ECC Report 266

The suitability of the current ECC regulatory framework for the usage of Wideband and Narrowband M2M in the frequency bands 700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2.1 GHz and 2.6 GHz

Approved 30 June 2017

0 EXECUTIVE SUMMARY

Machine to Machine (M2M) communication and the Internet of Things (IoT) are widely considered as applications with significant growth potential. Among M2M/IoT technologies, some are designed to operate in licensed spectrum, in the context of Mobile Fixed Communication Networks (MFCNs).

In particular, the standardisation (3GPP) has defined the following technologies: Extended Coverage GSM IoT (EC-GSM-IoT), LTE Machine Type Communication (LTE-MTC), evolved MTC (LTE-eMTC)[1] and Narrowband IoT (NB-IoT). For the purpose of this report, LTE-MTC and LTE-eMTC will be referred to as LTE-MTC/eMTC. The purpose of this report is to analyse whether these M2M technologies can be deployed in harmonised MFCN bands taking into account coexistence requirements and the current regulatory framework.

This report considers suitability of the current ECC regulatory framework in the CEPT harmonised MFCN frequency bands for the possible future usage of these bands by the wideband and narrowband M2M cellular IoT applications. The MFCN bands studied in this ECC Report are those listed in the title.

Scenarios such as M2M/IoT deployment in radio licence exempted, non-interference non-protected bands or operation on licensed spectrum in bands other than MFCN (e.g. PMR frequency bands) are outside the scope of this Report.

The following technology and deployment scenarios were studied:

Table 1: Technology and deployment scenarios studied

Technology	Harmonised standard	Deployment			Frequency/ Deployment band	3GPP User Equipment Category
		Stand alone	In band	Guard -band		
EC-GSM-IoT	ETSI EN 301 502 [9](BS) ETSI EN 301 511 [10] (UE) ETSI EN 301 908-18 [8] (BS)	X	X		900 MHz or 1800 MHz	
LTE-MTC/eMTC	ETSI EN 301 908-1 [15] ETSI EN 301 908-13 [7] (UE) ETSI EN 301 908-14 [11] (BS) ETSI EN 301 908-18 [8] (BS)		X		All MFCN Bands listed in the title	Cat-1 or Cat-0 / Cat. M1
NB-IoT	ETSI EN 301 908-1 [15] ETSI EN 301 908-13 [7] (UE) ETSI EN 301 908-14 [11] (BS) ETSI EN 301 908-18 [8] (BS)	X	X	X	In-band: All MFCN Bands listed in the title Standalone: 900 MHz and 1800 MHz (under conditions)* Guard-band: All MFCN bands listed in the title, under conditions in the 900 MHz and 1800 MHz bands* & **	Cat-NB1/2

[1] In 3GPP terms, LTE-MTC corresponds to LTE Cat-1 or LTE Cat-0 and LTE-eMTC corresponds to LTE Cat-M1.

*The revision of ECC Decision (06)13 [37] is required for operation in the 900 MHz and 1800 MHz bands.
** For deployment of guard band NB-IoT in harmonised MFCN bands, other than 900 MHz and 1800 MHz, the currently defined BEMs need to be respected, as well as the frequency separations defined below

The following harmonised MFCN bands in this report[2] are:

- 703-733/758-788 MHz (700 MHz Band);
- 791-821/832-862 MHz (800 MHz Band);
- 880-915/925-960 MHz (900 MHz Band);
- 1710-1785/ 1805-1880 MHz (1800 MHz Band);
- 1920-1980/2110-2170 MHz (2.1 GHz Band);
- 2500-2570/2620-2690 MHz (2.6 GHz Band);

The TDD and SDL bands below are not considered in this report.

- 738-758 MHz[3]
- 1452-1492 MHz (L-Band)[4];
- 2300-2400 MHz (2.3 GHz Band);
- 2570-2620 MHz (TDD 2.6 GHz Band)[5];
- 3400-3600 MHz (3.5 GHz Band)[6];
- 3600-3800 MHz (3.7 GHz Band)[6].

This report does not address cross-border coordination issues between M2M Cellular IoT systems and other MFCN systems (e.g. ECC Recommendations on cross-border coordination of MFCN networks)[7].

The report introduces the following technologies and provides an overview of their technical characteristics.

The following regulatory and technical analyses provide the following conclusions:

- EC-GSM-IoT in-band and standalone modes can be deployed only in the 900 and 1800 MHz bands;
- LTE-MTC/eMTC in-band mode can be deployed in any harmonised MFCN band;
- NB-IoT in-band mode can be deployed in any MFCN band.

Standalone NB-IoT operation is considered in this report only in the 900 and 1800 MHz bands, with the following minimum separation requirements:

- 200 kHz separation between the GSM channel edge and Wideband UMTS/LTE/WiMAX channel edge, where LTE includes LTE-MTC/eMTC, in-band NB-IoT and guard-band NB-IoT, GSM includes EC-GSM-IoT;
- 200 kHz separation between the standalone NB-IoT channel edge and Wideband UMTS/LTE/WiMAX channel edge, where LTE includes LTE-MTC/eMTC, in-band NB-IoT and guard-band NB-IoT(see Figure 1);
- 200 kHz separation between the standalone NB-IoT channel edge and the GSM channel edge, where GSM includes EC-GSM-IoT, subject to coordination between operators.

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[2] The possible introduction of Wideband and Narrowband M2M in the frequency bands 410-430 MHz and 450-470 MHz is provided in a separate ECC report as those band are not harmonized for MFCN in CEPT, but could be used for LTE-MTC/eMTC and NB-IoT.

[3] This band may contain SDL

[4] This is an SDL band.

[5] This band may contain SDL

[6] Band currently under consideration for 5G.

[7] Cross border coordination between MFCN networks and other services is outside of the current ECC framework and thus not considered in this report.

Guard band NB-IoT should operate provided that the NB-IoT RB band edge is placed at least 200 kHz away from the LTE channel edge. The usage of guard band NB-IoT within CEPT is foreseen only for LTE channel bandwidths of 10 MHz or higher. Operators may deploy guard band NB-IoT for smaller channel bandwidth in between their blocks, if agreed.

With regard to interference with adjacent services/applications no additional interference from guard band NB-IoT is expected compared to a LTE 5 MHz channel. Regarding operation in harmonised MFCN bands (excluding SDL and TDD) it is expected that no additional interference is created by guard-band NB-IoT, if placed at least 200 kHz away from the block edge. Also the receiver characteristics of NB-IoT are similar to those of regular LTE receivers. Therefore the conditions of operation of guard band NB-IoT are expected to be similar to those of regular LTE, provided that the currently defined BEMs are fulfilled.

Therefore the following areas may be considered by the ECC in regard to the regulatory framework:

1. LTE-MTC/eMTC and EC-GSM IoT are implemented as intrinsic parts of existing LTE and GSM technologies respectively. Therefore no change to the ECC regulatory framework is needed to address LTE-MTC/eMTC and EC-GSM-IoT;
2. Revision of ECC Decision(06)13 to accommodate the use of guard band and standalone NB-IoT in the 900/1800 MHz;
3. For the frequency bands other than 900/1800MHz bands, the current ECC regulatory framework allows mobile operators to deploy guard band NB-IoT anywhere in their blocks. The requirement of 200 kHz frequency separation between guard-band NB-IoT channel edge and operator block edge is not ensured by the current ECC regulatory framework where BEM are in force.

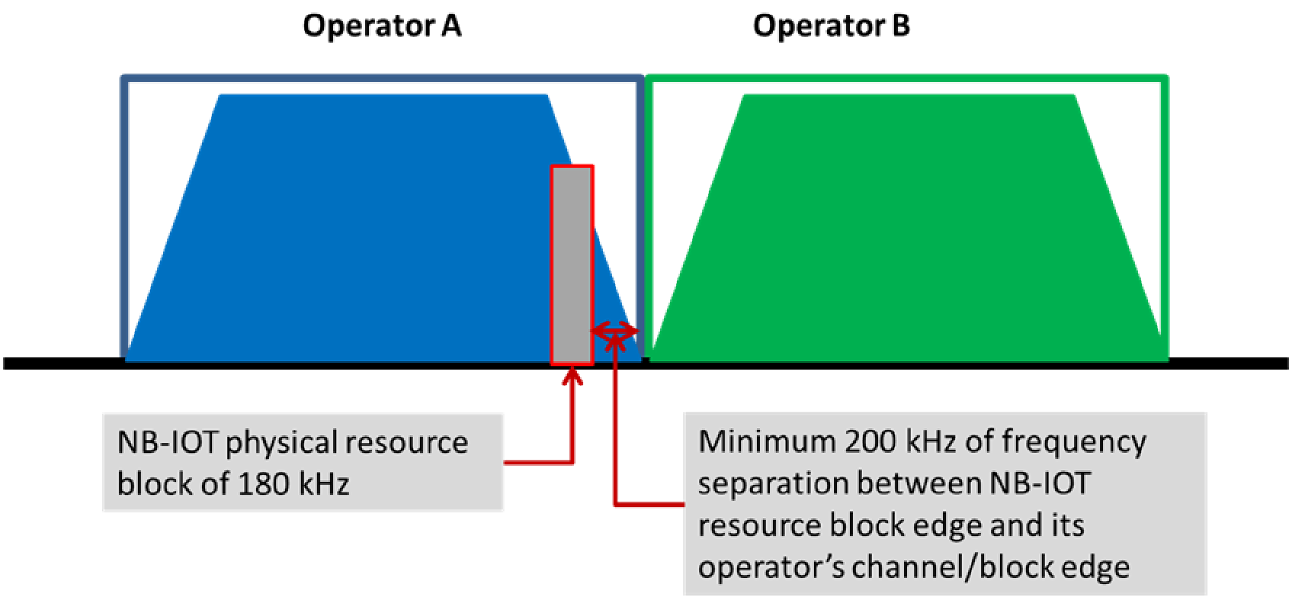

Figure 1: Frequency separation with channel edge required for guard-band NB-IoT and standalone NB-IoT

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
3GPP	Third Generation Partnership Project
ACLR	Adjacent Channel Leakage Ratio
A-MPR	Additional Maximum Power Reduction
ALD	Assistive Listening Device
BEM	Block Edge Mask
BS	Base Station
CEPT	European Conference of Postal and Telecommunications Administrations
DC	Direct Current
DME	Distance Measuring Equipment
ECC	Electronic Communications Committee
EDGE	Enhanced Data rates for GSM Evolution
EC-GSM-IoT	Extended Coverage GSM IoT
EIRP	Equivalent Isotropically Radiated Power
E-UTRA	Evolved Universal Terrestrial Radio Access
EU	European Union
FDD	Frequency Division Duplex
GB	Guard Band
GSM	Global System for Mobile Communications
GSM-R	GSM - Railway
IoT	Internet of Things
LPWAN	Low Power Wide Area Network
LRTC	Least Restrictive Technical Conditions
LTE	Long Term Evolution
LTE-eMTC	LTE evolved Machine Type Communications
LTE-MTC	LTE Machine Type Communications
MFCN	Mobile/Fixed Communications Networks
MNO	Mobile Network Operator
MPR	Maximum Power Reduction
MTC	Machine Type Communications
M2M	Machine to Machine
NBN	Narrowband Network
NB-IoT	Narrowband IoT

Abbreviation	Explanation
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OOBE	Out of band emission
PRB	Physical Resource Block
PUCCH	Physical Uplink Control Channel
RB	Resource Block
RF	Radio Frequency
RFID	Radio Frequency Identification
SA	Stand Alone
SC-FDMA	Single Carrier Frequency Division Multiple Access
SDL	Supplemental Downlink
SEM	Spectrum Emission Mask
SRD	Short Range Devices
TDD	Time Division Duplex
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
UTRA	Universal Terrestrial Radio Access
WAN	Wide Area Network
WiMAX	Worldwide Interoperability for Microwave Access

1 INTRODUCTION

Machine to Machine (M2M) communication and the Internet of Things (IoT) are widely considered as applications with significant growth potential. Among IoT technologies, some are designed to operate in licenced spectrum, in the context of Mobile Fixed Communication Networks (MFCNs).

