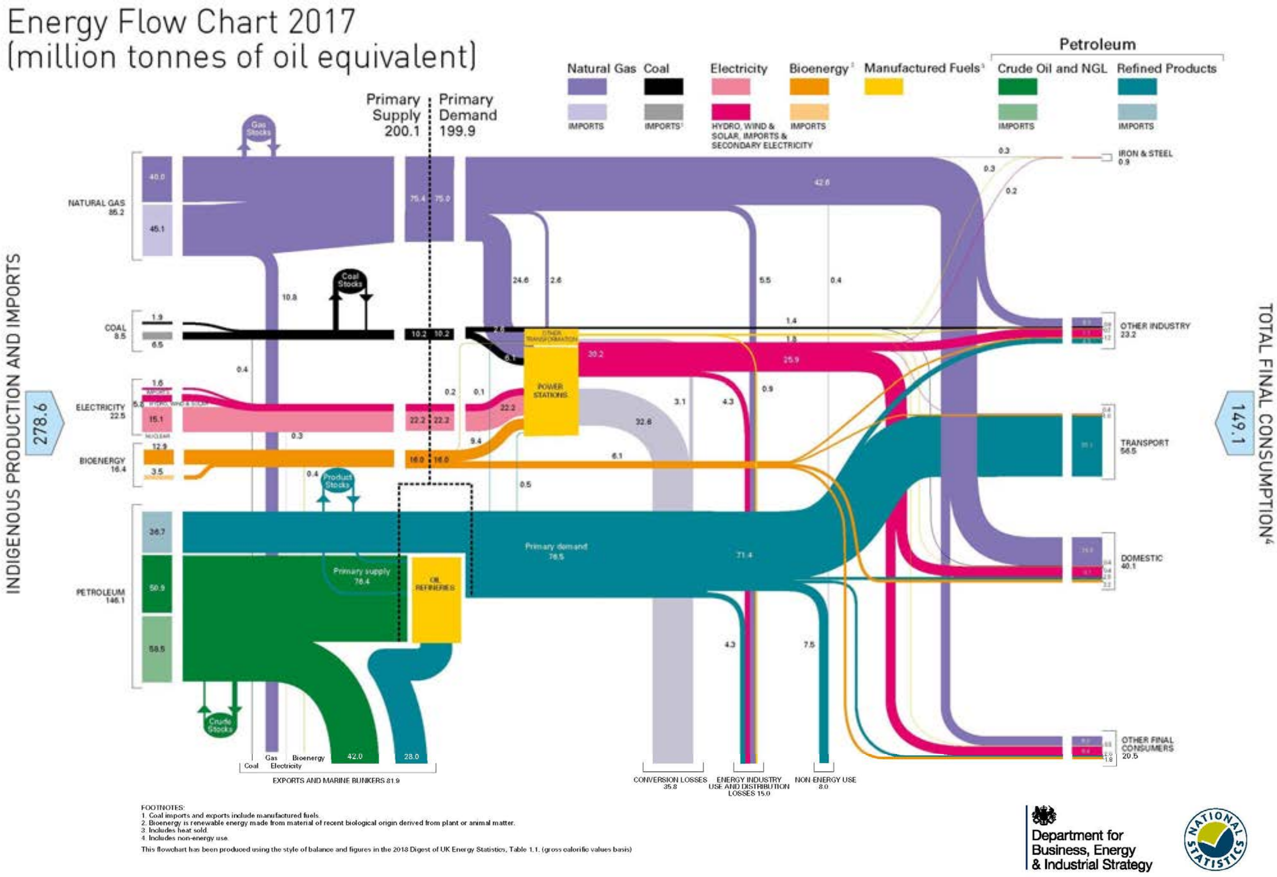

Figure 4.1: Example energy flow chart ("UK Department of Energy and Climate Change, 2014")

The European Community recognized the importance of the stable supply of electricity through Article 194 of the Treaty on the Functioning of the European Union [i.4] (TFEU/Treaty of Rome) which sets out that the aim of EU Energy policy is to *"ensure security of energy supply in the Union"*, i.e. to ensure that energy (including electricity and gas) is available to all when needed, and while doing so *"promote energy efficiency and energy saving and the development of new and renewable forms of energy"*. Electricity and gas Smart Grids will be used to deliver these energy policy objectives and related water policy objectives.

