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TECHNICAL REPORT

Smart Grid Systems and Other Radio Systems suitable for Utility Operations, and their long-term spectrum requirements

Reference

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Keywords

dPMR, M2M, PMR, resilience, Smart Grid

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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).

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Executive summary

The present document highlights the future requirements for the mission critical real-time systems, e.g. Smart Grids, that are necessary to meet Europe's need for the "*reliable provision of electricity wherever and whenever it is required*". It also emphasises that almost all of Europe's businesses are dependent on electricity, and/or gas (gas may also be used to generate electricity), to enable them to supply the goods and/or services to Europe's citizens and consumers.

Article 194 of the Treaty on the Functioning of the European Union [i.1] (TFEU/Treaty of Rome) 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) 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*". Smart Electricity Grids will be used to distribute and control these energy efficient/saving networks.

The present document builds on the Smart Grids Co-ordination Group Technical Report Reference Architecture for the Smart Grid [i.2] (RASG) in that it highlights that real-time mission critical Smart Grid systems typically need to be resilient, sometimes requiring best practice resilience [i.3]. By contrast best-effort, non-real-time, Smart Meter systems typically do not need to be resilient. This should clarify which of the systems mentioned within the RASG [i.2] may be suitable for Smart Grid systems and which may only be suitable for Smart Meter systems.

In line with the requirement of Mandate M/462 [i.25] to enable efficient energy use in fixed and mobile information and communication networks, the present document also highlights the power efficiencies of using 12,5 and 25 kHz narrow band equipment versus, say, 150 kHz wideband and MHz-wide broadband equipment.

The present document also highlights that there may be options for the existing ETSI standards suitable for low data rate electricity grid systems, e.g. 9,6 kbit/s within 12,5 kHz narrow band channels, to be updated to enable higher data rates, e.g. 64 kbit/s within 25 kHz channels, for use by Smart Grid systems.

The present document supports the RASG recommendation [i.2] that: *"deployment constraints mandate the need for both wire-line and wireless communications. Utility access to wireless network resources is necessary. Where spectrum is allocated for use by utility networks, this will help progress the Smart Grid deployments ensuring the standard work and products take into account the allocated spectrum for utilities*." It should be noted that there may be significant differences between the enhanced requirements of critical infrastructure utility (CIU) networks, such as those used by the electricity utilities, and the lesser requirements of non-critical infrastructure utility networks.

The present document highlights that when a radio link is used as the diversity route for another link, e.g. wired, the radio link needs to work immediately when required and continue to work despite any power disruptions, etc.

The present document highlights that Utility Operations have ~50 years of experience in designing, installing, operating, and maintaining resilient machine to machine (RM2M) systems such as those used to supervise and control electricity grids. The present document suggests that, whereas Member States are expected to provide an average of 1 200 MHz for IMT systems, the average spectrum requirements for Critical Infrastructure Utility Operations Networks, including Smart Grids, is likely to be ~1,5 percent of that for IMT systems.

Noting that, regarding spectrum for International Mobile Telecommunications (IMT) broadband use, "*the RSPG recommends that future discussions on spectrum management decisions avoid setting an arbitrary amount of spectrum to be harmonised*" [i.23]. It is expected that the evidence based identification of 18 MHz of spectrum within the VHF, 400 MHz UHF and 1,4 GHz bands will be seen as a realistic figure rather than an arbitrary one.

The details of the future spectrum requirements will be expanded within ETSI TR 103 492 [i.26].

Introduction

The present document has been developed to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Posts and Telecommunications Administrations (CEPT).

Almost every service or product offered to Europe's citizens and consumers relies directly or indirectly on the reliable provision of electricity and/or gas (gas can also be used to generate electricity) by Europe's Utility Operations. The European Commission, within its Energy Strategy [i.4], fully recognises and supports the important requirement for "*secure energy supplies to ensure the reliable provision of energy whenever and wherever needed*".

The European Commission's 2030 policy framework seeks to de-carbonise the energy system. The framework encourages the electrification of heat and transport, as well as the connection of more intermittent generation. As these policies take effect, the electricity system will become more complex to plan, control and balance. More flexibility will be needed to ensure that the energy system is able to cope with the future challenges. It will be key to delivering an affordable and climate-friendly energy system [i.5]. Natural disasters, terrorist attacks, and criminal activity can all disrupt the critical energy infrastructure Europeans depend on. While national authorities are primarily responsible for the protection of energy facilities such as power plants and transmission lines, energy disruptions can be felt across national borders. The EC considers that, inter alia, energy infrastructures and facilities for the generation and transmission of electricity in respect of supply electricity between member states are European Critical Infrastructures [i.6] (ECI). Likewise, Gas production, refining, treatment, storage and transmission by pipelines, and liquid natural gas (LNG) terminals, are considered to be ECI.

The EC's European Programme for Critical Infrastructure Protection [i.7] (EPCIP) identifies that "*European Critical Infrastructures (ECI) constitute those designated critical infrastructures which are of the highest importance for the Community and which if disrupted or destroyed would affect two or more Member States, or a single Member State if the critical infrastructure is located in another Member State. The identification and designation of National Critical Infrastructures is defined by a Member State according to predefined national criteria. With due regard to existing Community competences, the responsibility for protecting National Critical Infrastructures falls on the NCI owners/operators and on the Member States*".

The EC Directive 2008/114/EC on European Critical Infrastructures [i.8] fully recognises that the "*infrastructures and facilities for generation and transmission of electricity in respect of supply electricity*" is part of each member state's critical infrastructure. This criticality is emphasised by the European Commissions' acknowledgement of the continued requirement for electricity grids to have Resilience to ensure critical infrastructure protection (CIP). It should be noted that there may be significant differences between the enhanced requirements of critical infrastructure utility (CIU) networks, such as those used by the electricity utilities, and the lesser requirements of non-critical infrastructure utility networks.

Indeed, the importance of Smart Grid electricity is such that the EC has created the M/490 EN Smart Grid Mandate [i.9]. This is the "Standardization Mandate to European Standardisation Organisations (ESOs) to support European Smart Grid deployment". The objective of this mandate was/is to develop or update a set of consistent standards within a common European framework that integrates a variety of digital computing and communication technologies and electrical architectures, and associated processes and services that will achieve interoperability and will enable or facilitate the implementation in Europe of the different high level Smart Grid services. It should be noted that two of the high-level services the Smart Grids Task Force defined are "*enhancing efficiency in day-to-day grid operation*" and "*ensuring network security, system control and quality of supply*". It should also be noted that there are options for the existing 12,5 and 25 kHz narrow band grid systems to use higher data rate systems, e.g. 64 kbit/s in 25 kHz. This will enable any higher data rate Smart Grid systems the option to continue to use 12,5 and 25 kHz narrow bandwidth channels rather than having to move unnecessarily to, say, 150 kHz wideband systems or MHz broadband systems.

The need for reliable, secure, and resilient network operation is an over-riding influence on the choice of technologies or service provision model in some instances. The increasing number of attacks on utility monitoring and control systems makes it increasingly important for Utility Operations systems to be protected against intrusion. Fortunately, Utility Operations have circa 55 years of experience in designing, installing, operating, and maintaining resilient machine to machine (RM2M) systems. During this time, experience has proven that a simple solution to potential external attacks is to ensure that there is an "air gap" between critical utility control networks and the public networks to guarantee secure and reliable operation of the former.

The present document highlights which types of self-managed Resilient Machine to Machine (RM2M) system technologies and self-managed Machine to Machine (M2M) system technologies are currently being used for Utility Operations, and their spectrum requirements.

It is important to note that utility communications systems are typically incorporated for safety, security, system monitoring & control and not for economic gain. Ownership, or self-licensing, is seen as a cost effective method of accessing spectrum. It also ensures that the systems will work exactly as they are designed/intended to rather than risking using adapted generic systems that rely on a supplier meeting key performance indicators (KPI) even during extreme conditions, e.g. coverage during storms to remote rural locations with major power outages.

In considering these requirements, it should be noted that future Critical Infrastructure Utility Operations spectrum requirements are expected to be very limited compared with the spectrum requirements of, for example, broadband public mobile systems. Indeed, the European Utility Telecom Council (EUTC) spectrum proposal identified a potential requirement for 6 MHz of licensed 400 MHz UHF and 10 MHz of 1,4 GHz spectrum for Smart Grid utility operations. This potential requirement may be considered minimal in contrast to the 1 200 MHz of spectrum proposed for public mobile broadband data in the European Radio Spectrum Policy Programme (RSPP).