In particular, the standardisation (3GPP) has defined the following technologies: Extended Coverage GSM IoT (EC-GSM-IoT), LTE Machine Type Communication (LTE-MTC), evolved MTC (LTE-eMTC) and Narrowband IoT (NB-IoT), The purpose of this report is to analyse whether these M2M technologies can be deployed in harmonised MFCN bands (including 900/1800 MHz band) taking into account coexistence requirements and the current regulatory framework. Work in CEPT started in 2015, with the assessment of licensed IoT technology and their suitability of rolling-out these technologies in the 700 MHz band, as per ECC Report 242 [4]. The current report builds-up on this effort. For the purpose of this report, LTE-MTC and LTE-eMTC will be referred to as LTE-MTC/eMTC.

The report introduces the three technologies and provides an overview of their technical characteristics.

The report[8] studies the potential deployment of these three technologies in the MFCN bands currently harmonised by CEPT:

- 703-733/758-788 MHz (700 MHz Band);
- 791-821/832-862 MHz (800 MHz Band);
- 880-915/925-960 MHz (900 MHz Band);
- 1710-1785/ 1805-1880 MHz (1800 MHz Band);
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The TDD and SDL bands below are not considered in this report.

- 738-758 MHz[9]
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- 3400-3600 MHz (3.5 GHz Band)[12];
- 3600-3800 MHz (3.7 GHz Band)[12].

Coexistence and regulatory issues linked to the possible future introduction of the three technologies in the CEPT harmonised MFCN bands are analysed. Recommended amendments to the existing regulatory framework are provided where applicable.

[8] The possible introduction of Wideband and Narrowband M2M in the frequency bands 410-430 MHz and 450-470 MHz is currently being studied for inclusion in a separate ECC report as those band are not harmonized for MFCN in CEPT, but could be used for LTE-MTC/eMTC and NB-IoT.

[9] This band may contain SDL

[10] This is an SDL band.

[11] This band may contain SDL

[12] Band currently under consideration for 5G

2 IoT - TECHNOLOGY BACKGROUND

2.1 INTRODUCTION TO M2M CELLULAR IoT

3GPP is working on three Machine Type Communications (MTC) Technologies (Releases 12 to currently 14):

- LTE-eMTC (LTE evolved Machine Type Communication);
- EC-GSM-IoT (Extended Coverage GSM IoT);
- NB-IoT (Narrowband IoT).

Different solutions can be used for different Machine to Machine (M2M) applications. M2M cellular IoT technologies are typically narrowband compared to the technologies leveraged in mobile broadband, due to the lower data rate requirements, the need for lower power requirements (operating for a number of years on a battery) and the requirement for a better link budget. The three technologies listed above are considered for the purpose of this report.

2.2 DEPLOYMENT MODELS

Deployment models refer to how a Mobile Network Operator (MNO) decides to deploy IoT technologies, taking into account that these are narrowband technologies, while MNOs' networks are typically mostly wideband technologies. The IoT technologies can conceptually be deployed in three ways, namely:

- as a fully independent deployment (standalone (SA) deployment);
- by pre-empting some of the resources of an existing carrier (in-band deployment);
- by being deployed on the side of an existing carrier (guard-band (GB) deployment).

Each of the technologies is discussed in detail in following sections and Table 13 provides a mapping of the deployment models to the technologies considered in this report.

It has to be noted that EC-GSM-IoT is considered to be deployed in standalone mode and in band mode, LTE-MTC/eMTC is considered to be deployed in band mode and NB-IoT encompasses all the three modes referred above.

2.3 LTE-MTC AND LTE-eMTC

2.3.1 Technology description

LTE-MTC and LTE-eMTC have been standardised in 3GPP's Releases 12 and 13 and beyond of the LTE standard respectively. The main transmitter and receiver technical characteristics are described in TS 36.101 [5] for User Equipment (UE) and TS 36.104 for Base Station (BS) [6].

LTE-MTC and LTE-eMTC are covered by the ETSI EN 301 908-13 [7] for the mobile station and either ETSI EN 301 908-14 or ETSI EN 301 908-18 [8] for the base station.

From the UE perspective, LTE-MTC corresponds to UEs fulfilling 3GPP category 0 while LTE-eMTC correspond to UEs fulfilling 3GPP category M1 specifications. It is worth noticing that a terminal supporting category 0 and category M1 needs to also support LTE general requirements. In case there is a difference in requirements between the general LTE requirements and the additional requirements, the tighter requirements are applicable. This implies that LTE-MTC and LTE-eMTC transmitter requirements are equal or tighter than legacy LTE requirements.

For LTE-eMTC (UE category M1) two power classes are defined, namely class 3 which has 23 dBm maximum power and class 5 with maximum output power equal to 20 dBm. For the two power classes

Maximum Power Reduction (MPR) and Additional Maximum Power Reduction (A-MPR) have been defined in order to meet the legacy LTE emissions.

From the description above, it can be concluded that emission limits for LTE-MTC and LTE-eMTC are the same as the one specified for legacy LTE waveform. Although the description above is focused on UE aspects the same conclusions applies to BS.

There is no modification to the LTE SEM for the LTE-MTC and LTE-eMTC, either on the UE or BS side.

2.3.2 **Deployment models**

LTE-eMTC allows to use 6 contiguous resource blocks anywhere in a LTE channel for M2M applications, each resource block is 180 kHz, 6x180 =1080 kHz. Since LTE-MTC/eMTC is part of LTE system, the BS and UE spectrum masks are the same as a normal LTE system. LTE-MTC/eMTC can use all resource blocks available in the LTE channel. This is illustrated in Figure 2.

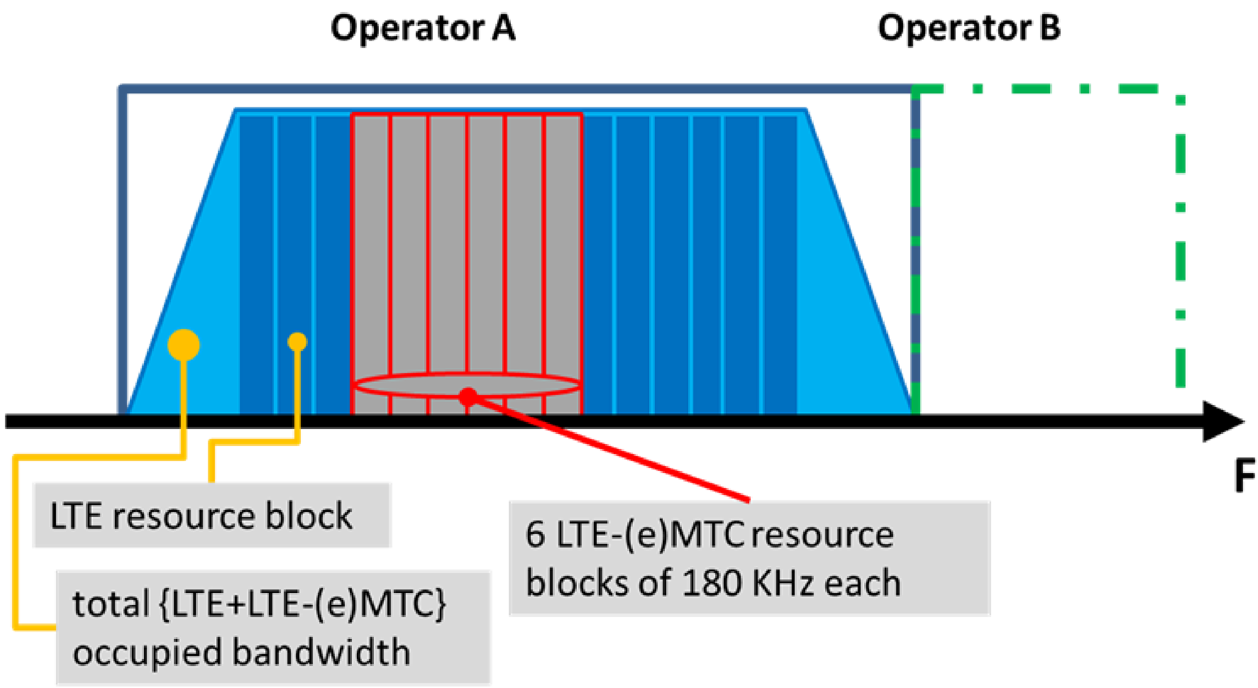

Figure 2: In-band deployment of LTE (e)-MTC

2.4 EC-GSM-IoT

2.4.1 **Technology description**

EC-GSM-IoT is an evolution of the existing GSM air interface with a channel bandwidth of 200 kHz. EC-GSM-IoT is part of the GSM system for carrying IoT traffic. Since EC-GSM-IoT is part of the GSM system, the BS and UE spectrum masks are the same as a normal GSM systems.

EC-GSM-IoT is covered by the ETSI EN 301 502 [9] (BS) and the ETSI EN 301 511 [10] (UE).

2.4.2 **Deployment models**

An EC-GSM-IoT system is deployed in a standalone mode and/or in-band mode in the 900 and 1800 MHz bands., EC-GSM-IoT uses the same frequency planning as GSM, e.g either with fixed frequency reuse or with frequency hopping. Some of the GSM network's radio resource (time slots) is dynamically allocated to

IoT. The number of carriers/slots for EC-GSM-IoT per BS depends on the number of devices and M2M traffic in the service area.

2.5 NB-IoT

2.5.1 Technology description

NB-IoT is standardised in 3GPP LTE release 13 and 14. The main transmitter and receiver technical characteristics are described in TS 36.101 [5] for UE and TS 36.104 [6] for BS.

NB-IoT is covered by the ETSI EN 301 908-13 [7] for the user equipment and either ETSI EN 301 908-14 [11] or ETSI EN 301 908-18 [8] for the base station.

For NB-IoT (UE category NB-IoT) two power classes are defined, namely class 3 which has 23 dBm maximum output power and class 5 with maximum output power equal to 20 dBm.

NB-IoT UE only needs to support half duplex operations.

NB-IoT is a new air interface using the Orthogonal Frequency Division Multiple Access (OFDMA) multiple access scheme in downlink and Single-Carrier Frequency Division Multiple Access (SC-FDMA) with a cyclic prefix in the uplink. In Release 13, a Half Duplex (for UE) and Frequency Division Duplex (for BS) scheme has been specified.

The channel bandwidth is 200 kHz and the transmission bandwidth 180 kHz (leaving 10 kHz guard bands on each side from channel edges), equivalent to one LTE resource block[13]. NB-IoT uses in both downlink and uplink a fixed total carrier bandwidth of 180 kHz so that it can utilise LTE resource blocks within a normal LTE carrier or unused blocks in the guard-band of an LTE carrier but it is not integrated dynamically into an LTE system.

In the downlink 12 sub-carriers with a sub-carrier bandwidth of 15 kHz are used for all modes of operation (standalone, in-band, guard-band).

In the uplink, multi-tone and single-tone transmissions are supported. Single tone transmission supports two configurations (sub-carrier spacing of 3.75 kHz with 2 ms slot duration or 15 kHz with 0.5 ms slot duration). Multi-tone transmission (with 3, 6 or 12 tones) uses 15 kHz sub-carrier spacing, 0.5 ms slot and 1 ms frame duration as LTE.

The channel raster for NB-IoT in-band, guard-band and standalone operation is 100 kHz.

The in-band power and spectrum emission mask of the NB-IoT (category NB-IoT UE is provided in Table 2 below. For frequencies greater than (ΔfOOB) as specified in Table 2 the general spurious requirements are applicable.

[13] 3GPP TS 36.101 [5]

Table 2: NB-IoT UE spectrum emission mask

ΔfOOB (kHz)	Emission limit (dBm)	Measurement bandwidth
± 0	26	30 kHz
± 100	-5	30 kHz
± 150	-8	30 kHz
± 300	-29	30 kHz
± 500-1700	-35	30 kHz

In addition to the spectrum emission mask requirement in Table 2, a NB-IoT UE shall also meet the applicable general E-UTRA spectrum emission mask requirement. The general E-UTRA spectrum emission requirement applies for frequencies that are offset away from edge of NB-IoT channel edge as defined in Table 3.

Table 3: F_{offset} for NB-IoT UE spectrum emission mask

Channel BW (MHz)	F_{offset} (kHz)
1.4	165
3	190
5	200
10	225
15	240
20	245

It is worth noticing that the offset in Table 3 is used to guarantee co-existence for guard-band operation.