Historically, in the first part of the 20th Century, energy supplies were generated and distributed based on local systems in towns and cities based on fossil fuels, mainly oils and coal to generate electricity and town gas. In the second part of the 20th Century, these systems were expanded and connected to form national systems with large scale generation and new sources of natural gas injected into transmission systems, delivering major reductions in costs whilst at the same time improving reliability. These networks injected energy into a transmission system at high voltage (electricity) and high pressure (gas) to service the whole country, before being transferred to distribution networks to deliver to customers at lower voltage/pressure. The networks were relatively 'dumb' with a unidirectional from high voltage/pressure to low and were easily controlled. Utility services were almost universally provided by government as a national service.

The 21st century has seen change in every aspect of this service:

- fossil fuels are being replaced by renewable sources of energy;
- utility networks now have to accommodate two-way flows of energy with generation and renewable gas sources integrated into the distribution networks;
- sources of energy may be intermittent and unpredictable (e.g. wind generation and solar power) in place of reliable and predictable power for 'dispatchable' large scale coal, gas and oil fired power stations;
- energy storage - especially batteries - are likely to appear on the networks very soon;
- electrification of heat and transport will place new stresses on the electricity distribution networks;
- society has become more dependent on reliable, secure, sustainable and affordable energy;
- utility services have been migrated to the private sectors and become competitive, requiring the energy networks to facilitate use of the networks for energy trading, a feature never envisaged when they were constructed;
- consumers expect to be more informed about their energy usage and empowered to become engaged in the market; and
- utility networks have become the focus on cyber-attacks to cause disruption and potentially facilitate fraud and terrorism.

Traditional electricity and gas grids were comparatively easy to manage before the introduction of distributed generation using renewable forms of energy, e.g. wind turbines. Distributed generation sources need to be suitably controlled so that they do not cause instability to the grid, power surges, and black outs. Also, the incorporation of energy efficiency systems and energy saving systems will further complicate the communications systems required to supervise and control the electricity grids.

Whilst certain minimum requirements will remain, the Smart Grids systems are very likely to be enhanced and expanded versions of the existing electricity and gas grid systems. For example, using the same infrastructure and communicating higher data rates to many times more remote locations, e.g. local electricity sub-stations.

Channel bandwidths used by utilities vary from 12,5/25 kHz narrow band systems to 1,25 MHz CDMA systems available to the utilities in some Member States, with potential upgrade paths to 1,4/3/5 MHz LTE systems if required. Narrowband systems generally comprise:

- systems constructed in accordance with ETSI EN 300 113 [i.6], ETSI EN 300 220 [i.7] and ETSI EN 302 561 [i.8]; or
- European standards for dPMR, DMR, and TETRA.

Annex B shows the Member States that have access to 400 MHz spectrum for utility systems already.

Electricity Smart Grid operators are therefore typically seeking access to 2 × 3 MHz of 400 MHz band spectrum across Europe on a technology neutral basis.

The present document does not include the high data rate microwave link backhaul requirements of the Smart Grids or satellite connectivity. Nor does it include any licence exempt spectrum requirements for Smart Meters or similar Smart systems. Access to those spectrum blocks are not expected to be an issue.

4.1 Smart Grid 400 MHz spectrum requirements

The existing 400 MHz UHF anchor band allocations and licensing of spectrum for Intelligent Electricity Grids within Europe include:

- Spain: 2 × 0,6 MHz (comprising 12,5/25 kHz narrow band channels);
- United Kingdom (UK): 2 × 1 MHz (comprising 12,5 kHz narrow band channels);
- Republic of Ireland (RoI): 2 × 1 MHz (comprising 12,5 kHz narrow band channels);

- Netherlands 2 × 3 MHz for 1,25 MHz channelized CDMA;
- Germany; and
- Austria.