It will be seen that in some cases, with the current absence of suitable licensed spectrum, utility operational systems may need to use alternative wireless solutions, but this does not necessarily indicate their suitability in the long-term.

The present document notes that the European Common Allocation Table shows 450 MHz to 470 MHz is identified for use by narrow band mobile systems complying with, for example, ETSI EN 300 086 [i.10], ETSI EN 300 113 [i.11], ETSI EN 301 166 [i.21], and ETSI EN 302 561 [i.13].

NOTE: The UK power utilities use 12,5 kHz narrow band UHF systems that operate within the technical requirements of ETSI EN 300 113 [i.11] and with no detrimental impact to adjacent 12,5 kHz narrow band private mobile radio users.)

The present document also notes ITU footnote RR No. 5.286AA [i.14]: "*The band 450-470 MHz is identified for use by administrations wishing to implement International Mobile Telecommunications (IMT). See Resolution 224 (Rev.WRC-07). This identification does not preclude the use of this band by any application of the services to which it is allocated and does not establish priority in the Radio Regulations. (WRC-07)*".

1 Scope

The present document considers:

1) systems suitable for Critical Infrastructure Utility Operations Smart Grids;

2) the essential requirements for systems suitable for other Utility Operations radio systems;

3) the long-term spectrum requirements for Utilities.

The present document identifies the functional requirements for existing and future radio systems for critical infrastructure utility operators, e.g. electricity and gas, and associated implications for spectrum requirements. Requirements for Smart Cities or Smart Homes are not within the scope of the present document. The present document does not contain any spectrum requests. It is envisaged that a further Technical Report (TR) will be developed complementing the present document and providing a formal System Reference Document for CEPT to consider.

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] "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.2] 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.3] CPNI: "Telecommunications Resilience Good Practice Guide", Version 4.

NOTE: Available at http://www.cpni.gov.uk/documents/publications/undated_pubs/1001002-guide_to_telecomms_resilience_v4.pdf

[i.4] EC Energy Strategy.

NOTE: Available at https://ec.europa.eu/energy/en/topics/energy-strategy.

[i.5] Smart Grid Task Force report: "Regulatory Recommendations for the Deployment of Flexiblity".

NOTE: Available at http://ec.europa.eu/energy/sites/ener/files/documents/EG3%20Final%20-%20January%202015.pdf.

[i.6] Council Directive 2008/114/EC on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection.

NOTE: Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:345:0075:0082:EN:PDF.

[i.7] European Programme for Critical Infrastructure Protection.

NOTE: Available at http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV%3Al33260.

[i.8] Council Directive 2008/114/EC on European Critical Infrastructures Annex 1.

NOTE: Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:345:0075:0082:EN:PDF.

[i.9] EC M/490 EN Smart Grid Mandate.

NOTE: Available at ftp://ftp.cencenelec.eu/CENELEC/Smartgrid/M490.pdf.

[i.10] ETSI EN 300 086: "Land Mobile Service; Radio equipment with an internal or external RF connector intended primarily for analogue speech; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.11] 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.12] ETSI EN 302 426: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Harmonized EN for CDMA spread spectrum Repeaters operating in the 450 MHz cellular band (CDMA450) and the 410 MHz, 450 MHz and 870 MHz PAMR bands (CDMA-PAMR) covering essential requirements of article 3.2 of the R&TTE Directive".

[i.13] ETSI EN 302 561: "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; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.14] ITU Radio Regulations footnote No. 5.286AA.

[i.15] EUTC position paper: "Spectrum needs for Utilities"

NOTE: Available at http://utc.org/europe/wp-content/uploads/sites/4/2016/04/EUTC-Spectrum-Position-Paper.pdf.

[i.16] IEC 61850: "Power Utility Automation".

[i.17] Ofcom (UK) MPT1411: "Performance Specifications and Frequency Assignment Criteria for Private Fixed Mobile Equipment for Telemetry and Telecontrol Purposes Operating in the Bands 457.5 to 458.5 MHz and 463.0 to 464.0 MHz". (January 1995).

[i.18] Ofcom (UK) OfW49: "Fixed Point-to-Point and Point-to- Multipoint Scanning Telemetry Radio Services with Analogue Modulation Operating in the Frequency Ranges 457.5 to 458.5 MHz paired with 463.0 to 464.0 MHz".

NOTE: Available at http://stakeholders.ofcom.org.uk/binaries/spectrum/spectrum-policy-area/spectrum-management/research-guidelines-tech-info/tfac/tfac_ofw49.pdf.

[i.19] British Radiocommunications Agency MPT1327: "Trunked Private Mobile Radio Systems".

[i.20] ScottishPower press release 16th February 2012.

NOTE: Available at http://www.scottishpower.com/news/pages/scottishpower_and_national_grid_award_contracts_to_deliver_major_electricity_grid_upgrade.asp

[i.21] ETSI EN 301 166: "Radio equipment for analogue and/or digital communication (speech and/or data) and operating on narrow band channels and having an antenna connector".

[i.22] Telent Study for UK Energy Networks Association (ENA).

[i.23] European Commission Radio Spectrum Policy Group: "RSPG Opinion on the implementation of the current RSPP and its revision to address the next period".

NOTE: Available at https://circabc.europa.eu/d/a/workspace/SpacesStore/4709f36a-f27b-4850-a19b-95df0154d5aa/FRSPG16-006final_RSPP_opinion.pdf.

[i.24] Joint Radio Committee history.

NOTE: Available at http://www.jrc.co.uk/about-us/history.

[i.25] EC M/462 Standardisation mandate addressed to CEN, CENELEC and ETSI in the field of ICT to enable efficient energy use in fixed and mobile information and communication networks.

[i.26] ETSI TR 103 492: " 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".

[i.27] ETSI TS 102 361: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Technical Requirements for Digital Mobile Radio (DMR)".

[i.28] ETSI TS 102 490: "Intelligent Transport Systems (ITS); Security; ITS communications security architecture and security management".

[i.29] ETSI TS 102 658: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Digital Private Mobile Radio (dPMR) using FDMA with a channel spacing of 6,25 kHz".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

400 MHz UHF band: spectrum within the range 380 MHz to 470 MHz

best practice resilience: measures that can be taken to guarantee resilience, irrespective of cost [i.3]

broadband: channel widths of 1 300 kHz and greater

good practice resilience: measures which can be taken to provide a degree of resilience commensurate with the Corporate risk strategy [i.3]

Machine to Machine (M2M) systems: any past, existing, or future wireless, wired, fibre, or combination of technologies that enable connected devices to exchange information and perform actions typically without the manual assistance of humans

narrow band: channel widths of 6,25 kHz, 12,5 kHz and 25 kHz

Resilient Machine to Machine (RM2M) systems: any suitably enhanced/hardened past, existing, or future wireless, wired, fibre, or combination of technologies that enable connected devices to exchange information and perform actions typically without the manual assistance of humans

upload centric: remote communication point that primarily transmits data to a central point rather than primarily receives data from a central point

NOTE: This is opposite to a typical public mobile system.

wide band: 50 kHz to 14 300 kHz channel widths

3.2 Symbols

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

dBi	dB gain with respect to an isotropic radiator
dBW	dB gain with respect to one watt
kHz	Kilo Hertz
MHz	Mega Hertz
N_{RX}	Receiver noise power density typical

3.3 Abbreviations

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

BER	Bit Error Rate
CENELEC	European Committee for Electro-technical Standardisation
CCTV	Closed-Circuit TeleVision
CDMA	Code Division Multiple Access
CEPT	European Conference of Posts and Telecommunications Administrations
CIU	Critical Infrastructure Utilities
CIP	Critical Infrastructure Protection
DMR	Digital Mobile Radio

NOTE: 12,5 kHz digital radio technology as defined in ETSI TS 102 361 [i.27].

dPMR	Digital Private Mobile Radio

NOTE: 6,25 kHz digital radio technology as defined in ETSI TS 102 490 [i.28] and ETSI TS 102 658 [i.29].

EC	European Commission
ECC	Electronic Communications Committee
ECI	European Critical Infrastructures
EHV	Extra High Voltage

NOTE: 275 kV and 400 kV.

e.i.r.p.	Effective Isotropically Radiated Power
EPCIP	European Programme for Critical Infrastructure Protection
ESO	European Standardisation Organisations
ETSI	European Telecommunications Standards Institute
EU	European Union
EUTC	European Utilities Telecom Council
FM	Frequency Modulation
FS	Fixed Services
FSK	Frequency Shift Keying
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HV	High Voltage

NOTE: 11 kV, 33 kV, 66 kV and 132 kV.