For ACLR computation, the NB-IoT UE channel power and adjacent channel power are measured with filters and measurement bandwidths specified in Table 4. If the measured adjacent channel power is greater than -50 dBm then the NB-IoT UE ACLR shall be higher than the value specified in Table 4. The GSM ACLR requirement is intended for protection of GSM systems. The UTRA ACLR requirement is intended for protection of UTRA and E-UTRA systems.

Table 4: NB-IoT UE ACLR requirements

Parameter	GSM	UTRA
ACLR	20 dB	37 dB
Adjacent channel centre frequency offset from NB-IoT Channel edge	±200 kHz	±2.5 MHz
Adjacent channel measurement bandwidth	180 kHz	3.84 MHz

Parameter	GSM	UTRA
Measurement filter	Rectangular	RRC-filter α=0.22
NB-IoT channel measurement bandwidth	180 kHz	180 kHz
NB-IoT channel measurement filter	Rectangular	Rectangular

The additional requirements specified for NB-IoT are equal or tighter than those specified for legacy LTE waveforms.

In terms of emission power, the power of the NB-IoT can be boosted, with this possibility limited to 1 NB-IoT carrier per LTE carrier (i.e. in case of a second NB-IoT carrier, it cannot be power boosted). The dynamic range of the difference between the power of NB-IoT carrier and the average power over all carriers (both LTE and NB-IoT) must be higher than 6 dB.

2.5.2 **Deployment models**

There are 3 deployment modes for NB-IoT specified in 3GPP: in band, in guard bands and standalone deployment.

2.5.2.1 Inband NB-IoT

For an in-band deployment, the NB-IoT technology will use some of the resources of an existing wideband carrier. This corresponds to a change of transmission mode on some subcarriers of a wideband signal. This is very similar to what happens when a specific modulation is selected by the BS to serve a specific terminal.

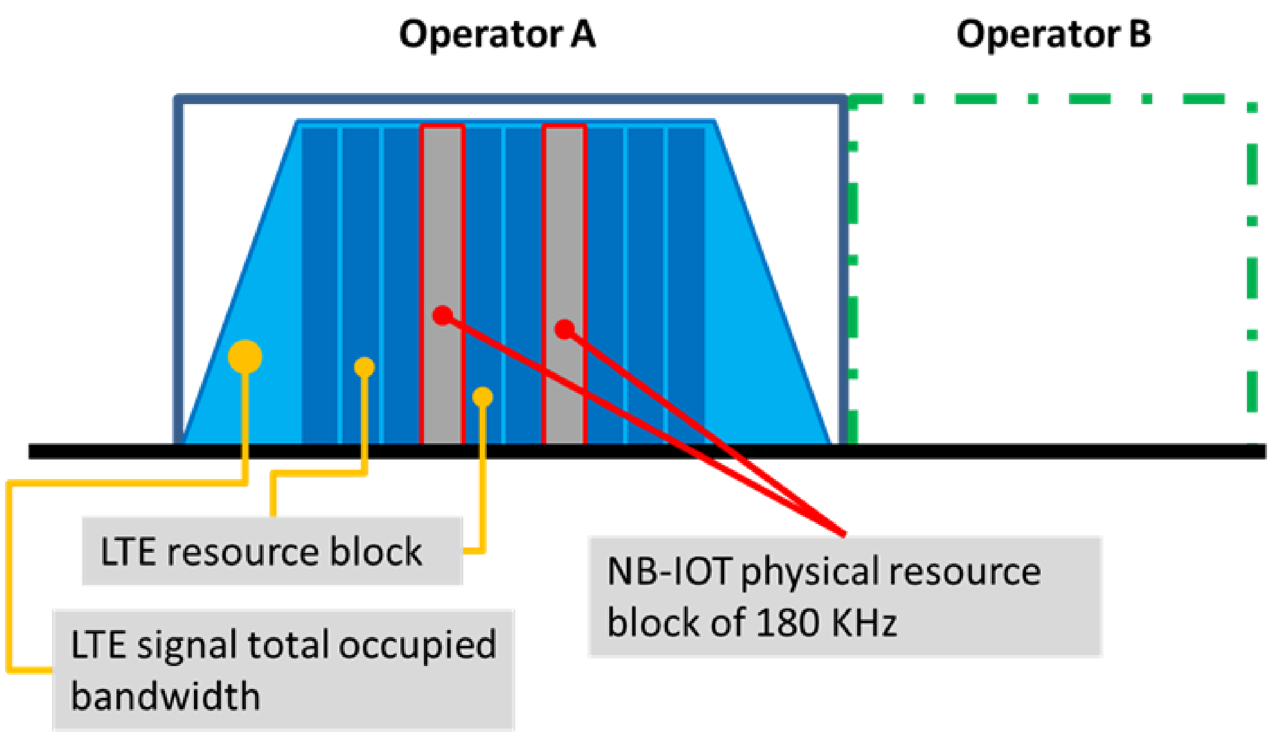

Figure 3: In-band deployment of IoT

As shown in Figure 3, in-band NB-IoT is the case where the NB-IoT carrier of 180 kHz is placed inside of a LTE channel on a 100 kHz raster within a frequency band allocated to a given mobile operator. The idea is to free one or several RBs (Resource Block) in an LTE system to deploy NB-IoT within a LTE channel.

Embedding an NB-IoT in an LTE carrier does not change the power or the Spectrum Emission Mask (SEM), either on the BS or the UE side. In particular, it is not possible to go closer to block edge than a current LTE UE could go.

It is important to note that 'in-band' in the denomination 'in-band NB-IoT' does not refer to the band of operation (for example the band 880-915/925-960 MHz), but to the channel of an MNO. From a CEPT point of view, the system would have been more adequately described as 'in-channel NB-IoT'.

The deployment model is therefore the allocation of some existing LTE resource blocks to NB-IoT carriers with the same frequency reuse as LTE. The number of carriers for NB-IoT per BS depends on the number of devices and M2M traffic in the service area.

2.5.2.2 Guard band NB-IoT

A guard-band deployment corresponds to the case where a narrowband transmission is added on the side of an existing wideband carrier. This is made possible by the fact that wideband transmission technologies typically transmit a signal narrower than the channel bandwidth, i.e. they implement implicit guard-bands within their transmission channel. The M2M cellular IoT can leverage these implicit guard-bands as operating spectrum.

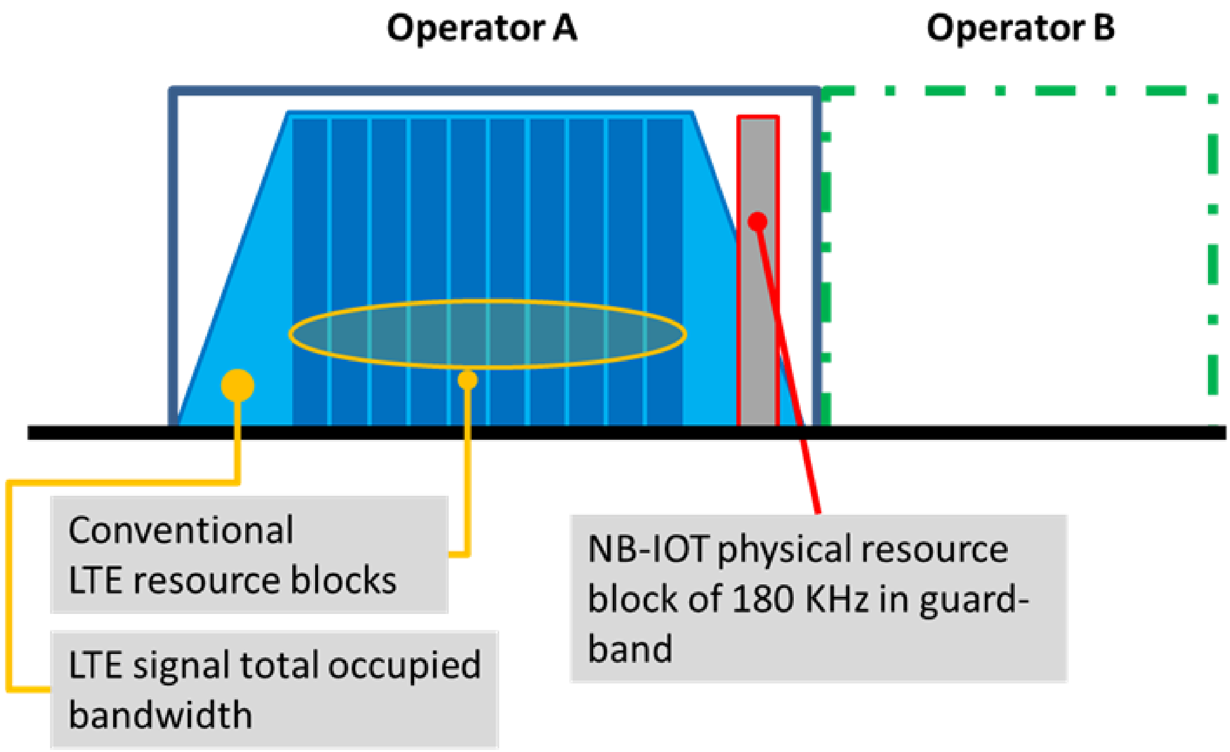

Figure 4: Guard-band deployment of IoT

It is important to note that 'Guard-band' does not refer to any potential guard band between bands of operation (for example the frequency separation 694-703 MHz between NB-IoT in 703-733 MHz and broadcasting services below 694 MHz), but to the spectrum on the side of an LTE channel, where the emission masks rolls out in order to meet the out of block requirement. From a CEPT point of view, the system would have been more adequately described as 'channel edge NB-IoT' or 'block edge NB-IoT'.

As shown in Figure 5, in an LTE system, a 10 MHz LTE channel occupies an effective bandwidth of 9 MHz so that at each side, there is 500 kHz “guard band”. Therefore the NB-IoT guard band option consist of using these remaining guard bands for introducing NB-IoT.

NB-IoT carriers use a 100 kHz channel raster. It is up to the MNO to position the NB-IoT carrier in the guard band within the LTE transmission channel.

For guard-band operation with several NB-IoT carriers, the NB-IoT carrier that can be power boosted should be placed adjacent to the LTE signal edge as close as possible (i.e., away from edge of the LTE transmission channel).

Technical Conditions for compatibility with other adjacent systems

NB-IoT is operating in a guard-band deployment scenario when it utilises the unused frequencies/resource block(s) within a E-UTRA carrier’s guard-band(s). According to TS 36.104 [6], one NB-IoT carrier can be placed in each guard band of an LTE carrier, lower or upper when the LTE channel bandwidth is 5 MHz or greater.

The centre frequency of an LTE carrier is assumed to be on a 100 kHz channel raster (known also as carrier grid) in order to allow the LTE UEs to search a limited number of carrier frequencies in the frequency bands they support and synchronise within a reasonable amount of time after being activated. The channel raster is 100 kHz for all bands, which means that the LTE carrier centre frequency should be an integer multiple of 100 kHz. Similar to existing LTE UEs, an NB-IoT UE is required to search for a carrier only on a 100 kHz raster. An NB-IoT carrier that is intended for facilitating UE initial synchronisation is referred to as an anchor carrier.

The NB-IoT carrier in a Guard band scenario is one additional 180 kHz Physical Resource Block (PRB) consisting of 12 OFDM sub-carriers (tones) with 15 kHz frequency separation. To avoid interference to LTE in-band sub-carriers the OFDM orthogonality must be maintained therefore each tone has to be ideally centred in a frequency offset that is a multiple of 15 kHz like the rest of the physical layer sub-carriers.

Considering as an example an LTE 10 MHz carrier in downlink as shown in Figure 5, one can realise that a gap of 2.5 kHz exists between the ideal position of the centre frequency of NB-IoT carrier and the position on a 100 kHz raster. This originates from the DC 15 kHz sub-carrier in downlink which makes the first PRB right above it (PRB#25 in this case) to be centred at 97.5 kHz above the centre LTE carrier frequency. Therefore, PRB#25 is centred in 2.5 kHz offset from the 100 kHz raster. Continuing with 180 kHz spaced physical resource blocks one sees that NB-IoT will be offset by 2.5 kHz from the nearest 100 kHz grid. It can be shown that for LTE carriers of 10 MHz and 20 MHz, there exists a set of PRB indexes that are all centred at 2.5 kHz from the nearest 100 kHz grid, whereas for LTE carriers of 3 MHz, 5 MHz, and 15 MHz bandwidth, the PRB indexes are centred at least 7.5 kHz away from the 100 kHz raster [12]. So, an NB-IoT anchor carrier in the guard-band deployment needs to have centre frequency no more than 7.5 kHz away from the 100 kHz raster in order to allow NB-IoT UEs to cell-search and synchronise to the network.