With the move towards Smart Grids, some of the operators of the broadband systems listed above are seeking to migrate from 1,25 MHz CDMA systems to 1,4 MHz or 3 MHz LTE systems. In some cases, this may require a slight increase in licensed/allocated spectrum to 3 MHz and/or a slight re-alignment of the spectrum. See Annex 2 of [i.9]: European 400 MHz band plan options. In the UK, the increase in data rates necessary for controlling Smart Grids means that the existing 9,6 kbit/s in 12,5 kHz narrow band channel systems need to upgrade to 32 kbit/s in 12,5 kHz, 64 kbit/s in 25 kHz, and 128 kbit/s in 50 kHz narrow band channels for use in areas where only low data rate communications are required, e.g. for wide-area rural and remote rural coverage. The number of these rural and remote rural links are predicted to increase at least ten-fold [i.5] so a significant increase in spectrum is required. The EUTC Spectrum Position Paper [i.5] recommends 2 × 3 MHz.

The narrow band, wide band, and broad band scenarios above, will require 2 × 3 MHz of usable spectrum. Ideally, a harmonised tuning range could be found across Europe, in the 450 MHz to 470 MHz band. Where this is not possible, 2 × 3 MHz anywhere within the 400 MHz Band (380 MHz to 470 MHz) will be acceptable.

This requirement is reflected within the ETSI TR 103 401 [i.1] requirement for 2 × 3 MHz of 400 MHz spectrum across Europe for Smart Grids.

Depending on national circumstances, regulation and policy preferences, it might be necessary for utilities to manage the spectrum collaboratively though a Spectrum Management Organization (SMO) to avoid placing additional administrative burdens on national spectrum regulators.

4.2 Smart Grid VHF spectrum requirements

2 × 1 MHz of VHF spectrum, e.g. for 12,5/25 kHz narrow band channels.

This requirement is reflected within the ETSI TR 103 401 [i.1] requirement for VHF spectrum across Europe for Smart Grids.

Recognizing that European utilities operate in largely varying geographies and population densities, VHF spectrum may sometimes be required to complement UHF spectrum to adequately serve lower density population regions and undulating terrains. Technologies in this area are generally designed to conform to ETSI standards ETSI EN 300 113 [i.6] and ETSI EN 300 220 [i.7].

4.3 Smart Grid 1 350/1 400 MHz spectrum requirements

10 MHz of TDD/FDD channels.

This requirement is reflected within the ETSI TR 103 401 [i.1] requirement for 1,4 GHz spectrum across Europe for Smart Grids. Conversely, in some densely populated areas, L-band spectrum in the 1 GHz to 2 GHz range may be required to address these population densities whilst still retaining the ability to penetrate urban structures. Although it is recognized that WiMax™ is unlikely to continue as a generally deployed technology in consumer facing networks, for non-3GPP harmonised bands, it may continue as an attractive technology for specialist utility networks.

Annex A: Utility Requirements

Electric utilities are the dominant users of utility telecoms to add intelligence to the networks, for diverse applications including:

- **Tele-protection** to isolate part of the network when a fault is detected, whilst at the same time avoiding interruptions to other users of the network. These systems operate before the fault currents reach the level at which protective circuit breakers operate, minimizing disruption to supplies and reducing the risk of damage to infrastructure through excessive current flows.
- **Supervisory Control and Data Acquisition (SCADA) systems** to initiate controls and monitor voltage, current, temperature levels and switch positions throughout the network, with the opportunity to reconfigure the network remotely in response to changing demand and faults in the network.
- **Distributed Automation** whereby monitoring and control functions can be embedded in the network to remotely control equipment and reconfigure the network automatically without operator intervention, reporting the actions of the automation system to the control room.
- **Dynamic Asset Management** to continuously monitor the condition and loading of assets on a dynamic basis to increase capacity, avoiding the need to re-enforce networks. Real-time measurements can also help to predict failures, avoiding breakdowns and interruptions to customer supplies.
- **Resilient mobile voice communications** enable communications between the control room and field staff for routine operations, safety and emergency restoration of supplies, especially during severe weather and electricity supply outages when commercial networks may not be available.
- **Closed Circuit TeleVision (CCTV)** to monitor remote sites for security, safety and remote monitoring of assets.