IEC	International Electro-technical Commission
IMT	International Mobile Telecommunications
ITU-R	International Telecommunications Union - Radiocommunications
KPI	Key Performance Indicator
LNG	Liquefied Natural Gas
LTE	Long Term Evolution
LV	Low Voltage

NOTE: 230 volts and 400 volts.

M2M	Machine to Machine
MW	Mega Watt
NB-IoT	Narrow Band Internet of Things

NOTE: 180 kHz channel width.

NB-LTE	Narrow Band Long Term Evolution

NOTE: 200 kHz channel width.

NCI	National Critical Infrastructures
P25	Project 25
PBR	Private Broadband Radio

PLC	Power Line Communications
PMR	Private Mobile Radio (ITU definition)

NOTE: Also known as Professional Mobile Radio.

PMP	Point to Multi-Point
PP	Point to Point
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RASG	Reference Architecture for the Smart Grid
RM2M	Resilient Machine to Machine
RSPG	Radio Spectrum Policy Group
RSPP	Radio Spectrum Policy Programme
SCADA	Supervisory Control And Data Acquisition
SINAD	(signal + noise + distortion) / (noise + distortion) ratio
SR	Systems Reference document
ST	Scanning Telemetry
TDMA	Time Division Multiple Access
TEDS	TETRA Enhanced Data Service
TETRA	TErrestrial Trunked RAdio
TFEU	Treaty on the Functioning of the European Union (The Treaty of Rome)
TR	Technical Report
Tx	Transmit
UHF	Ultra High Frequency (300 to 3,000 MHz)
UON	Utility Operations Networks
VHF	Very High Frequency (30 to 300 MHz)

4 Utility operations requirements

Utilities have a wide and diverse range of requirements. In an effort to simplify and codify these requirements, the European Utilities Telecoms Council's (EUTC) Spectrum Group distilled the requirements of a number of different utilities to identify the Smart Grid and Smart Meter services which may require radio connections [i.15]. These are shown in Table 4.1.

Table 4.1: EUTC Smart Grid telecommunications service requirements summary table for a typical European distribution network operator

RADIO CONNECTED DEVICES ONLY													
Service	**Description**	**Priority or criticality**	**Type of service**	**Coverage**	**Volume in 2010**	**Predicted volume in 2016**	**Predicted volume in 2020**	**Predicted volume in 2030**	**Data rate required**	**Data volume**	**Latency**	**availability**	**Comments**
PROTECTION													
ClassA: Unit Protection (over 100 kV)	Connection between protection devices at either end of a transmission line	High	pt-pt	main routes	0	5	10	15	64 kbit/s	Continuo us	5 ms	99,99 %	duplicated circuits with max 400 us differential delay
ClassB: Distance protection (over 100 kV)	fast over-current protection on long transmission lines	High	area	specified sites	0	5	25	50		1 kbyte	5 ms	99,99 %	
ClassC: Blocking signals (over 100 kV)	Broadcast signal from a protection relay detecting a fault to delay the operation of adjacent protection relays	High	pt-pt	main routes	0	10	30	60		Continuo us	5 ms	99,99 %	duplicated curcuits with max 400us differential delay
ClassD: protection for circuits of less than 100 kV	Protection equipment for medium voltage equipment	high	pt-pt	main routes	0	20	100	200		Continuo us	10 ms	99,99 %	duplicated circuits with max 1ms differential delay
ClassE: remote access to protection relays	remote configuration of protection relays from control centre	medium	pt-pt	specified sites	0	20	50	100		1 Mbyte	1 s	90 %	
SCADA													
ClassA: Grid level substations (more than 100 kV)	Monitoring and control of devices at transmission substations	high	pt-pt	main routes	0	5	20	20	64 kbit/s	1 kbyte	100 ms	99,99 %	radio used to provide alterative routing

RADIO CONNECTED DEVICES ONLY													
Service	**Description**	**Priority or criticality**	**Type of service**	**Coverage**	**Volume in 2010**	**Predicted volume in 2016**	**Predicted volume in 2020**	**Predicted volume in 2030**	**Data rate required**	**Data volume**	**Latency**	**availability**	**Comments**
ClassB: Primary Distribution level substations (transforming from above 100 kV to below 100 kV)	Monitoring and control of devices at primary distribution substations	high	pt-pt	all routes	500	500	500	500	64 kbit/s		100 ms	99,99 %	
ClassC: Distribution substations below 100 kV	Monitoring and control of devices at secondary distribution substations	high	pt-multipt	100 % of utility service area	1 000	5 000	20 000	20 000	64 kbit/s		1 s	99,99 %	
ClassD: distribution automation	Monitoring and control of devices at substations with the possibility of autonomous actions	low	mesh		50	500	5 000	10 000	8 kbit/s		1 s	99 %	
ClassE: major generation sites (more than 100 MW)	Monitoring and control for remote connection and disconnection of generation plant	high	pt-pt	specified sites	10	11	12	13	64 kbit/s		100 ms	99,99 %	radio used to provide alterative routing
ClassF: medium size generation sites (100 MW down to 1 MW)	Monitoring and control for remote connection and disconnection of generation plant	medium	pt-pt		20	25	30	35	64 kbit/s		1 s	99,99 %	radio used to provide alterative routing
ClassG: small size generation sites (less than 1 MW)	Monitoring and control for remote connection and disconnection of generation plant	low	pt-pt		100	120	150	200	8 kbit/s		10 s	99 %	
ClassH: Smart Grid Hub	Allows monitoring and control of local distribution points in response to changes in local supply and demand	medium	pt-pt	100 % of utility service area	0	500	5 000	6 000	64 kbit/s		1 s	99,9 %	
ClassI: Smart Grid concentrator	Allows collection of local demand and supply data	low	mesh		0	1 500	50 000	60 000	10 kbit/s		10 s	99 %	

RADIO CONNECTED DEVICES ONLY													
Service	**Description**	**Priority or criticality**	**Type of service**	**Coverage**	**Volume in 2010**	**Predicted volume in 2016**	**Predicted volume in 2020**	**Predicted volume in 2030**	**Data rate required**	**Data volume**	**Latency**	**availability**	**Comments**
SCADA													
ClassJ: data recorders	allows data from various event recorders (temperature, wind speed, etc.) to be downloaded	low	pt-multipt	specified sites	500	1 000	2 500	3 000	64 kbit/s	1 Mbyte	1 min	99 %	assumes 50 % by radio and 50 % wire borne
VOICE													
Emergency voice from substations (fixed)	Allows communication between staff at the control centre and remote sites during fault rectification and other operations	high	pt-pt	specified sites	0	10	20	30	32 kbit/s	n/a	100 ms	99,99 %	assumes majority of comms use copper or fibre
Emergency voice from mobile staff	Allows communication between staff at the control centre and field staff when not at fixed locations	medium	mobile	100 % of utility service area	600	550	500	500	8 kbit/s	n/a	500 ms	99 %	assumes declining maintenance workforce
CCTV													
ClassA: site security	Allows control room staff to monitor remote sites in real time and download images and video streams	medium	pt-pt	specified sites	0	250	500	1 000	256 kbit/s	5 Mbytes	1 s	99,9 %	assumes 50 % by radio and 50 % wire borne; and is likely to be merged with other traffic for backhaul
ClassB: management of site operations remotely	Allows control room staff to monitor operations at remote sites and interact with field force workers on site	low	pt-pt		0	150	250	500	256 kbit/s	10 Mbytes	1 s	99 %	
ClassC: Site Entry Control	Allows control room staff to view images of visitors to remote sites before granting access	low	pt-pt		0	500	1 000	1 500	64 kbit/s	1 Mbyte	1 s	99,9 %	
ClassB: Operations telecoms	Enables monitoring and control of operational telecoms infrastructure from a central location	medium	pt-pt	urban	0	10	20	30	64 kbit/s	1 Mbyte	500 ms	99,99 %	assumes radio only used where wired systems have failed