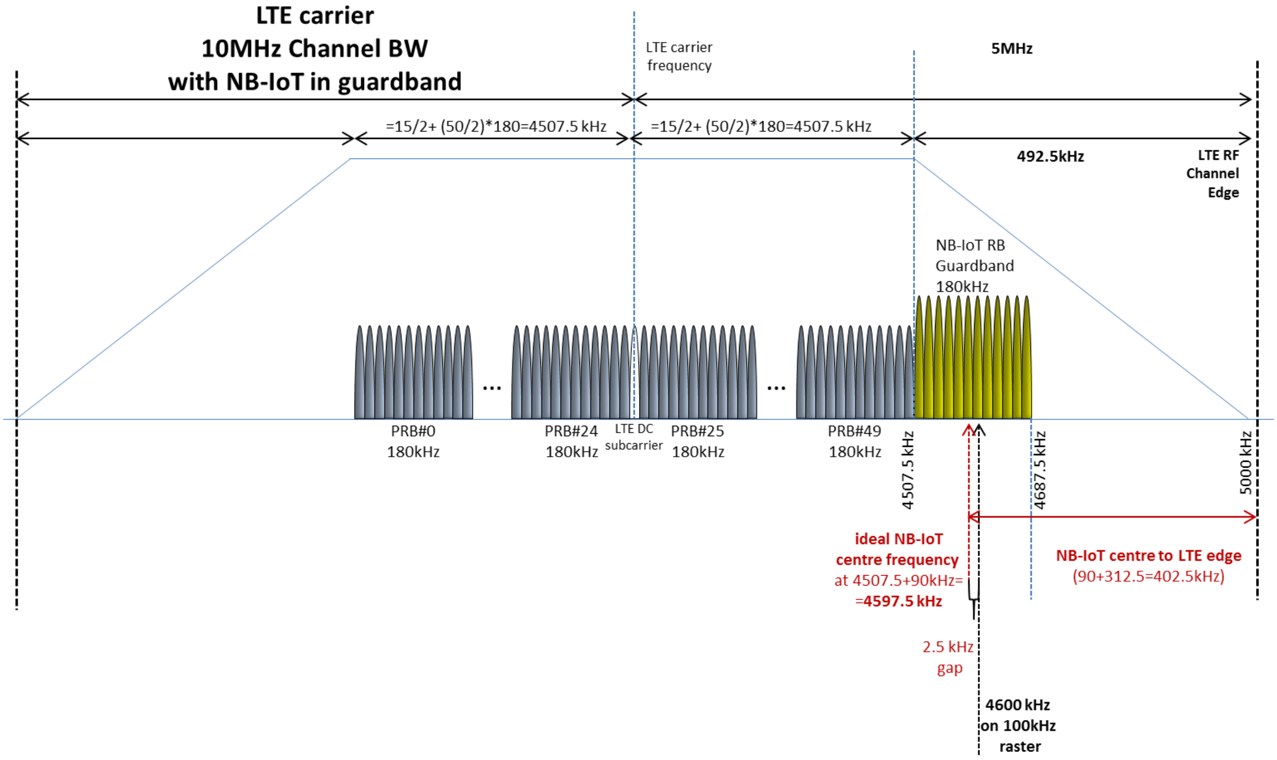

Figure 5: NB-IoT in guard band operating mode for LTE 10 MHz Carrier

For the above reasons the exact placement of the NB-IoT carriers in the guard band depends on the total LTE channel bandwidth. For a 10 MHz LTE carrier, NB-IoT carrier will be eventually in a 2.5 kHz offset from a 100 kHz grid as shown in the figure and explained above but for a 15 MHz LTE carrier which has 75 PRBs (one PRB contains the DC sub-carrier), the NB-IoT centre frequency after the last LTE PRB will have a 52.5 kHz gap from 100 kHz grid but this can be compensated with a further offset by 3x15 kHz tones from the LTE centre frequency so that the separation from the 100 kHz raster is no more than 7.5 kHz.

See the following table for further details:

Table 5: NB-IoT carrier placement within the LTE channel guard band

LTE Chan. BW (MHz)	#RBs	Half LTE channel band width (kHz)	Last RB edge frequency (kHz)	Ideal NB-IoT centre frequency for OFDM orthogonality	Distance from a 100 kHz grid (kHz)	Offset from LTE (m*15kHz) m=0..4	Gap after offset (kHz)	Final NB-IoT frequency (kHz)	Maximum NB-IoT RB edge to LTE edge	NB-IoT GB centre frequency offset to the lower/ upper Base Station RF Bandwidth (kHz)
1.4	6	700	547.5	637.5	62.5	60	2,5	697.5	-87.5	No NB-IoT GB (exceeds LTE channel edge)
3	15	1500	1357.5	1447.5	52.5	45	7.5	1492.5	-82.5	No NB-IoT GB (exceeds LTE channel edge)
5	25	2500	2257.5	2347.5	52.5	45	7.5	2392.5	17.5	NB-IoT carrier close to LTE channel edge
10	50	5000	4507.5	4597.5	2.5	0	2.5	4597.5	312.5	402.5
15	75	7500	6757.5	6847.5	52.5	45	7.5	6892.5	517.5	607.5
20	100	10000	9007.5	9097.5	2.5	0	2.5	9097.5	812.5	902.5

According to 3GPP technical specifications TS 36.104 [6], the NB-IoT PRB power dynamic range (or NB-IoT power boosting) is the difference between the power of NB-IoT carrier and the average power over all carriers (both LTE PRBs and NB-IoT PRB). The minimal requirement for NB-IoT PRB power dynamic range is to be at least 6 dB for one anchor carrier placed in the guard band (or in-band) scenario and therefore the NB-IoT PRB should be ideally placed adjacent to the LTE PRB edge as close as possible (away from the edge of system bandwidth).

The LTE emission requirements will be fulfilled if one NB-IoT is positioned within each of the guard bands (lower or upper) and away from the LTE system edge. Guard-band deployment in bandwidths lower than 5 MHz is not defined in 3GPP. Deployment of guard-band NB-IoT in the 3GPP standard starts with 5 MHz LTE bandwidths. For LTE bandwidths 10, 15 and 20 MHz, the guard-band bandwidth (which for both lower and upper guard bands is 10% of the total channel bandwidth) is adequate for more than one NB-IoT carrier. The guard band must contain a filter roll-off and as the loss of the filter increases, the further out to the edge a carrier can be placed but this depends on the implementation.

Considering co-located wide area base stations with adjacent LTE carriers in guard band operation mode and the minimum narrowband blocking requirements for LTE BS as explained in TS 36.104 [6], the wanted and the interfering signals coupled to the BS antenna input are specified in the following tables:

Table 6: TS 36.104, Table 7.5.1-1: Narrowband blocking requirement for NB-IoT standalone

	E-UTRA channel BW of the lowest/highest carrier received (MHz)	NB-IoT Wanted signal mean power (dBm)	Interfering signal mean power (dBm)	Type of interfering signal
Wide Area BS	5	PREFSENS + 11 dB*	-49	See Table 7.5.1-2
	10	PREFSENS + 6 dB*	-49	See Table 7.5.1-2
	15	PREFSENS + 6 dB*	-49	See Table 7.5.1-2
	20	PREFSENS + 6 dB*	-49	See Table 7.5.1-2
Note: The mentioned desensitisation values consider only 1 NB-IoT in the guard band				
Note*: PREFSENS depends on the sub-carrier spacing as specified in Table 7.2.1-5.				

Table 7: TS 36.104, Table 7.5.1-2: Interfering signal for Narrowband blocking requirement for E-UTRA BS

E-UTRA channel BW of the lowest/highest carrier received (MHz)	Interfering RB centre frequency offset to the lower/upper Base Station RF Bandwidth edge or sub-block edge inside a sub-block gap (kHz)	Type of interfering signal
1	±(252.5+m*180), m=0, 1, 2, 3, 4, 5	1.4 MHz E-UTRA signal, 1 RB*
3	±(247.5+m*180), m=0, 1, 2, 3, 4, 7, 10, 13	3 MHz E-UTRA signal, 1 RB*
5	±(342.5+m*180), m=0, 1, 2, 3, 4, 9, 14, 19, 24	5 MHz E-UTRA signal, 1 RB*
10	±(347.5+m*180), m=0, 1, 2, 3, 4, 9, 14, 19, 24	5 MHz E-UTRA signal, 1 RB*
15	±(352.5+m*180), m=0, 1, 2, 3, 4, 9, 14, 19, 24	5 MHz E-UTRA signal, 1 RB*
20	±(342.5+m*180), m=0, 1, 2, 3, 4, 9, 14, 19, 24	5 MHz E-UTRA signal, 1 RB*
Note*: Interfering signal consisting of one resource block is positioned at the stated offset, the channel bandwidth of the interfering signal is located adjacently to the lower/upper Base Station RF Bandwidth edge.		

For an LTE 10 MHz carrier with guard band NB-IoT and an interfering 5 MHz E-UTRA signal of 1 RB located close to the edge i.e. at the lowest frequency (m=0), a 347.5 kHz frequency offset is needed between the LTE system edge and the interfering RB centre frequency in order to meet the desensitisation requirements.

So if there is one NB-IoT PRB in guard band as the interfering RB of an LTE carrier, then the narrowband blocking offset requirements are met and there is still a frequency “safety margin” as shown in the table below:

Table 8: NB-IoT frequency offset safety margins

LTE Chan. BW (MHz)	NB-IoT GB centre frequency offset to the lower/upper base station RF bandwidth (kHz)	Interfering RB centre frequency offset to the lower/upper base station RF bandwidth edge or sub-block edge inside a sub-block gap (kHz)	Safety margin (kHz)	NB-IoT RB edge to LTE edge (kHz)
10	402.5	347.5	55	312.5
15	607.5	352.5	255	517.5
20	902.5	342.5	560	812.5

Using such safety margin combined with a sharp filter roll-off and loss to compensate the +6 dB power dynamic range of NB-IoT RB will fulfil the LTE spectrum emission requirements.

On the other hand, if one considers the separation of the last in-band PRB edge in an LTE carrier from the system band edge this is well below 200 kHz:

Table 9: Separation of last in-band PRB edge to system band edge

LTE Ch. BW (MHz)	#RBs	Guard band width (kHz)	LTE edge frequency (kHz)	Last RB edge frequency (kHz)	Offset of last RB edge to LTE edge (kHz)
1.4	6	70	700	547.5	152.5
3	15	150	1500	1357.5	142.5
5	25	250	2500	2257.5	242.5
10	50	500	5000	4507.5	492.5
15	75	750	7500	6757.5	742.5
20	100	1000	10000	9007.5	992.5

Based on the above analysis, the edge of an NB-IoT RB in a guard band scenario is proposed to be at least 200 kHz away from the LTE channel edge in order to fulfil the LTE criteria (this corresponds to the cases of LTE 10, 15 and 20 MHz channel bandwidths).

The deployment model is therefore the allocation of frequencies in used LTE resource blocks in guard-band to NB-IoT carriers with the same frequency reuse as LTE. The number of carriers for NB-IoT per BS depends on the number of devices and M2M traffic in the service area, as well as on the size of LTE channel and a size of a guard band accordingly.

2.5.2.3 Standalone NB-IoT

In a standalone deployment, the IoT carrier is deployed independently, in its own narrowband spectrum. Typically, the NB-IoT carrier only uses a fraction of the band allocated to an MNO. This is exactly the same deployment mode as GSM. For the purpose of this report, standalone NB-IoT is considered only for operation in the 900/1800 MHz bands.