Although recent developments facilitate carriage of critical utility communications over commercially available networks, utilities retain a number of uniquely demanding requirements:

- Utility telecommunications growth comes from increasing geographic coverage of the monitoring networks, numbers of connection points and speed of response, rather than necessarily increased data rates.
- Enhanced resilience to enable networks to operate in the absence of main electric power for an extended period, which may extend from a few minutes to 72 hours, and even beyond.
- Resilience against severe weather, including high winds, flooding, snow, icing, extreme temperatures.
- Geographic coverage includes less populated areas, especially where power lines traverse remote regions where there is little population to attract commercial telecom operators. Renewable energy and water resources are also often in remote locations.
- Telecom signal latency and asymmetry requirements in the electricity industry are linked to voltage levels, requiring latencies as low as 6 ms with associated asymmetry of less than 300 µs if protection systems are to function correctly. These requirements emerge from the need to compare 'in cycle' values across an electricity network in real time where the duration of a half-cycle is 10 ms to maintain stability and identify faults.
- Whereas commercial networks are inherently download-centric, utility networks are upload-centric with a small number of control rooms remotely monitoring large geographic areas.
- Utilities need high levels of security for their telecoms networks, not only in terms of integrity to prevent malicious disruption of utility operations; but also guaranteed access where denial of service occurs either from network congestion or malicious intent, denying the utility visibility of its network.
- Consumer telecom product cycles are decreasing so that products can be obsolete within a year, whereas utility infrastructure has a typical life of 50 years. Telecoms equipment embedded in large plant operates continuously such that replacing obsolete telecoms equipment is a major exercise.

Gas networks have less complex requirements than electricity, generally requiring much lower data rates - as low as 600 bits/s. Their specialist requirement is that they may have to operate in environments requiring safety features such as intrinsic safety, and lower voltage requirements, usually 48 volts or less.

Water networks special features are that they are frequently required in remote areas where water resources are located, often isolated from a source of mains electrical power and at ground level, or even sometimes in gullies or below ground.

Annex B: European 450 MHz to 470 MHz band plan options

It should be noted that several Member States have existing licensed CDMA systems within 450 MHz to 460 MHz paired with 460 MHz to 470 MHz used for Smart Grid systems.

Some of these systems above are seeking to migrate to 1,4 MHz or 3 MHz bandwidth LTE systems within that spectrum. Scandinavia is already using some LTE equipment in 450 MHz to 470 MHz to service utility operations, although with a slightly different market structure.

Several spectrum options for Smart Grids have been suggested. A selection of these options are shown within Figure B.1.