RADIO CONNECTED DEVICES ONLY													
Service	**Description**	**Priority or criticality**	**Type of service**	**Coverage**	**Volume in 2010**	**Predicted volume in 2016**	**Predicted volume in 2020**	**Predicted volume in 2030**	**Data rate required**	**Data volume**	**Latency**	**availability**	**Comments**
MANAGEMENT													
ClassA: Remote data management	Enables field staff to access key centrally-held and real time operational data in support of work routines at remote sites	low	area	rural	0	1 000	2 000	3 000	512 kbit/s	10 Mbytes	500 ms	99,99 %	radio likely to be used only for access network. Backhaul via fixed networks.
ClassB: Operations telecoms	Enables monitoring and control of operational telecoms infrastructure from a central location	medium	pt-pt	urban	0	10	20	30	64 kbit/s	1 Mbyte	500 ms	99,99 %	assumes radio only used where wired systems have failed
METERING													
ClassA: Metering data for revenue collection	Collection of data to enable customers to be charged for energy usage and credited for energy exported	low	mesh	100 % of utility service area	500	2 000 000	5 000 000	5 000 000	10 kbit/s	10 kbytes	1 min	90 %	non-radio technologies such as PLC may also be used, or public networks such as GSM/GPRS, or unlicensed frequencies.
ClassB: Metering data for network management	Allows network operator to determine aggregate demand and infeed to predict short term network changes, and to collect data to enable designers to scope the network.	low			500	20 000	50 000	100 000		100 kbytes	1 min for alarms & 24 hours for bulk data	95 %	
ClassC: Outage alarms and restoration confirmation	Enable network operator to be aware when customers are off-supply, and confirm restoration of supply	medium			500	2 000 000	5 000 000	5 000 000		1 kbyte	3 mins	95 %	
ClassD: Remote tariff management	Enables consumer tariffs to be changed in real time to encourage take-up of surplus energy and to reduce demand at peaks times	low			100	2 000 000	5 000 000	5 000 000		100 kbytes	30 mins	90 %	

RADIO CONNECTED DEVICES ONLY													
Service	**Description**	**Priority or criticality**	**Type of service**	**Coverage**	**Volume in 2010**	**Predicted volume in 2016**	**Predicted volume in 2020**	**Predicted volume in 2030**	**Data rate required**	**Data volume**	**Latency**	**availability**	**Comments**
METERING													
ClassE: Remote connection/disconnection /supply restriction	Enables supply to be terminated for empty properties or restricted or terminated where consumers have not paid bills	low			0	2 000 000	5 000 000	5 000 000		1 kbyte	1 min	99 %	non-radio technologies such as PLC may also be used, or public networks such as GSM/GPRS, or unlicensed frequencies
ClassF: Remote tariff enablement for pre-payment meters	Enables energy supplier to make available a pre-paid amount of energy with warnings as credit approaches limit, and further credits to be added.	low			0	1 000	1 500	10 000		1 kbyte	10 mins	99 %	assumes management of customer accounts for fuel poor improves
ClassG: Demand management	Remotely connecting or disconnecting customer loads in response to network requirements and availability of supply	medium	mesh	100 % of utility service area	0	1 000 000	2 000 000	3 000 000	10 kbit/s	10 kbytes	10 mins	95 %	non-radio technologies such as PLC may also be used, or public networks such as GSM/GPRS, or unlicensed frequencies.
ClassH: Electric vehicle charging	Recharging (& possible use as a source of power) electric vehicle batteries with capability to schedule charging to balance load on distribution feeders, and also charge the customer's account for the electricity wherever vehicle is connected.	low			0	5 000	20 000	50 000		1 kbyte	10 mins	90 %	

RADIO CONNECTED DEVICES ONLY													
Service	**Description**	**Priority or criticality**	**Type of service**	**Coverage**	**Volume in 2010**	**Predicted volume in 2016**	**Predicted volume in 2020**	**Predicted volume in 2030**	**Data rate required**	**Data volume**	**Latency**	**availability**	**Comments**
IN-HOME DISPLAY													
Messaging directly to a display in domestic properties	Providing critical network related information to consumers through their in-home displays, especially planned outages and emergency restoration times.	low	mesh	100 % of utility service area	0	2 000 000	5 000 000	5 000 000	10 kbit/s	1 kbyte	5 mins	90 %	non-radio technologies such as PLC may also be used, or public networks such as GSM/GPRS, or unlicensed frequencies.
Load Control Devices	Allowing supplier, transmission or distribution operator to remotely control devices (eg thermostats) in homes and businesses.	low	mesh		100	1 00 000	250 000	1 000 000		1 kbyte	10 mins	90 %	

Table 4.1 is intended to emphasise the array of requirements for critical infrastructure utility operations systems. A summary of key requirements includes:

- 100 % coverage of the utility service area, including remote and unpopulated areas;
- designed to meet exacting technical requirements, rather than for economic gain;
- ability for best practice resilience/Resilient Machine to Machine (RM2M) operation;
- instant and guaranteed channel access;
- up to 99,99 % link availability (e.g. for power line protection and SCADA) plus link diversity;

NOTE: When the primary route is interrupted, it is essential that the diversity route works immediately and correctly.

- access to sufficient licensed spectrum, in bands with different propagation characteristics:
  - 2 x 1 MHz within the VHF bands (e.g. for wide-area voice and low data rate links);
  - 400 MHz UHF Band (e.g. low data rate links over medium to long distances);
  - 1,4 GHz Band (≤ 2 Mbit/s links over medium to long distances);
  - 7,5 GHz, 13 GHz, 23 GHz and 38 GHz (≥ 2 Mbit/s links over medium to short distances);
- the above bands may be used for redundant/diversity routing, e.g. using two or more wireless and/or wired/fibre links from different sources to a remote station;
- system and transmitted data have high levels of network security and integrity, including:
  - no connection to external and/or public communications systems, e.g. the Internet;
  - hardened to ensure reliable operation in severe environmental conditions, including electromagnetic disturbances such a lightning strikes;
  - up to 96 hours power backup;
- ability for very low end-to-end latency, e.g. 10 ms for protection circuits;
- low jitter and synchronous requirements; and
- longevity of life and support, e.g. 10 to 20 years.

Systems with the higher percentages of availability are more resilient.

It is important to note that, unlike many communications systems, power utility systems are typically incorporated for safety, security, system monitoring and control, and not for direct economic gain. Ownership, or self-licensing, is seen as a much more cost effective method of accessing spectrum rather than using systems from third-party spectrum owners who are primarily seeking economic gain. It also ensures that the systems are designed, constructed, and maintained to work exactly as they are intended even during the most adverse of conditions. This is in contrast to risking using adapted generic systems that rely on a supplier meeting key performance indicators (KPI) whilst perhaps minimising their costs to do so.

Caution should be observed when assessing which communication systems may be used for each of the above systems. Some technologies, or their typical network architecture, may only be suitable for best effort Smart Metering rather than mission critical real-time Smart Grids.

The UK has used 12,5 kHz narrow band Electronic Tele-control Equipment Scanning Telemetry systems very successfully to control and monitor power utility systems during the past 55 years [i.24]. These narrow band systems typically offer very efficient operation. It is usual for only the minimum spectrum to be occupied, with those channels perhaps having full 24 hour control and monitoring activity. For example, a 24 hour Scanning Telemetry (ST) system may use only a single 12,5 kHz narrow band channel and cover an area with a 35 km radius. There is likely to be a requirement for these narrow band systems to continue to be used.

Annex A gives an overview of the UK's electricity transmission and distribution systems. It highlights that, in future, most of the thousands of 11 kV sub-stations will need to be monitored and controlled as part of the Smart Grid.

Scanning Telemetry systems are point-to-multi-point systems and may be the core of a SCADA system. As an example of a typical requirement in the UK, the power (electricity and gas) and water utilities have primary access to 80 x 12,5 kHz channels (2 x 1 MHz) for ST systems.

The basic parameters for these UK systems are:

- system availability approaching 99,9 %;
- cells each with a 25 km radius;
- 6 channels per cell, giving 2 channels per utility;
- 12 cells per cluster, giving a co-channel re-use distance of 150 km; and
- potential channel re-uses of 23 times across the UK.

Further details of a typical scanning telemetry system are given within annex B.

The details of the future spectrum requirements will be expanded within ETSI TR 103 492 [i.26].

5 Existing and potential utility operations technologies

5.1 Data systems

Table 4.1 shows that the current typical data rates of the fixed radio links vary from 1 kbit/s to 256 kbit/s. In the UK, the typical channel bandwidths used to transmit these data rates vary from 12,5 kHz (e.g. within the VHF and 400 MHz UHF bands) to 512 kHz (e.g. within the 1,4 GHz and microwave bands).

Figure A.3 shows the predicted significant increase in the percentage of high voltage (HV) sub-stations requiring connection as part of the upgrade to Smart Grids. With Smart Grids, the typical 9,6 kbit/s data rates are expected to rise. Improvements in technology will enable these higher data rates to be transmitted within the existing narrow bandwidths, e.g. 32 kbit/s within a 12,5 kHz channel and 64 kbit/s within a 25 kHz channel.