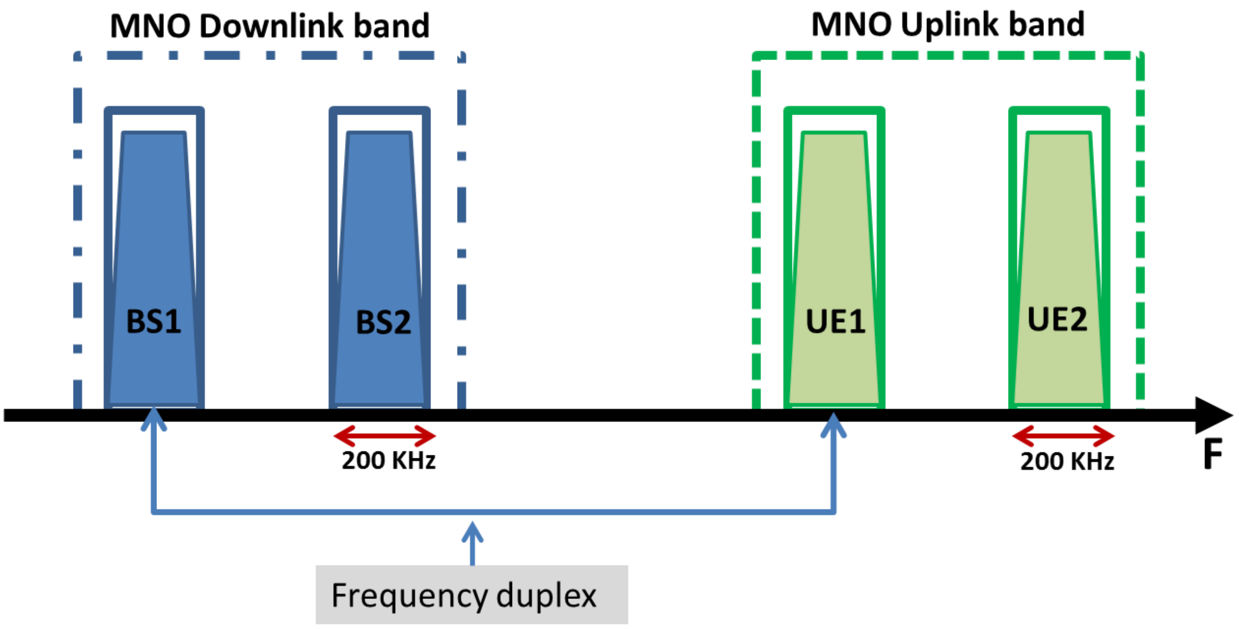

Figure 6: Standalone deployment of IoT

<u>Base station standalone NB-IoT technical characteristics</u>

NB-IoT is operating standalone when it utilises its own spectrum, for example the spectrum currently being used by GSM systems as a replacement of two GSM carriers, as well as scattered spectrum for potential IoT deployment. The transmission bandwidth of Standalone NB-IoT as shown in table below is the same as GSM, 200 kHz.

Table 10: Transmission bandwidth (3GPP TS 36.104 [6] Table 5.6-3)

NB-IoT	Standalone
Channel bandwidth BW Channel (kHz)	200

For NB-IoT standalone operation, NB-IoT requirements for receiver and transmitter shall apply with a frequency offset Foffset as defined in Table 5.6-3A of 3GPP TS 36.104 [6].

Table 11: Foffset for NB-IoT standalone operation (3GPP TS 36.104 [6] Table 5.6-3A)

Lowest or Highest Carrier	Foffset
Standalone NB-IoT	200 kHz

This will result in a frequency separation of 200 kHz between NB-IoT carrier and channel edge of adjacent services/systems.

Channel raster

The channel raster for NB-IoT is 100 kHz for all bands, which means that the carrier centre frequency must be an integer multiple of 100 kHz.

Minimum requirements for standalone NB-IoT Wide Area BS

For standalone NB-IoT BS, emissions shall not exceed the maximum levels specified in the tables below:

Table 12: Standalone NB-IoT BS operating band unwanted emission limits (3GPP TS 36.104 [6] Table 6.6.3.2E-1)

Frequency offset of measurement filter -3dB point, Δf	Frequency offset of measurement filter centre frequency, f_offset	Minimum requirement (Note 1, 2, 3, 4, 5)	Measurement bandwidth (Note 8)
0 MHz ≤ Δf < 0.05 MHz	0.015 MHz ≤ f_offset < 0.065 MHz	$Max(5dBm - 60 \cdot \left(\frac{f_{offset}}{MHz} - 0.015\right) dB + XdB, -14dBm)$	30 kHz
0.05 MHz ≤ Δf < 0.15 MHz	0.065 MHz ≤ f_offset < 0.165 MHz	$Max(2dBm - 160 \cdot \left(\frac{f_{offset}}{MHz} - 0.065\right) dB + XdB, -14dBm)$	30 kHz

NOTE 1: The limits in this table only apply for operation with a NB-IoT carrier adjacent to the Base Station RF Bandwidth edge.

NOTE 2: For a BS supporting non-contiguous spectrum operation within any operating band the minimum requirement within sub-block gaps is calculated as a cumulative sum of contributions from adjacent sub blocks on each side of the sub block gap.

NOTE 3: For a BS supporting multi-band operation with Inter RF Bandwidth gap < 20MHz the minimum requirement within the Inter RF Bandwidth gaps is calculated as a cumulative sum of contributions from adjacent sub-blocks or RF Bandwidth on each side of the Inter RF Bandwidth gap.]

NOTE 4: In case the carrier adjacent to the RF bandwidth edge is a NB-IoT carrier, the value of X = PNB-IoTcarrier – 43, where PNB-IoTcarrier is the power level of the NB-IoT carrier adjacent to the RF bandwidth edge. In other cases, X = 0.

NOTE 5: For BS that only support E-UTRA and NB-IoT multi-carrier operation, the requirements in this table do not apply to an E-UTRA BS from Release 8, which is upgraded to support E-UTRA and NB-IoT multi-carrier operation, where the upgrade does not affect existing RF parts of the radio unit related to the requirements in this table. In this case, the requirements in subclauses 6.6.3.1 and 6.6.3.2 shall apply.

This corresponds to Table 6.6.2.2-2 in ETSI TS 137 104 [13] which is applicable for GSM/EDGE, standalone NB-IoT and E-UTRA 1.4 or 3 MHz.

For a standalone NB-IoT carrier, the spacing between the NB-IoT centre frequency and the centre frequency of an adjacent GSM or UMTS carrier should be at least 0.3 MHz and 2.8 MHz respectively. A standalone NB-IoT carrier in a band used by GSM systems would replace two GSM carriers to leave 100 kHz unoccupied spectrum on both sides. As a result, frequency re-planning in the deployment area is required in order to allow a tighter frequency reuse.

If standalone NB-IoT is deployed in a GSM band within a 200 kHz GSM carrier, then there is a need to consider how to apply the current ECC regulatory rules for standalone NB-IoT in GSM bands. The current

900 MHz and 1800 MHz bands are regulated for GSM/UMTS/LTE/WiMAX referring to the relevant harmonised standards.

NB-IoT will be included in the LTE harmonised standard [14]. As such a terminal supporting NB-IoT standalone needs to also support LTE general requirements. In case there is a difference in requirements between the general LTE requirements and the additional requirements, the tighter requirements are applicable. The current ECC regulatory rules are defined for MFCN on a technology neutral basis, and the deployment of Standalone NB-IoT has to meet the defined regulatory conditions.

Since NB-IoT will be included in a LTE harmonised standard, the current ECC regulatory conditions have not considered the case of LTE 200 kHz. It is more likely that the current ECC regulatory conditions have to be modified for the standalone NB-IoT deployment in 900 MHz and 1800 MHz bands.

The deployment model is therefore the allocation of some existing GSM carried to NB-IoT carriers, but with the frequency reuse of one similar to LTE. The number of carriers for NB-IoT per BS depends on the number of devices and M2M traffic in the service area.

2.6 SUMMARY TABLE OF M2M CELLULAR IOT TECHNOLOGY DESCRIPTIONS

Table 13: M2M cellular IoT technologies references

Technology	Harmonised standard	Deployment			3GPP User Equipment Category (for information)	Bandwidth (kHz)
		Stand alone	In-band	Guard -band		
EC-GSM-IoT	ETSI EN 301 502 [9](BS) ETSI EN 301 511 [10] (UE) ETSI EN 301 908-18 [8] (BS)	X	X			200
LTE-MTC	ETSI EN 301 908-1 [15] ETSI EN 301 908-13 [7] (UE) ETSI EN 301 908-14 [11] (BS) ETSI EN 301 908-18 [8] (BS)		X		Cat. 0	1080 - 18000
LTE-eMTC	ETSI EN 301 908-1 [15] ETSI EN 301 908-13 [7] (UE) ETSI EN 301 908-14 [11] (BS) ETSI EN 301 908-18 [8] (BS)		X		Cat. M1	1080
NB-IoT	ETSI EN 301 908-1 [15] ETSI EN 301 908-13 [7] (UE) ETSI EN 301 908-14 [11] (BS) ETSI EN 301 908-18 [8] (BS)	X	X	X	Cat. NB-IoT	15/3.75 - 180

3 TECHNICAL REGULATIONS

3.1 GENERIC REGULATION

In response to the mandate to "Develop Least Restrictive Technical Conditions for frequency bands addressed in the context of WAPECS" [18], the CEPT developed Report 19 [19] which identified Block Edge Masks (BEMs) to determine Least Restrictive Technical Conditions (LRTCs) for a given frequency band. CEPT later adopted Block Edge Masks (BEM) as the regulatory approach of choice for the definition of a set of “common and minimal (least restrictive) technical conditions” optimised for, but not limited to, Mobile/Fixed Communications Networks (MFCN).

CEPT published in ECC Recommendation (11)06 on "Block Edge Mask Compliance Measurements for Base Stations" [20] which provides a common measurement method to enable CEPT administrations to verify BEM compliance in the field.

In addition to BEM, CEPT published ECC Recommendations on cross-border coordination for each MFCN frequency bands, including cases of cross-border coordination between narrowband and wideband systems. Finally, for some of the bands CEPT has additional deliverables addressing band specific aspects.

Regarding the European Union administrations within the CEPT, the Framework Directive [16] introduced the concept of technology neutrality, i.e. the idea that the regulatory framework should not be technology specific, but allow different technologies as much as possible. The Framework Directive states (Recital 18):

"The requirement for Member States to ensure that national regulatory authorities take the utmost account of the desirability of making regulation technologically neutral, that is to say that it neither imposes nor discriminates in favour of the use of a particular type of technology, does not preclude the taking of proportionate steps to promote certain specific services where this is justified, for example digital television as a means for increasing spectrum efficiency."

Technology neutrality was reinforced in 2009 during the revision of the EU telecommunication framework [17] by introducing the notion that all spectrum licences are supposed to be technology neutral - with some exceptions allowed.

"(68) The introduction of the requirements of service and technology neutrality in granting rights of use, together with the increased possibility to transfer rights between undertakings, should increase the freedom and means to deliver electronic communications services to the public, thereby also facilitating the achievement of general interest objectives. However, certain general interest obligations imposed on broadcasters for the delivery of audiovisual media services may require the use of specific criteria for the granting of rights of use when it appears to be essential to meet a specific general interest objective set out by Member States in conformity with Community law. Procedures associated with the pursuit of general interest objectives should in all circumstances be transparent, objective, proportionate and non-discriminatory."

3.2 BAND SPECIFIC REGULATION

The MFCN bands currently harmonised by CEPT are:

- 703-733/758-788 MHz (700 MHz Band);
- 738-758 MHz
- 791-821/832-862 MHz (800 MHz Band);
- 880-915/925-960 MHz (900 MHz Band);
- 1452-1492 MHz (L-Band);
- 1710-1785/ 1805-1880 MHz (1800 MHz Band);
- 1920-1980/2110-2170 MHz (2.1 GHz Band);

- 2300-2400 MHz (2.3 GHz Band);
- 2500-2570/2620-2690 MHz (2.6 GHz Band);
- 2570-2620 MHz (TDD 2.6 GHz Band);
- 3400-3600 MHz (3.5 GHz Band);
- 3600-3800 MHz (3.7 GHz Band).

Table 14 below lists the relevant CEPT/ECC/EU documents for each MFCN frequency band.

The frequency bands can be separated in 2 categories, depending on how technology neutrality is applied for these bands:

- The 900 MHz and 1800 MHz bands achieved technology neutrality by explicit authorisation of each candidate technology in the band with corresponding technical conditions to co-exist with incumbent technologies in the band;
- All other MFCN bands have specific LRTCs, namely BEMs complemented by specific conditions to protect services in adjacent bands.