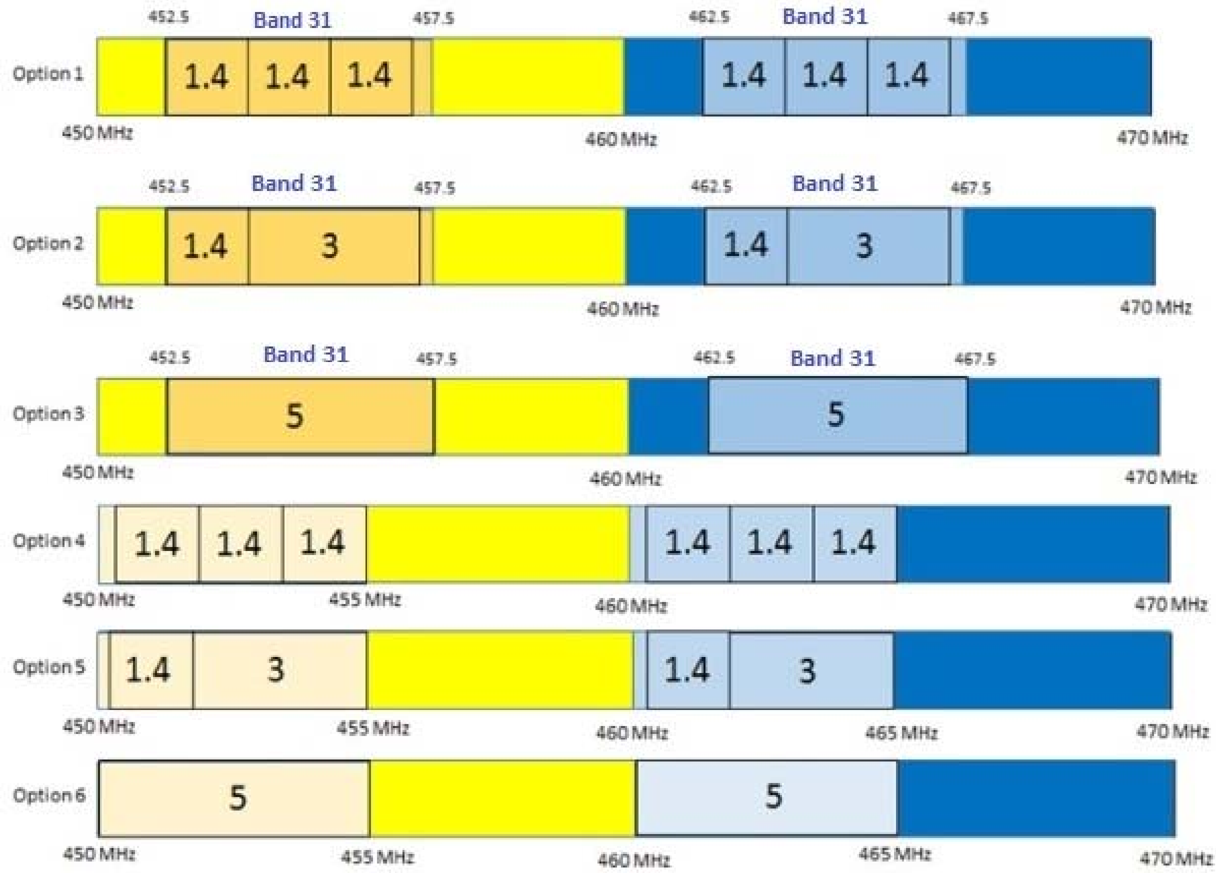

Figure B.1: Spectrum arrangement options for the 450 MHz to 470 MHz band

These spectrum band concepts are now being progressed in standardization through the 3GPP process as shown in Figure B.2.

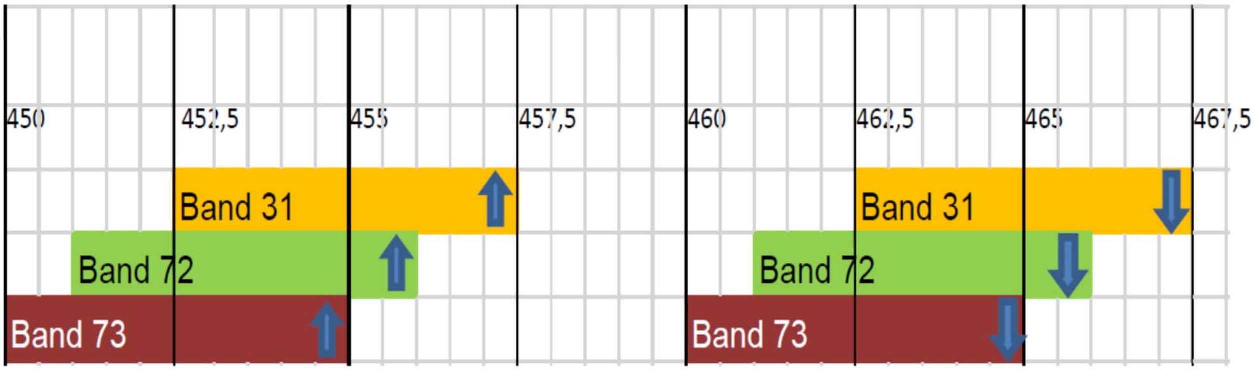

Figure B.2: Spectrum band concepts being progressed through 3GPP

Overall, the spectrum situation in the 400 MHz region is very fluid at present with the following 450 MHz to 470 MHz spectrum allocations in Europe shown in Figure B.3.