In line with the requirement of Mandate M/462 [i.25], to enable efficient energy use in fixed and mobile information and communication networks, and with spectrum being recognised as a scarce resource, utility systems already tend to use the narrowest channel possible to communicate. For example, a 12,5 kHz narrow band channel is more likely to be used than a 150 kHz wideband channel to transmit low data rates. It should be noted that, with the anticipated increase in data rates to 64 kbit/s to 100 kbit/s, it is expected that 25 kHz and 50 kHz channels may be required in future.

Existing UK SCADA systems typically have a data rate of 9,6 kbit/s. With their potentially being used as the core of many Smart Grid systems, this data rate is likely to increase significantly to circa 64 kbit/s. This will require 12,5 kHz and 25 kHz narrow band equipment that can offer much higher modulation levels. This sounds simple but, physics is physics so, you don't get something for nothing. This higher modulation equipment will need to be operated at correspondingly higher powers than existing equipment. This will result in a wider area of signal coverage and therefore extended channel re-use distances. This may also result in a proportional increase in the number of 12,5 kHz and 25 kHz narrow band channels required.

ETSI EN 300 113 [i.11] is suitable for future 12,5 kHz and 25 kHz equipment compliance.

Another option that would also enable higher data rates to be transmitted would be to use 25 kHz and 50 kHz channels, and perhaps 100 kHz and 150 kHz channels.

ETSI EN 302 561 [i.13] is suitable for future 25 kHz, 50 kHz, 100 kHz and 150 kHz equipment compliance.

Member States may prefer to licence blocks of 12,5 kHz and 25 kHz narrow band channels because of their spectrum efficiency, e.g. 160 x 12,5 kHz narrow band channels can be fitted into a 1 x 200 kHz, so called, narrow band LTE channel. Another advantage of using 12,5 kHz and 25 kHz narrow band channels is that they only sterilise narrow channels of spectrum from access by other users during the periods that they are not being accessed.

NOTE 1: Smart Grids will be controlled for 24 hours a day so periods of non-access are expected to be minimal.

It should be noted that the resilience of a system does not necessarily depend on the technology being used. Resilience is typically a necessary overhead that is required to make a utility system robust even under the most extreme conditions. Unfortunately, systems that are built to make a profit do not typically include suitable resilience. The option to operate resilient private broadband radio on-site systems is likely to be a requirement.

Table 5.1 identifies examples of the existing and potential technologies that may be suitable for Smart Grids.

Table 5.1: example existing and potential technologies that may be suitable for Smart Grids

Technology	Channel (kHz)	Data rate (kbit/s)	Adjacent channel selectivity (dB)	Co-channel rejection (dB)	Receiver sensitivity (dBm)	Standard
Analogue	12,5	1,2 to 2,4	55	12	-94 (27dB SINAD)	MPT1411
Digital	12,5	9,6	60	12	-110	ETSI EN 300 113 [i.11]
Digital	12,5	16	60	17	-105	
Digital	12,5	38,4	60	24	-98	
Digital	12,5	> 38,4	60	29	-93	
Digital	25	9,,6	70	8	-110	
Digital	25	38,4	70	12	-105	
Digital	25	76,8	70	19	-98	
Digital	25	> 76,8	70	24	-93	
Digital	25	38,4	45	12	-111	ETSI EN 302 561 [i.13]
Digital	25	76,8	45	19	-104	
Digital	25	> 76,8	45	24	-99	
Digital	50	76,8	39	12	-108	
Digital	50	153,6	39	19	-101	
Digital	50	> 153,6	39	24	-95	
Digital	100	153,6	35	12	-105	
Digital	100	307,2	35	19	-98	
Digital	100	> 307,2	35	24	-93	
Digital	150	230,4	33	12	-103	
Digital	150	460,8	33	19	-97	
Digital	150	> 460,8	33	24	-91	
Digital	1 250	[Tbd]	40	[Tbd]	[Tbd]	ETSI EN 302 426 [i.12]

It should be noted that, so called, NB-LTE was considered but is not included because it can only upload 144 kbit/s within its 200 kHz channel whereas ETSI EN 302 561 [i.13] compliant equipment can upload 153 kbit/s within a 50 kHz channel.

NOTE 2: Utility communications are typically upload centric rather than download centric. Also, the out-of-band characteristics of, so called, NB-LTE are likely to be significantly relaxed compared to those of ETSI EN 302 561 [i.13]. (It should be also noted that NB-LTE and NB-IoT are not the same technology.)

In the UK, Utility Operations are replacing their older 12,5 kHz analogue systems, e.g. conforming to MPT1411 [i.16], with digital systems. These 12,5 kHz digital systems have become very popular because they meet the same frequency assignment criteria as the adjacent channel PMR systems.

Utility Operations access communications are often managed by using Supervisory Control and Data Acquisition (SCADA) systems. This includes point-to-multipoint networks referred to as Scanning Telemetry or Polling Radio. The Ofcom (UK) OfW49 [i.17] document is used to plan Scanning Telemetry (ST) systems within the UK. Unfortunately, there is currently no harmonised European equivalent. Additionally, current ST frequency assignment criteria rules generally restrict modulation schemes such that 9,6 kbit/s is typically the highest usable data rate in a 12,5 kHz channel.

Table 5.1 shows that some higher data rates digital systems, including SCADA, may already be available using equipment that is compliant with ETSI EN 300 113 [i.11] and ETSI EN 302 561 [i.13]. Unfortunately, suitable spectrum for licensing the 25 kHz, 50 kHz, 100 kHz, and 150 kHz channel widths aren't typically available in most EU Member States. Likewise, wideband systems may be suitable for significantly higher data rate systems, e.g. for backhaul and core, the need for broadband 1,25, 1,4, and 3 MHz UHF channels has limited their deployment because these wider bandwidths are not available in many EU Member States. This could be resolved if an allocation of spectrum, e.g. 2 x 3 MHz in the 400 MHz band, for Utility Operations systems were to be made available.

It is recognised that there may already be significant use of the 400 MHz spectrum, e.g. within 450 MHz to 470 MHz, by some Member States so it may be necessary to identify different 2 x 3 MHz blocks in some EU Member States.

Other technologies have been suggested as being suitable for utility operations networks but their system installation would need to include at least the essential criteria listed in clause 4.

Satellite systems may be used for some utility operations systems where end-to-end latency is not an issue. Licence exempt equipment, e.g. within 870 MHz to 876 MHz, may be used for best effort systems, e.g. Smart Meters. Likewise, public mobile systems may be used for best effort systems, e.g. using General Packet Radio Service (GPRS).

Best practice resilience sites are likely to include 96-hour independent power backup. This backup is designed to ensure that, in a worst-case scenario, mains power will be returned as smoothly as possible despite a lengthy passage of time. This re-supply is likely to be controlled so that citizens, and businesses, are connected in phases. This would include the reconnection of mobile phone masts/base stations that may have been without power for most of the disruption.

NOTE 3: Public mobile phone systems would therefore need to have appropriate resilience and power backup measures before they could be considered suitable for Utility Operations use. This would likely result in a considerable additional cost that would need to be passed on to the consumer.

5.2 High-definition Real-time Video

There is much debate about the need for 2 Mbit/s high-definition real-time video and whether this video is operationally critical such that it needs to be carried on a resilient network. Ultimately, the need of real-time video, and other high speed data services, will only become clear as Smart Grids are rolled out. If required, it may be sufficient to use resilient private broadband radio (PBR) on-site systems for video and other high data rate mobile systems.

5.3 Other Utility Operations Radio Systems

The present clause identifies systems that may be suitable for Other Utility Operations Radio Systems, e.g. point-to-area.

These systems are used by critical utility operations for day-to-day engineering work and also during emergencies such as when repairing storm damage. With the majority of Europe's citizens, consumers, and businesses relying on the 'reliable provision of electricity wherever and whenever it is required', and its speedy reconnection in the event of a power cut, these systems need to continue to work when all other communications have failed. They are therefore likely to be designed to include at least the following essential criteria:

- priority channel/system access;
- 100 % coverage of the utility service area, including remote/unpopulated areas;
- cost efficient systems (i.e. any increase in cost may need to be passed on to the consumer in their energy bills):
  - e.g. self-provided resilient systems within self-licensed spectrum;
- and ability for best practice resilience operation.

In the UK, digital systems are now being rolled out by Utility Operations to replace older analogue frequency modulated (FM) systems and trunked MPT1327 [i.19] Private Mobile Radio (PMR) Systems. Several technologies exist for the VHF and UHF bands, e.g. dPMR, DMR, Tetrapol, TETRA, and P25, that may be used in Member States where suitable channels are available.