The reason for this dual approach is that narrowband systems - GSM networks - and wideband systems - UMTS, LTE, WiMAX - can be deployed in the 900 and 1800 MHz bands, rendering the identification of LRTCs more complex. From a purely regulatory perspective, M2M technologies covered by the harmonised standards can already legally be deployed in the 900 MHz and 1800 MHz bands. The introduction of a new technology in the band can be achieved through inclusion of the appropriate Harmonised Standard. For EU administrations, similar introduction of new technologies should consider the Commission Implementing Decision of 18 April 2011 (2011/251/EU).

The LRTCs for other MFCN bands have been developed on the basis of 5 MHz blocks, with the underlying assumption that the systems deployed in these bands would have a bandwidth at least equal to 5 MHz. Though narrowband systems are - from a pure regulatory perspective - allowed in these bands, the LRTCs have been developed based on studies for wideband systems. Therefore, further studies would be required to ensure that narrowband systems can be deployed under the current LRTCs without creating interference to networks in adjacent blocks - and in adjacent bands.

The technical conditions applicable to each MFCN band are summarised in Table 15 below. The requirements are expressed differently in the different bands, with BEMs including or not maximum power, expressed in different BWs and with limits either per BS or per antenna. The following bands include specific considerations/limits to protect services in adjacent bands:

- 700 MHz - broadcasting below 694 MHz;
- 800 MHz- broadcasting below 790 MHz;
- 900 MHz- PMR/PAMR above 915 MHz, GSM-R in 876-880/921-925 MHz, Aeronautical systems above 960 MHz.

CEPT identified the need to carry out adjacent band compatibility studies at 925MHz between guard-band/standalone NB-IoT and GSM-R (below 925MHz) but also at 915MHz between guard-band/standalone NB-IoT with SRD’s (above 915MHz). This is being addressed in Section 5.

Though the regulatory framework of MFCN bands at CEPT/ECC level is technology neutral, licences at national level are sometimes technology or service specific, according to ECO Report 03 [22]. It is necessary for these countries to examine the exact terms of the licences impacted in order to determine whether M2M networks can be deployed under such licences.

Table 14: Band specific regulatory framework

Band	Report	ECC Decision	EC Decision based on CEPT reports	Cross-border coordination
700 (B28)	CEPT Report 60 [23] CEPT Report 53 [24]	ECC/DEC(15)01 [25]	EC Decision 2016/687/EU [26]	ECC/REC(15)01 [27]
800 (B20)	CEPT Report 31 [28] CEPT Report 30 [29]	ECC/DEC(09)03 [30]	Commission Decision 2010/267/EU [31]	ECC/REC(11)04 [32]
900 (B8)	ECC Report 229 [33] ECC Report 146 [34] ECC Report 82 [35] ECC Report 96 [36] CEPT Report 40 [1] CEPT Report 41 [2] CEPT Report 42 [3]	ERC/DEC/(94)01 [63] ERC/DEC/(97)02 [64] ECC/DEC(06)13 [37]	EC Decision 2011/251/EU [21] EC Decision 2009/766/EC [38]	ECC/REC(05)08 [40] ECC/REC(08)02 [39]
1800 (B3)	ECC Report 146 [34] ECC Report 82 [35] ECC Report 96 [36] ECC Report 146 [34] CEPT Report 40 [1] CEPT Report 41 [2] CEPT Report 42 [3]	ERC/DEC/(95)03 [65] ECC/DEC(06)13 [37]	EC Decision 2011/251/EU [21] EC Decision 2009/766/EC [38]	ECC/REC(05)08 [40] ECC/REC(08)02 [39]
2.1 (B1)	CEPT Report 39 [41]	ECC/DEC(06)01 [42]	EC Decision 2012/688/EU [43]	ERC/REC/(01)01 [62]
2.3 (B40)	ECC Report 172 [44] ECC Report 216 [45] CEPT Report 55 [46] CEPT Report 56 [47]	ECC/DEC(14)02 [48]		ECC/REC(14)04 [49]
2.5 (B7)	ECC Report 119 [50] ECC Report 131 [51] CEPT Report 19 [19]	ECC/DEC(05)05 [52]	EC Decision 2008/477/EC [53]	ECC/REC(11)05 [54]
TDD 2.5 (B38)	ECC Report 119 [50] ECC Report 131 [51] CEPT Report 19 [19]	ECC/DEC(05)05 [52]	EC Decision 2008/477/EC [53]	ECC/REC(11)05 [54]
3.5 (B42)	ECC Report 100 [55] ECC Report 216 [45] ECC Report 203 [56] CEPT Report 49 [57]	ECC/DEC(07)02 [58] ECC/DEC(11)06 [59]	EC Decision 2008/411/EC [60] EC Decision 2014/276/EU [61]	ECC/REC(15)01 [27]
3.7 (B43)	ECC Report 100 [55] ECC Report 216 [45] ECC Report 203 [56] CEPT Report 49 [57]	ECC/DEC(07)02 [58] ECC/DEC(11)06 [59]	EC Decision 2008/411/EC [60] EC Decision 2014/276/EU [61]	ECC/REC(15)01 [27]

Table 15: Overview of technical conditions in MFCN bands

Band	In-band	Adjacent bands
Bands achieving technology neutrality through reference to specific technologies		
900 MHz + 1800 MHz ECC/DEC/(06)13 [37]	UMTS vs GSM: Carrier separation of 2.8 MHz or more LTE/WiMAX vs GSM: Frequency separation of 200 kHz or more between the LTE channel edge and the GSM carrier's channel edge	No specific emission limits but recommendations on coordination for: PMR/PAMR above 915MHz, GSM-R in 876-880/921-925 MHz, Aeronautical systems above 960MHz, Fixed Service operating above 1805MHz, Are available in various ECC/CEPT Reports (See Table 14)
Bands achieving technology neutrality through LRTCs		
700 MHz ECC/DEC/(15)01 [25]	Base Stations: MFCN BS in-block power limit not mandatory, if desired: 64 dBm/5 MHz per antenna. Transition requirements: Maximum mean e.i.r.p. dBm/5MHz/antenna Baseline Requirements: Maximum mean e.i.r.p. dBm/cell or antenna/varying BW (depends on precise band) Terminal Stations: Maximum mean in-block power: 23 dBm	Base Stations: Adjacent bands above 703 MHz: Maximum mean e.i.r.p. in dBm/antenna/varying BW Below 703 MHz: Maximum mean e.i.r.p. in dBm/cell/varying BW Terminal Stations: Adjacent bands above 694 MHz: Maximum mean out-of-block e.i.r.p. in dBm/ varying BW 470-694 MHz: Maximum mean unwanted emission power of -42dBm/8MHz
800 ECC/DEC/(09)03 [30]	Base Stations: MFCN BS in-block power limit not mandatory, if desired: 56 to 64 dBm/5 MHz per antenna. Transition requirements: Maximum mean e.i.r.p. dBm/5MHz/antenna for 1 to 4 antennas Baseline Requirements: Maximum mean e.i.r.p. dBm/MHz/antenna for 1 to 4 antennas Terminal Stations: Maximum mean in-block power: 23 dBm Out-of-block requirements: Maximum mean out of band power in dBm/varying BW	Base Stations: Spectrum allocated to broadcasting: Maximum mean e.i.r.p. varying with BS in block e.i.r.p.. Limit expressed in dBm/8MHz Terminal Stations: Adjacent bands below 790 MHz: Maximum mean out of band power of -65 dBm/8 MHz

Band	In-band	Adjacent bands
2.1 ECC/DEC/(06)01	Base Stations: MFCN BS in-block power limit not mandatory, if desired: 61 to 65 dBm/5 MHz. Out-of-block requirements: Maximum mean e.i.r.p. dBm/5 MHz/antenna for up to 4 antennas per sector Terminal Stations: Maximum mean in-block power: 24 dBm	
2.3 ECC/DEC/(14)02 [48]	Base Stations: MFCN BS in-block power limit not mandatory in 2300-2390, if desired: 61 to 68 dBm/5 MHz per antenna. 2390-2400 MHz: maximum in-block e.i.r.p. of 45 dBm / 5 MHz. Out-of-block requirements: Maximum mean e.i.r.p. sometimes depending on in-band power, dBm/5MHz/either cell or antenna User Equipment: Maximum e.i.r.p of 25 dBm for fixed UE Maximum Total Radiated Power of 25 dBm for mobile/nomadic UEs.	Base Stations: Above 2403 MHz: MFCN BS maximum e.i.r.p. varying with BS in block e.i.r.p.. Limit expressed in dBm/5 MHz
2.5 + TDD2.5 ECC/DEC/(05)05 [52]	Base Stations: MFCN BS maximum e.i.r.p. 61 to 68 dBm/5 MHz. Out-of-block requirements: Maximum mean e.i.r.p. in dBm/ varying BW User Equipment: Maximum e.i.r.p of 35 dBm/5 MHz for fixed UE Maximum Total Radiated Power of 31 dBm/5 MHz for mobile/nomadic UEs.	
3.5 + 3.7 ECC/DEC/(11)06 [59]	Base Stations: MFCN BS in-block power limit not mandatory, if desired, no more than 68 dBm/5 MHz/antenna. Out-of-block requirements: Maximum mean e.i.r.p. sometimes depending on in-band power dBm/5MHz/antenna Terminal Stations: Maximum e.i.r.p of 25 dBm for fixed UE Maximum Total Radiated Power of 25 dBm for mobile/nomadic UEs.	Base Stations: Countries with military radiolocation systems below 3400 MHz: maximum e.i.r.p. below 3400 MHz: -50 or -59 dBm/MHz

4 COMPLIANCE OF M2M CELLULAR IoT TECHNOLOGIES[14] WITH THE MFCN REGULATORY FRAMEWORK

4.1 LTE-MTC AND LTE-eMTC REGULATORY ANALYSES

4.1.1 900 MHz and 1800 MHz bands

LTE-MTC and LTE-eMTC are covered by EN 301908-13 [7] and EN 301908-14 [11]. Therefore, LTE-MTC and LTE-eMTC may be used under the technical conditions relating to LTE as specified by the current ECC regulatory framework in the bands 900 MHz and 1800 MHz, (see Annex of ECC/DEC/(06)13 [37]).

4.1.2 Other MFCN bands

Since there is no modification to the LTE SEM, either on the UE or BS side, LTE-MTC and LTE-eMTC BSs and UEs will comply with the BEM. As such, the current ECC regulatory framework does not pre-empt the deployment of LTE-MTC and LTE-eMTC in the MFCN bands.

4.2 EC-GSM IOT REGULATORY ANALYSES

4.2.1 900 MHz and 1800 MHz bands

EC-GSM-IoT is covered by EN 301 502 [9] and EN 301 511 [10]. Therefore, EC-GSM-IoT is allowed in the 900 and 1800 MHz band through the ERC/DEC/(94)01 [63], ERC/DEC/(95)03 [65] and ERC/DEC/(97)02 [64] Decisions with technical conditions relating to GSM.

4.2.2 Other MFCN bands

From purely regulatory perspective MNO's, EC-GSM-IoT may be deployed under a BEM. However, compatibility studies to derive the BEM did not consider this case. The BEMs were derived for wideband technologies and did not consider narrowband technologies. Therefore, at this stage, deployment of EC-GSM-IoT is not considered in frequency bands other than 900/1800 MHz.

4.3 NB-IOT REGULATORY ANALYSES

4.3.1 Generic analysis

NB-IoT covers very different systems, since NB-IoT is a narrowband system under a standalone deployment, a wideband system under an in-band deployment, and the sum of a wideband carrier and a narrowband component under a guard-band deployment. Typically, regulatory conditions applicable to wideband and narrowband systems are not the same.

[14] See section 2.1, technologies is to be understood as EC-GSM, LTE-MTC, LTE-eMTC and NB-IoT, e.g. ECC Report 242 [4].

4.3.2 **900 MHz and 1800 MHz bands**

The 900 MHz and 1800 MHz bands are regulated for GSM/UMTS/LTE/WiMAX referring to the respective harmonised standards. NB-IoT standalone is a narrowband system and is specified by 3GPP in TS 36.101 [5] and TS 36.104 [6].

NB-IoT will be covered by the LTE Harmonised Standards (EN 301908-13 [7] and EN 301908-14 [6]) [14].

As described in Section 5, any harmful interference caused by NB-IoT Standalone will be no greater than that caused by existing deployments of GSM in the 900/1800 MHz bands. As such the regulatory technical conditions applicable to GSM are also applicable to NB-IoT Standalone; to reflect this, the ECC Decision(06)13 [37] would need to be amended.