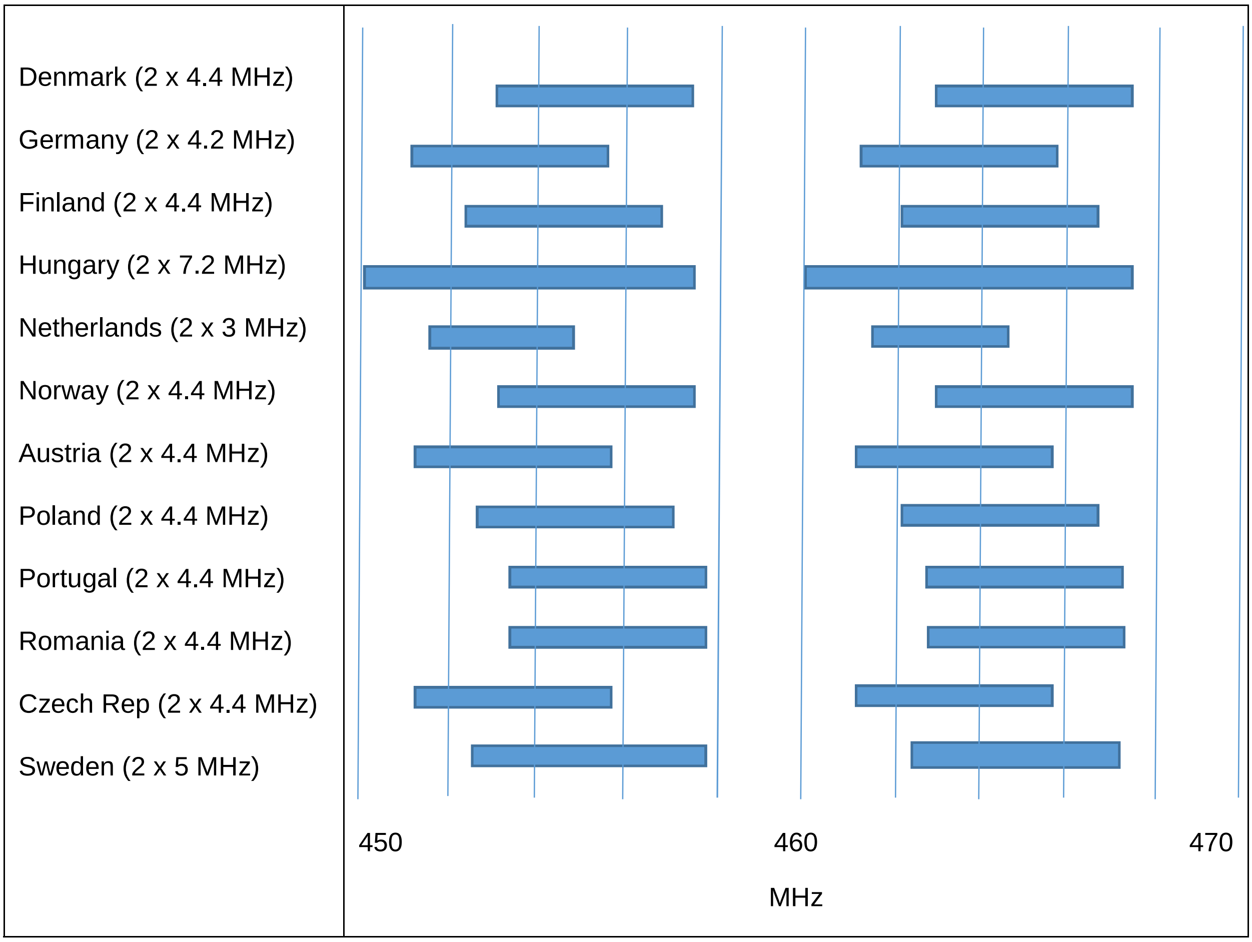

Figure B.3: Example allocations of spectrum in 450 MHz to 470 MHz to broadband services within Europe

Annex C: Essential requirements for Smart Grids

From a radio regulation point of view, the essential requirements for smart grids can be summarized as:

- High availability
- High reliability
- Resilient architecture
- Mains power independence
- Low latency and guaranteed symmetry
- Cyber security
- Wide area coverage
- Cost effective
- 9,6 kbits/s to 10 Mbits/s data rates/bandwidth
- Capable of supporting distributed control
- Longevity of support for technology(ies)
- Graceful degradation
- Air-ground-air operation
- Flexible payloads, but primarily uplink centric

Annex D:
Change History

Date	Version	Information about changes
December 2017	0.1.1	Late draft version. Version 0.1.1 prepared by the Rapporteur
May 2018	0.2.1	Final Version 0.2.1 prepared by the Rapporteur
August 2018	0.0.4	Final version 0.3.1 prepared by the Rapporteur

History

Document history		
V1.1.1	January 2019	Publication