6 Long-term spectrum requirements for utility operations

Clause 4 highlights that the number of links required to transport Utility Operations data will rise very significantly. Indeed, Smart Grids are predicted to need to monitor ten times the number of existing locations, e.g. sub-stations. The resulting spectrum requirements are likely to be compounded by access systems needing to increase their data rates, e.g. from 9,6 kbit/s to perhaps 64 kbit/s, or greater.

As detailed above, some higher data rates digital systems may already be available using equipment that is compliant with ETSI EN 300 113 [i.11] and ETSI EN 302 561 [i.13]. Unfortunately, as already noted, suitable spectrum for licensing the 25 kHz, 50 kHz, 100 kHz, and 150 kHz channel widths isn't typically available in most EU Member States. Also, whilst wideband systems may be suitable for significantly higher data rate systems, the need for 1,25, 1,4, and 3 MHz UHF channels has limited their deployment because these bandwidths are also not available in many EU Member States. These shortfalls may be resolved if an allocation of spectrum, e.g. 2 x 3 MHz in the 400 MHz band, for Utility Operations systems were to be made available. The 400 MHz UHF band, and VHF band, are identified here for Utility Operations access systems because of their ability for wide-area coverage into remote/unpopulated areas. Additionally, it is usual for a replacement system to operate within the existing band. This is because the same infrastructure may be used. This makes it unlikely that additional transmitter sites, with their high masts, will be required as would be necessary if the frequency band of operation were to be increased.

Ideally, the 400 MHz UHF/VHF spectrum for the Utility Operation Networks (UON) will be self-owned/self-managed so as to ensure that the required resilience, quality of service (QoS), etc., are maintained and, especially, the cost of operation is kept similar to existing costs. Some utility operations may consider allowing a third-party to supply the necessary communications so long as the spectrum remains under the control of the utility. This is to ensure that the supplier meets the resilience, etc., requirements and keeps the costs similar to existing costs. If required, the utility will also be able to stipulate the technology to be used. The required resilience will typically include having autonomous power supplies so that communications can continue during the loss of mains power supplies. Apart from failing their customers, electricity suppliers may incur significant fines for even short power outages. For example, having the confidence that the radio system will communicate with an engineer, especially with potential safety-of-life information, in even the remotest locations, so that they can bring their customers back on line quickly and safely is a priority. Compensation offered by a third-party system supplier for failure to meet the contracted QoS during an emergency is not suitable practice for utility communications systems.

Utility Operations will also need spectrum for its higher capacity backhaul systems. Whilst some backhaul systems may be able to operate within the 400 MHz band in some areas, the EUTC Spectrum Plan identifies a requirement for 10 MHz in the 1 400 MHz band.

The EUTC Spectrum Plan [i.15] predicts the following spectrum requirements:

- 2 x 1 MHz within the VHF bands, e.g. for access and day-to-day/emergency systems;
- 2 x 3 MHz within the 400 MHz UHF band, e.g. for access systems; and
- 10 MHz within the 1 400 MHz band, e.g. for high data rate backhaul systems.

It is recognised that there may already be significant use of the 400 MHz spectrum, e.g. within 450 MHz to 470 MHz, in some geographical areas. It may therefore be necessary to identify different 2 x 3 MHz blocks in some Member States.

The details of the future spectrum requirements will be expanded within ETSI TR 103 492 [i.26].

7 Conclusion

The present document highlights that critical infrastructure utility systems, e.g. Smart Grids, typically need to be bespoke rather than a best-fit version of any generally available system(s).

The present document also highlights that licence exempt spectrum and public mobile systems may be suitable for non-critical infrastructure utility systems, e.g. Smart Meter systems.

Whilst some Distribution/Smart Grid companies are obligated to supply Smart Meters, the present document highlights that Smart Grids and Smart Meters can be operated as two independent systems.

NOTE 1: Despite this obligation, there is continuing discussion as to the perceived benefits including, perhaps, 1 000's of Smart Meters all simultaneously trying to communicate that they have lost power when the local Smart Grid substation(s) will have already communicated that power has been lost in that area.

The present document highlights the following Critical Infrastructure Utility Operations Networks requirements:

- 100 % coverage of the utility service area, including remote and unpopulated areas;
- 90,0 % (e.g. metering) to 99,99 % (e.g. protection and SCADA) link availability;
- instant and guaranteed channel access;
- ability for best practice resilience/Resilient Machine to Machine (RM2M) operation;
- licensed self-managed spectrum, in bands with different propagation characteristics:
  - 2 x 1 MHz VHF Mid/High band (e.g. wide-area voice, and low data rate systems);
  - 2 x 3 MHz in 400 MHz UHF Band (e.g. low data rates for medium to long distances);
  - noting the need to increase low data rates from 9,6 kbit/s to ~64 kbit/s;
  - 1,4 GHz Band (≤ 2 Mbit/s, over medium to long distances);
  - access to 7,5 GHz, 13 GHz, 23 GHz and 38 GHz (≥ 2 Mbit/s, over medium to short distances);
  - the above bands may be used for redundant/diversity routing, e.g. using two or more wireless and/or wired/fibre links from different sources to a remote station;

NOTE 2: If/when the primary route is interrupted, it is essential that the diverse route works immediately and correctly.

- system and transmitted data have high levels of network security and integrity, including:
  - no connection to external and/or public communications systems, e.g. the Internet;
  - hardened to ensure reliable operation in severe environmental conditions, including electromagnetic disturbances such a lightning strikes;
  - up to 96 hours power backup;
- ability for very low end-to-end latency, e.g. 10 ms for protection systems;
- low jitter and synchronous requirements; and
- longevity of life and support, e.g. 10 to 20 years.

It is essential that the Utility Operation system is self-managed so as to enable the operator(s) to maintain control of the spectrum licence and system so that spectrum access costs may be kept low and the system's functionality can be assured, e.g. priority access, coverage, latency, and power backup requirements.

Private broadband radio (PBR) systems may be used for video and other high data rate systems.

It is anticipated that the details of the future spectrum requirements will be expanded within ETSI TR 103 492 [i.26].

Annex A: Simple Electricity Grid Network

Figure A.1 shows the UK mainland's Extra High Voltage (EHV) 400 kV and 275 kV electricity transmission system. These connections are typically both directly and via one or more diverse routes. This diversity is intended to ensure that there will always be an alternative route if the direct route were to be interrupted, e.g. by storm damage. The diagram shows that the 400 kV lines are stepped down to 275 kV around the areas of densest population.

The transmission system feeds into the regional High Voltage (HV) 132 kV, 66 kV, 33 kV and 11 kV distribution networks. The 11 kV sub-stations are ultimately converted down to 230 V, with 400 V between phases, Low Voltage (LV).

Figure A.1: UK mainland's 400 kV and 275 kV electricity transmission system [i.20]

Figure A.2 shows the population densities within the UK in 2011.

NOTE: One hectare is 10 m x 10 m. So, 100 hectares in 1 km x 1 km.

There is likely to be good wire-line/fibre communications to sub-stations in densely populated areas. Whereas communications to sub-stations in less densely populated areas may be a challenge.

There is also a need for wide-area resilient voice communications. This system is likely to need to cover everywhere there are power lines, e.g. the remotest rural areas. A third-party non-resilient system that only covers, say, major roads would not be suitable.