4.3.3 **Other MFCN bands**

Regarding NB-IoT deployed in guard band mode there is no modification of the LTE out-of-Band emissions on the BS side, beyond a specific frequency separation defined in Table 3. Since the in-band and out-of-band EIRP of the total composite {NB-IoT + LTE} signal transmitted by the base station does not exceed the limits which apply to a single LTE carrier, and where applicable, the BEM and/or OOBE requirements are met, the composite signal {NB-IoT+LTE} does not create more interference than a single LTE signal occupying the same bandwidth and transmitting at the same power.

Regarding other adjacent services, some studies within the ECC framework already integrate the fact that the mobile service does not occupy fully its bandwidth. Therefore, although the overall in-band and out-of-band powers of the signal may not change with the addition of the NB-IoT resource blocks, these latter may be seen as additional sources of interference by the victim receiver based on its ACS, in particular if the ACS of the victim receiver is not flat within the whole LTE bandwidth. However, in Section 2 it is shown that guard-band NB-IoT can be deployed only within LTE channels of 10, 15, 20 MHz bandwidth in order to fulfil the required 200 kHz channel edge frequency separation. Comparing the impact of {LTE 5 MHz} with {LTE 10/15/20 MHz and guard-band NB-IoT} on adjacent services (see section 5), it is concluded that the impact of guard-band NB-IoT is not greater than the one of LTE 5 MHz without guard-band NB-IoT.

A review of the existing adjacent band compatibility studies is described in Section 5.

5 TECHNICAL COMPATIBILITY STUDIES

This section discusses the technical compatibility of M2M technologies and provides an overview of compatibility requirements in terms of:

- Compatibility with other in-band applications;
- Compatibility with other radio systems operating in adjacent bands.

5.1 CASES WHERE COMPATIBILITY STUDIES ARE NOT REQUIRED

5.1.1 **LTE-MTC/eMTC technical compatibility**

LTE-MTC/eMTC is embedded in a 'standard' LTE Carrier and does not modify the LTE SEM. BEMs were developed taking into account LTE SEM and Tx power and remain unchanged. Therefore, LTE-MTC/eMTC is perfectly equivalent to LTE from an adjacent channel/adjacent band compatibility standpoint, with no change in power control nor spectrum emission. No new study is required in bands where LTE is allowed.

5.1.2 **EC-GSM-IoT technical compatibility**

Since EC-GSM-IoT reuses the same modulation/SEM as GSM, it is perfectly equivalent to 'standard' GSM from an adjacent channel/adjacent band compatibility standpoint, with unchanged SEM and Tx requirements. No new study is required in bands where GSM deployments were already specifically addressed i.e. in the 900 MHz/1800 MHz (e.g as in CEPT Report 40, 41 and 42). For deployments in any other bands, further studies are required.

5.1.3 **In-band NB-IoT technical compatibility**

NB-IoT in-band deployment would not modify the LTE SEM. BEM's were developed taking into account LTE SEM and Tx power and remain unchanged. In-band deployment of NB-IoT does not require changes in power control nor spectrum emissions. No new study is required in bands where LTE is allowed.

5.2 COMPATIBILITY WITH OTHER IN-BAND APPLICATIONS

3GPP performed adjacent channel coexistence studies for NB-IoT, considering all the possible deployment scenarios, namely in-band, in LTE guard-band and standalone. Victim systems analysed in these studies were LTE, UMTS and GSM. The outcome of this study is described in 3GPP Technical Report 36.802 [12]. 3GPP concludes in TR 36.802 that NB-IoT can co-exist with LTE, UMTS and GSM. A summary of the simulation coexistence cases analysed by 3GPP for standalone NB-IoT is reported in Table 16. In particular:

- Both UL to UL and DL to DL coexistence are taken into account;
- NB-IoT is considered as both aggressor and victim system;
- Coexistence with LTE, UMTS and GSM is taken into account.

5.2.1 Standalone NB-IoT

Table 16: Simulation cases of coexistence study for standalone NB-IoT (from TR 36.802 [12])

Cases	Operation mode	Aggressor	Victim	Direction
1	Standalone	NB-IoT	LTE	Downlink
2	Standalone	LTE	NB-IoT	Downlink
3	Standalone	NB-IoT	UMTS	Downlink
4	Standalone	UMTS	NB-IoT	Downlink
5	Standalone	NB-IoT	GSM	Downlink
6	Standalone	GSM	NB-IoT	Downlink
7	Standalone	NB-IoT	LTE	Uplink
8	Standalone	LTE	NB-IoT	Uplink
9	Standalone	NB-IoT	UMTS	Uplink
10	Standalone	UMTS	NB-IoT	Uplink
11	Standalone	NB-IoT	GSM	Uplink
12	Standalone	GSM	NB-IoT	Uplink

A complete list of the adopted simulation parameters can be found in 3GPP TR 36.802. The main goal of this study was to analyse the impact of unwanted emission from NB-IoT (LTE/UMTS/GSM) to LTE/UMTS/GSM (NB-IoT). It is worth noticing that the study was run considering no frequency separation between aggressor and victim systems. In order to derive the relevant coexistence RF requirements, i.e. NB-IoT ACLR and ACS, the following criteria were adopted for impact to the victim systems:

- LTE Throughput degradation less than 5% for 5%-ile and average;
- UMTS Outage less or equal to 5%;
- GSM Outage less or equal to 5%;
- NB-IoT Average of SNR value loss is less or equal to 1 dB.

The outcome of this study was the set of RF requirements specified in TS 36.101 [5] as described in section 2.5.1. Those parameters ensure coexistence in terms of unwanted emission even for the worst case of no separation between aggressor and victim systems.

In order to derive a clear requirement in terms of frequency separation needed between NB-IoT and other IMT systems, additional considerations for narrow-band blocking need to be taken into account. The focus here is on the separation between NB-IoT standalone and adjacent UMTS/LTE services. Since NB-IoT has similar transmit requirements compared to the GSM systems (as observed in section 2.5.1), similar observations as those made in ECC Report 82 [35] and CEPT Report 40 [1] can be drawn here.

In ECC Report 82 coexistence between UMTS and GSM was analysed. The conclusion of the report was that the recommended carrier separation between UMTS carrier frequency and the nearest GSM carrier frequency should be 2.8 MHz or more. Considering a UMTS channel bandwidth of 5 MHz and a GSM channel bandwidth of 200 kHz this corresponds to a channel edge to channel edge frequency separation of 200 kHz.

The coexistence between LTE and GSM systems was analysed in CEPT Report 40 based on an analogy with UMTS systems. As a final conclusion, a recommended frequency separation of 300 kHz between GSM carrier frequency and LTE channel edge was proposed, or alternatively 200 kHz separation between GSM and LTE channel edges. One of the main reasons for this requirement was that LTE receiver rejection requirements were also based on narrow-band blocking requirements, which are based on 200 kHz separation from channel edges. For smaller frequency separation the impact from GSM to LTE was not verified.

Following the observations above, and considering the similarity between NB-IoT and GSM systems, the same technical conditions should apply for coexistence between NB-IoT and UMTS/LTE systems. As a consequence the frequency separations summarised in.

Table 17 are recommended for NB-IoT standalone.

Table 17: Minimum frequency spacing between NB-IoT standalone and UMTS/LTE carrier

Frequency spacing between NB-IoT standalone carrier centre frequency and UMTS channel edge	Frequency spacing between NB-IoT standalone channel edge and UMTS channel edge	Frequency spacing between NB-IoT standalone carrier centre frequency and LTE channel edge	Frequency spacing between NB-IoT standalone channel edge and LTE channel edge
300 kHz	200 kHz	300 kHz	200 kHz

For the frequency separation between two standalone NB-IoT carriers or between a standalone NB-IoT and a GSM carrier of different operators, the existing practice of frequency separation between two GSM carriers of different operators should be used, i.e.200 kHz frequency spacing between channel edges.

Such arrangement is possible provided that deployment of these technologies is coordinated between operators.

5.2.2 Guardband NB-IoT

In case of guard-band NB-IoT operation between mobile operators, the NB-IoT RB band edge needs to be placed at least 200 kHz away from the LTE channel edge in order to fulfil the LTE criteria set out in Section 2. Within CEPT, guard-band operation of NB-IoT is foreseen only for frequencies with LTE bandwidth of 10 MHz or higher.

5.3 COMPATIBILITY IN ADJACENT BANDS

By adjacent bands, it is referred to applications operating in a band adjacent to the band where the IoT carrier is deployed. The sections below address compatibility studies between NB-IoT systems (guard-band and standalone) and adjacent services/applications in different frequency ranges and in particular in the 900 MHz band.

5.3.1 Frequency arrangement in 880-960 MHz

As shown in Figure 7, in the 900 MHz mobile band (GSM/UMTS/LTE UL: 880-915 MHz, DL: 925-960 MHz, GSM-R DL: 921-925 MHz), unlicensed SRDs occupy the 915-921 MHz band.

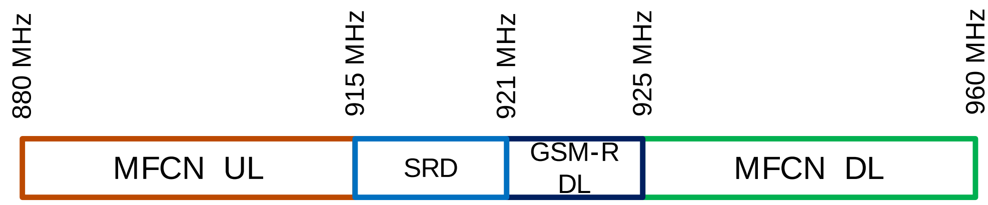

Figure 7: Frequency arrangement in 880-960 MHz

915-921 MHz is regulated as unlicensed band, used by multiple applications: RFID, SRDs 100 mW, SRDs 25 mW, ALD, etc. The overview of the usage in 915-921 MHz unlicensed band is given in Figure 8 (ECC Report 246 Figure 1)[66].

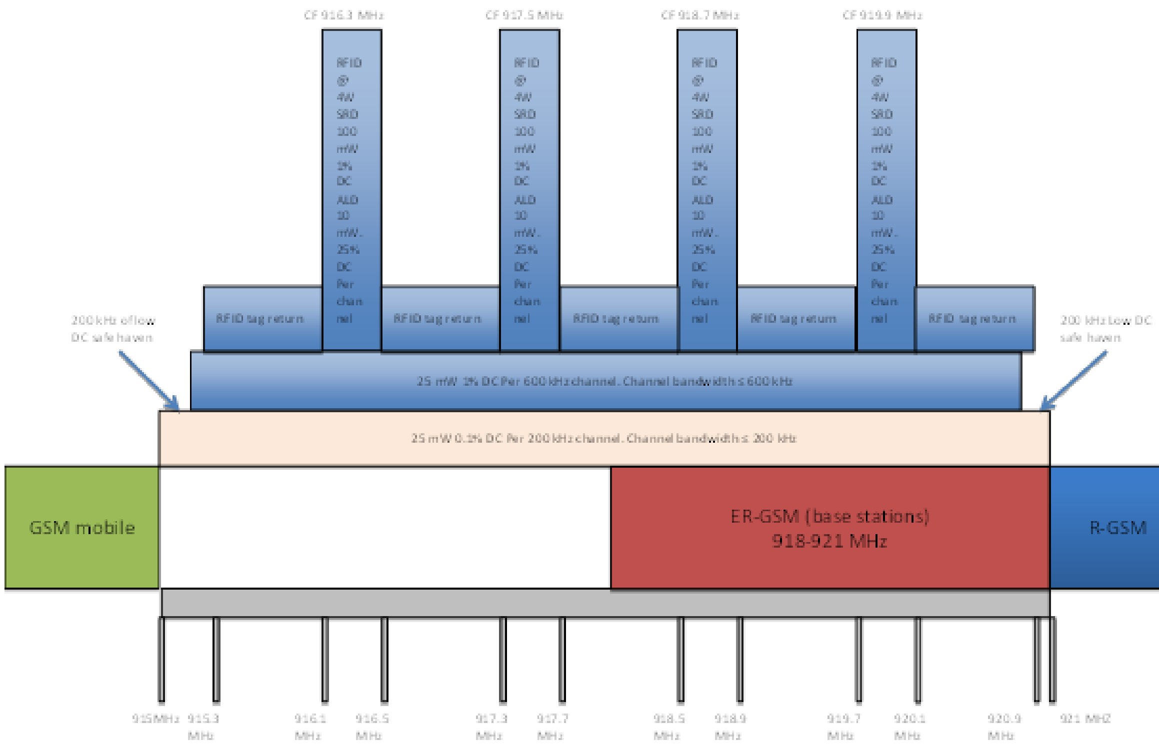

Figure 8: Overview of 915-921 MHz unlicensed band (ECC Report 246 figure 1)

The addendum report [68] to CEPT Report 59 has proposed several new regulatory entries to the EC SRD Decision for the frequency band 915-921 MHz band [70] in reference to the ECC Report 246.