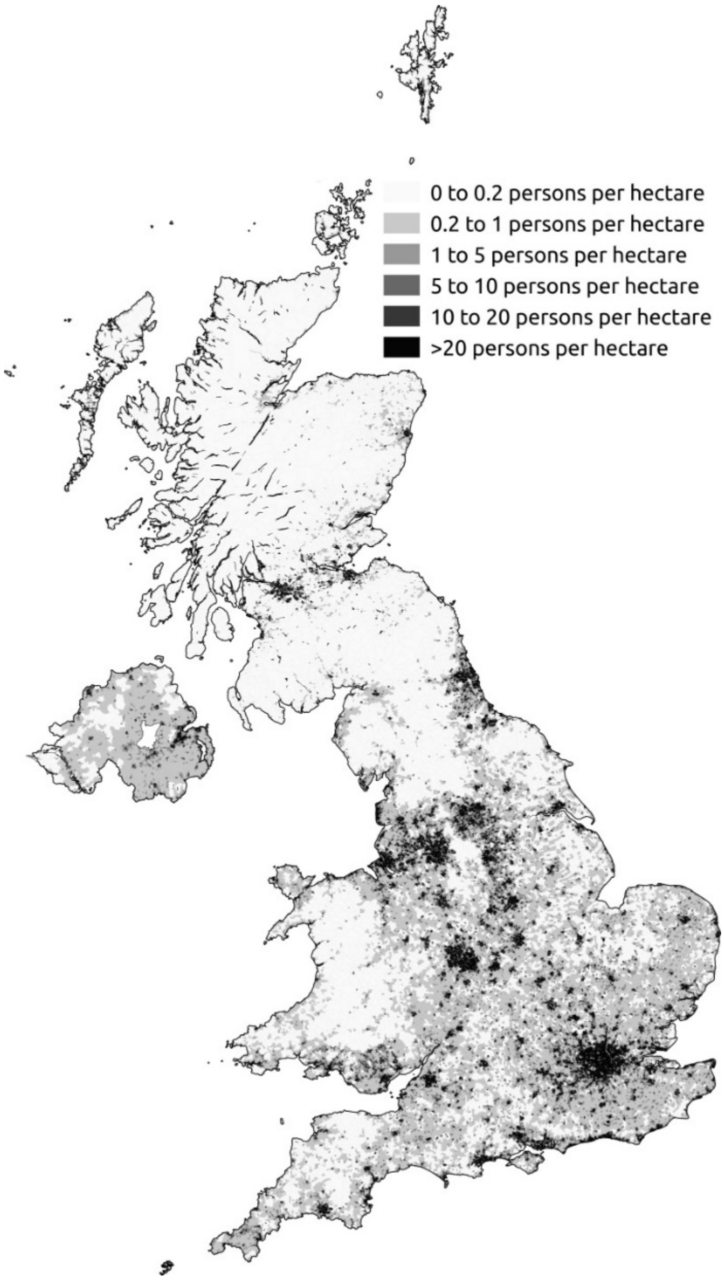
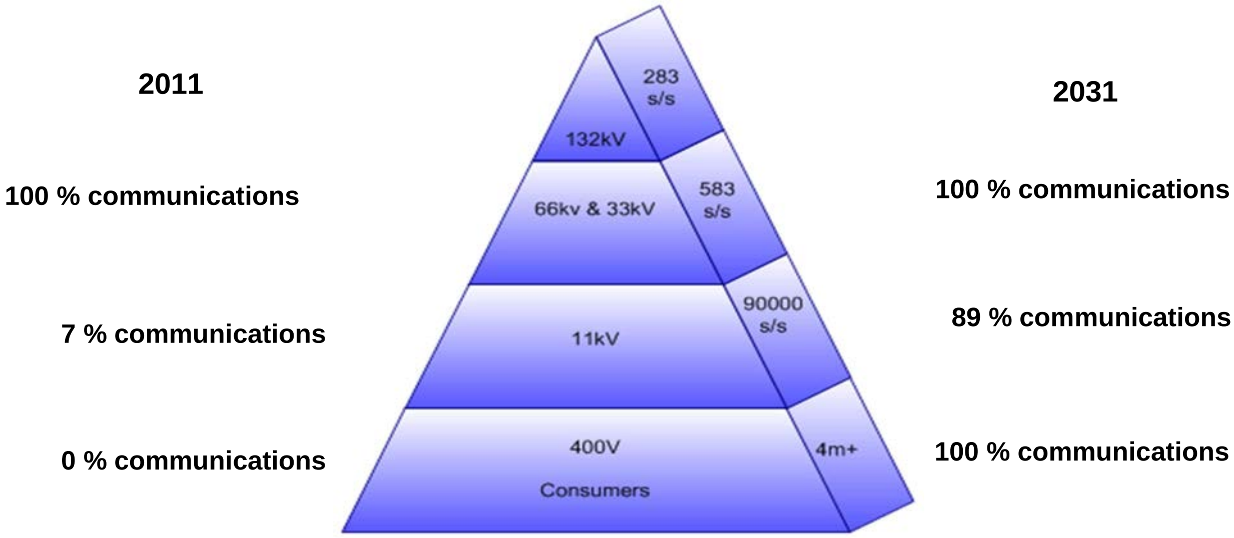


Figure A.2: Population densities within the UK in 2011

Figure A.3, highlights the estimated percentage of sub-stations that had communication connections in 2011 in the UK. It also shows the estimated percentage of 11 kV high voltage sub-stations that will need to be connected by 2031 as part of the Smart Grid. (These percentages are expected to be representative of the requirements in most other Member States.)



	Quantity of sites requiring communications (% increase over year 2011)	
	Year 2021	Year 2031
Total	775 %	1 199 %

Figure A.3: Predicted percentage increase in the number of high voltage sub-station connections [i.22]

Typically, the distribution of the 11 kV sub-stations will be proportional to the adjacent population/industrial densities. As a guide, within the UK, each 11 kV sub-station supplies a few hundred residential properties. A sub-urban town with a population of 50 000 will therefore have approximately two hundred 11 kV sub-stations. In rural areas the sub-stations are smaller, often mounted on poles, and serve just a few homes.

The predicted 12 times increase in sub-stations needing control and monitoring, plus further increases in the number of control and monitoring points for the Smart Grid, is likely to have an impact on spectrum requirements. For example, within the UK, each 12,5 kHz narrow band scanning telemetry system controls ~20 sub-stations. The predicted 12-fold increase in sub-stations needing monitoring could therefore increase the number of channels by 12 times. Additionally, the predicted increase in data rates from 9,6 kbit/s to 64 kbit/s may require the existing 12,5 kHz narrow band channels to be increased to 25 kHz narrow band channels. If so, this may further double the spectrum needs to 24 times the existing requirements. Further, the increased modulation levels of the 25 kHz systems will require an increase in the channel re-use distances. This would then multiply the spectrum requirement by approximately a further four times.

At first sight, the future spectrum requirement appears to be equivalent to approximately 50 times the present number of 12,5 kHz narrow band channels. Of course, a percentage of the future sub-stations requiring connection will be within the coverage areas of existing control systems so, with efficient planning, it should be possible to add a significant number of them to the existing sub-station control systems. Additionally, an allocation of 10 MHz in the 1 350 MHz band for TDMA systems would reduce the amount of 400 MHz UHF spectrum required.

The details of the future spectrum requirements will be expanded within ETSI TR 103 492 [i.26].

Annex B: Electricity Grid control and monitoring

B.0 Background

This annex highlights a simple system to monitor and control an electricity and/or gas grid system. The monitoring and control of a water supply system may be similar but it is unlikely to include the resilience measures and very low end-to-end latency requirements that are essential for electricity and gas systems.

The communication system monitors and controls the electricity generation, including distributed/renewable generation, and the extra high voltage transmission lines and sub-stations.

The majority of the communications system, however, monitors and controls the high voltage and low voltage distribution lines and sub-stations.

With spectrum being a scarce resource, utility systems tend to use the narrowest channel possible to communicate. For example, a 12,5 kHz narrow band channel is more likely to be used within the UK than a 150 kHz wideband channel to transmit low data rates. It should be noted that, with the anticipated increase in data rates to 64 kbit/s to 100 kbit/s, it is expected that 25 kHz and 50 kHz channels may be required in future.

B.1 Point-to-multipoint systems

As are used within the UK, the control and monitoring of the distribution system may be by using a point-to-multipoint narrowband 12,5 kHz cellular private mobile radio system. The UK system was designed in 1989 and has continued to operate very reliably. The only major change during this time is an increase in the data rates required.

NOTE 1: The data rates are expected to increase again, e.g. to 64 kbit/s to 100 kbit/s, as part of the system update to monitor and control smart grids.

The UK links are typically planned for 99,9 % availability with link paths of up to 40 km. The system is designed to cover the whole of a utility's service territory, including remote rural locations. For resilience purposes, the remote stations may be have fixed link communications to and from two or more master/scanner stations.

In the UK, there are 12 cells per cluster. Figure B.1 shows the locations of the clusters and cells.

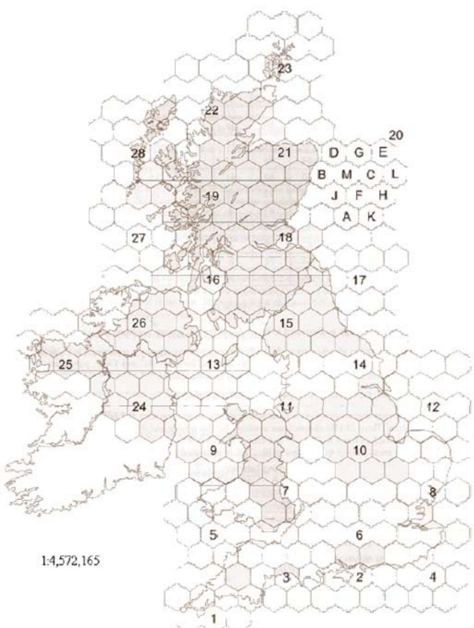


Figure B.1: UK's point-to-multipoint cellular plan [i.18]

Figure B.2 shows the locations of the cells within the clusters more clearly.

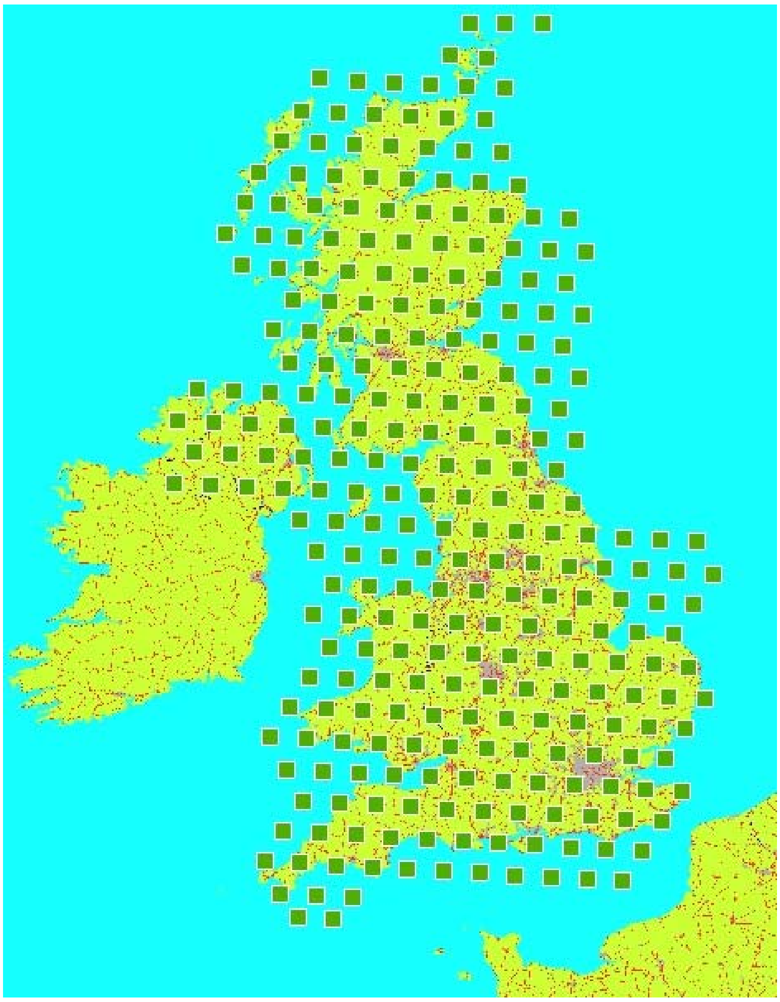


Figure B.2: Centre locations of the UK's point-to-multipoint cells

Each cell has a central station and a number of remote stations. The number of remote stations is typically dependent on the number of electricity sub-stations, etc., within the surrounding area. The number of sub-stations will usually increase in line with the density of the local population.

NOTE 2: The smart grid system will require a significant increase in the number of monitored and controlled sub-stations. This is likely to require a significant increase in the number of channels required.

In urban areas, some system operators have the option to connect their remote stations using low data rate, low-latency, wired connections. Unfortunately, whilst this option may be ideal for some utilities, it appears that there is a push to replace these copper cables with fibre.

NOTE 3: This replacement of wire with fibre, and the inherent latency issues, is likely to put additional pressure on the number of channels required.

B.2 Point-to-point systems

The point-to-point systems may be used to connect sites that need very low end-to-end latency communications, e.g. 6 ms for power line protection. Point-to-point systems may also be used as part of system resilience, e.g. as diversity connections. Power line protection may be used anywhere along the transmission and distribution network. The increasing connection of renewable energy sources to the electricity grid requires a further increase in the number of power line protection circuits.

NOTE 1: These increases are likely to result in an enhanced requirement for more channels.

Narrow band 12,5 kHz channels within the 400 MHz band may be used for low data rate links and the 1.4 GHz band may be used for higher data rate links. Wideband 150 kHz TEDS and 1,25 MHz CDMA, etc., may also be used for higher data rate links. The backhaul links are likely to be in frequency bands higher than 1,4 GHz.

The fixed point-to-point links used to control critical infrastructure, such as power line protection, are typically planned for 99,99 % availability, with very low end-to-end latency, and best practice resilience. In metropolitan and some urban areas the primary communications link may be fibre and the fixed link being used as the diversity/backup link. In rural areas, the fixed link is likely to be the primary route, with a second fixed link being used as the diversity link.

NOTE 2: The diversity link is likely to operate in a different band, e.g. 1,4 GHz.) Whilst a diversity link may be used as a backup to the primary link, it is essential that the system has immediate access to that link at the moment it is required.

B.3 Point-to-point and Point-to-multipoint technical details

The systems shown within table B.1 (point-to-multipoint) and table B.2 (point-to-point) are already being used within the UK to control, monitor, and protect the electricity grid.

Table B.1: System parameters of existing PMP FS systems in part of the 400 MHz Band

Frequency range	**450 MHz to 470 MHz**	
Reference ITU-R Recommendation		
Modulation format	Central Stations QPSK, 4FSK	Terminal Stations QPSK, 4FSK
Channel spacing and receiver noise bandwidth (MHz)	0,012 5	0,012 5
Maximum Tx output power range (dBW)	1 to 10	1 to 10
Maximum Tx output power density range (dBW/MHz) (see note 1)	20 to 29	20 to 29
Minimum feeder/multiplexer loss range (dB)	1 to 3	1 to 4
Maximum antenna gain range (dBi)	2 to 11 (omni/sectoral)	8 to 17 (directional)
Maximum e.i.r.p. range (dBW)	14 to 20	18 to 24
Maximum e.i.r.p. density range (dBW/MHz) (see note 1)	33 to 39	37 to 43
Receiver noise figure (dB)	4	4
Receiver noise power density typical (=N_{RX}) (dBW/MHz)	-159 (in 12,5 kHz) -140 (in 1 MHz)	-159 (in 12,5 kHz) -140 (in 1 MHz)
Normalized Rx input level for 1×10^{-6} BER (dBW/MHz)	-140 (in 12,5 kHz) -121 (in 1 MHz)	-140 (in 12,5 kHz) -121 (in 1 MHz)
Nominal long-term interference power density (dBW/MHz) (see note 2)	-159 + I/N (in 12,5 kHz) -140 + I/N (in 1 MHz)	-159 + I/N (in 12,5 kHz) -140 + I/N (in 1 MHz)
NOTE 1: To calculate the values for the Tx/e.i.r.p. densities, channel spacing/bandwidth needs to be identified. NOTE 2: Nominal long-term interference power density is defined by "Receiver noise power density + (required *I/N*)").		

Table B.2:System parameters for existing PP FS systems in part of the 400 MHz Band

Frequency range	450 MHz to 470 MHz
Reference ITU-R Recommendation	
Modulation	4-FSK, QPSK
Channel spacing and receiver noise bandwidth (MHz)	0,012 5
Maximum Tx output power range (dBW)	1 to 10
Maximum Tx output power density range (dBW/MHz) (see note 1)	20 to 29
Minimum feeder/multiplexer loss range (dB)	0 to 4
Maximum antenna gain range (dBi)	11 to 17 (yagi)
Maximum e.i.r.p. range (dBW)	14 to 20
Maximum e.i.r.p. density range (dBW/MHz) (see note 1)	33 to 39
Receiver noise figure (dB)	4
Receiver noise power density typical (=N_{RX}) (dBW/MHz)	-159 (in 12,5 kHz) -140 (in 1 MHz)
Normalized Rx input level for 1 × 10^{-6} BER (dBW/MHz)	-144 (in 12,5 kHz) -125 (in 1 MHz)
Nominal long-term interference power density (dBW/MHz) (see note 2)	-159 + I/N (in 12,5 kHz) -140 + I/N (in 1 MHz)
NOTE 1: To calculate the values for the Tx/e.i.r.p. densities, channel spacing/bandwidth needs to be identified. NOTE 2: Nominal long-term interference power density is defined by "Receiver noise power density +(required *I/N*)").	

In addition to the above systems, 1,25 MHz broadband CDMA systems are being used for the monitoring and control of utility power systems within the Netherlands.

History

Document history		
V1.1.1	November 2016	Publication