It should be noted that in the 915-921 MHz band, four 4 W e.r.p. RFID channels of 400 kHz are proposed: interrogator transmissions at 4 W e.r.p. only permitted at the centre frequencies 916.3 MHz, 917.5 MHz, 918.7 MHz and 919.9 MHz.

WAN NBN SRD 500 mW / 200 kHz in 915-921 MHz is proposed as an amount of 3 times 400 kHz can be used with a bandwidth of ≤ 200 kHz for 500 mW e.r.p. data networks. Transmissions are only permitted within the bands 917.3-917.7 MHz, 918.5-918.9 MHz and 919.7-920.1 MHz. Adaptive Power Control (APC) is required, or other mitigation techniques which achieve at least an equivalent level of spectrum compatibility.

Based on this new entry, LPWAN (Low Power Wide Area Network) of 500 mW e.r.p. may be deployed within the three 4W RFID channels in 915-921 MHz band.

In the executive summary of the addendum report to the CEPT Report 59, it is clearly written that

"*Article 3 of Commission Implementing Decision (2006/771/EC* [69], *latest amended by 2013/752/EU* [70]) *on harmonisation of the radio spectrum for use by short-range devices requires that "Member States shall designate and make available, on a non-exclusive, non-interference and non-protected basis, the frequency bands for the categories of short-range devices, …".*

Article 2 of this Decision defines that " *'non-interference and non-protected basis' means that no harmful interference may be caused to any radio communications service and that no claim may be made for protection of these devices against harmful interference originating from radio communications services.*"

In addition, it is highlighted in recital-3 of EC Decision 2006/771/EC that "… *radiocommunications services, as defined in the International Telecommunications Union Radio Regulations, have priority over short-range devices and are not required to ensure protection of particular types of short-range devices against interference.*"

Based on this principle, ECC Report 246 has not studied the interference from the 900 MHz cellular systems (GSM/UMTS/LTE) to SRDs (RFID, WAN NBN, etc.), but studied only the interference from SRDs (RFID, WAN NBN, etc.) to the cellular systems uplink without taking into account the NB-IoT. In the ECC Report 246 on the interference from SRDs to cellular system, LPWAN was not considered.

In order to analyse the impact of guard-band NB-IoT on adjacent services, interference from **guard-band NB-IoT out-of-band emissions** and **blocking impact of the victim receiver** in adjacent bands should be considered.

Regarding the impact of **out-of-band emissions of GB NB-IoT**: as stated in section 4.3.3, the out of band emission of {LTE + GB NB-IoT} is the same as OOB emission of {LTE} thus there is no additional impact on adjacent services from GB NB-IoT.

With respect to the **blocking impact of the victim receiver**: in section 2.5.2.2 it is shown that guard-band NB-IoT can be deployed in the guard-band of LTE carriers with 10, 15, 20 MHz channel bandwidth. Table 8 and Table 9 reveal that in such cases the distance (offset) from the NB-IoT resource block edge to the LTE (band) edge is larger than the last in-band resource block of LTE 1.4, 3 and 5 MHz channels. Therefore, the impact of guard-band NB-IoT due to adjacent receiver blocking capabilities is not larger than LTE 1.4, 3 and 5 MHz channels without guard-band NB-IoT. The following figure shows this:

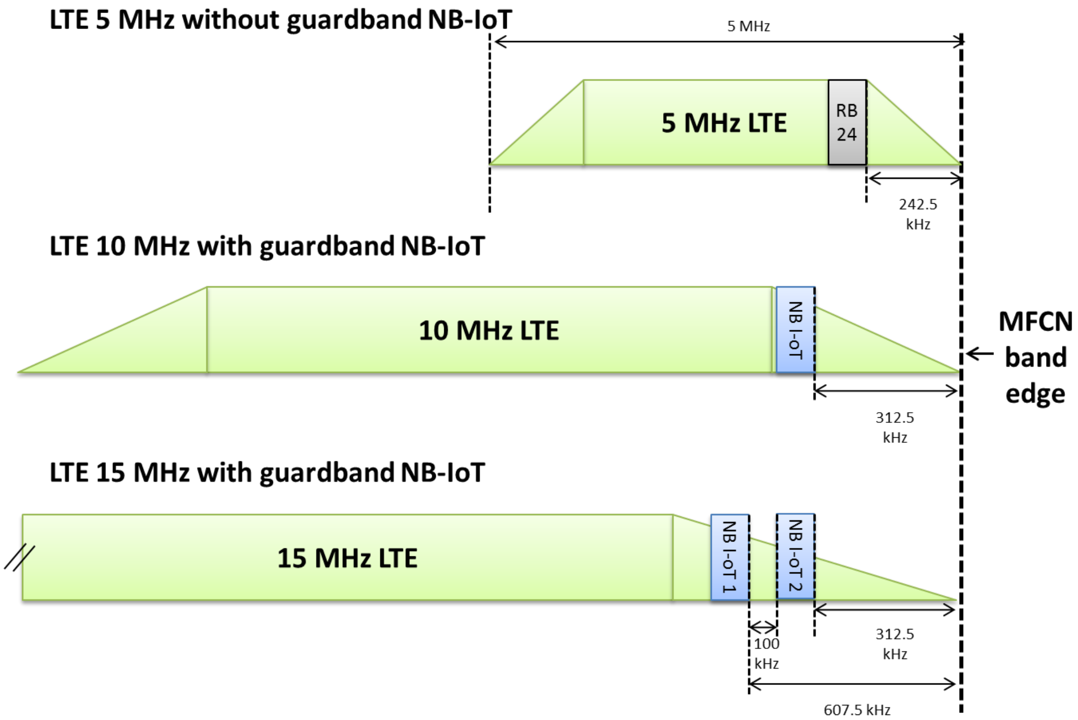

Figure 9: Offset from the NB-IoT resource block edge to the LTE band edge

The conclusion from the above analysis is that introducing guard-band NB-IoT into all MFCN bands should not cause any additional impact on adjacent services provided that currently defined BEMs are fulfilled.

In the particular case of LTE/WiMAX DL and GSM-R DL coexistence at 925 MHz, according to CEPT Report 41 [2], the frequency separation between the nearest GSM-R channel centre frequency and LTE/WiMAX channel edge should be at least 300 kHz (200 kHz between channel edges). For some critical cases (e.g. with high located antenna, open and sparsely populated areas served by high power LTE/WiMAX BS close to the railway tracks, which would lead to assumption of possible direct line of sight coupling) coordination is needed for a certain range of distances (up to 4 km or more from railway track) when the GSM-R signal is close to the sensitivity level. Further to the above CEPT report, ECC adopted ECC Report 229 [33] providing guidance for improving coexistence between GSM-R and MFCN in 900 MHz band.

Based on conclusions from the above CEPT Report, a 10 MHz or larger LTE carrier with NB-IoT in guard band where the NB-IoT block edge is 200 kHz away from LTE channel edge, having at least a 200 kHz edge-to-edge frequency separation between LTE channel edge and GSM-R edge, is not expected to cause more harmful interference than an LTE carrier without NB-IoT, considering that the out of band emissions in DL are similar.

In case of UL transmissions for regular LTE wave forms, single RB transmission at the edge of the channel is already in use for PUCCH, which is similar in nature to narrow-band emissions. This single RB can potentially be scheduled to operate at full power without RBs present. Furthermore such transmission could occur on a regular basis to provide control plane information from UE to BS. Thus such signal could potentially create more interference than NB-IoT carrier which usually transmits information with lower duty cycles. Therefore introduction of guard band NB-IoT with frequency offset larger than the minimum frequency offset of RB used for PUCCH in 5 MHz channels won’t create more interference than the signal of the regular LTE.

Regarding compatibility between guard-band NB-IoT and SRDs in 900 MHz band, ECC Report 246 studied only the interference from SRDs (RFID, WAN NBN, etc) to cellular systems (GSM/UMTS/LTE). However, the studies did not cover LPWAN, which at that time wasn’t an entry among the SRDs. Regarding the sharing between SRD’s and guard-band NB-IoT, the same explanation as above applies. Therefore no additional interference from guard-band NB-IoT is anticipated into SRD bands and the conditions of operation between LTE and SRD’s apply.

5.3.2 **Interference of adjacent services into guard-band NB-IoT**

The co-existence between LTE 900 and GSM-R at 925 MHz was described in CEPT Report 41 [2]. CEPT Report 41 concludes that there is no need for additional guard-band between LTE 900 and GSM-R, whatever the channelization or bandwidth considered for LTE 900. Therefore a frequency separation of 200 kHz between channel edges was considered to be sufficient for the compatibility between LTE 900 and GSM-R.

Given that the receiver characteristics of NB-IoT are similar to those of regular LTE receivers, it is expected that the behaviour of both receivers is the same. Therefore the conditions of operation of guard-band NB-IoT are expected to be similar to those of regular LTE, provided that the currently defined BEMs are fulfilled.

5.3.2.1 Potential interference from SRDs/IoT/LPWAN to guard band NB-IoT

In ECC Report 246, the interference from all SRDs (Wideband IoT 802.11ah, RFID, ALD, generic SRDs 25 mW) operation in 915-921 MHz to cellular system (GSM/UMTS/LTE) uplink below 915 MHz was studied with Monte-Carlo simulations. But NB-IoT was not standardised yet and therefore was not considered in the study. The simulation results show that the cellular system data service capacity/throughput loss caused by SRDs/IoT operations above 915 MHz depends on the SRD/IoT devices density and duty cycle. Under the assumption that SRDs operate at their regulatory duty cycle limits and high density as assumed, cellular system uplink capacity/throughput loss can be more than 20%. Given that the receiver characteristics of NB-IoT are similar to those of regular LTE receivers, it is expected that the behaviour of both receivers is the same and therefore the potential interference from SRDs/IoT/LPWAN to guard-band NB-IoT below 915 MHz would be similar to LTE.

5.3.3 **Standalone NB-IoT**

There are two possible mechanisms for harmful interference from NB-IoT to adjacent services to 900/1800 MHz bands; namely a) spectral power leakage from NB-IoT equipment, and b) blocking of equipment in other services.

5.3.3.1 Spectral power leakage

As described in section 2.5.1, the standalone NB-IoT emission mask is comparable to that of GSM requirements. As such, for the same levels of maximum permitted carrier EIRP and frequency separation, the propensity of standalone NB-IoT equipment to cause harmful interference – via spectral leakage inside and outside the 900/1800 MHz bands – is no greater than that of GSM equipment.

5.3.3.2 Blocking

Standalone NB-IoT is a narrowband cellular technology with a 200 kHz channel bandwidth. As such, for the same levels of maximum permitted carrier EIRP and frequency separation, the propensity of standalone NB-IoT equipment to cause harmful interference – via blocking of radio receivers in adjacent bands to 900/1800 MHz bands – is no greater than that of GSM equipment.

In fact, it can be readily seen that standalone NB-IoT user equipment are less likely than GSM equipment to block other receivers. This is because NB-IoT user equipment has a maximum EIRP of 23 dBm, as opposed to 33 dBm for GSM.

5.4 SUMMARY OF COMPATIBILITY STUDIES

Based on the above discussions, it can be concluded that standalone NB-IoT equipment complying with the relevant technical conditions (maximum permitted EIRPs and minimum frequency separations from other adjacent services) which apply in the context of GSM, may be deployed in the 900/1800 MHz bands without any increase in the likelihood of harmful interference.

For the frequency separation between two standalone NB-IoT carriers or between a standalone NB-IoT and a GSM carrier of different operators, the existing practice of frequency separation between two GSM carriers of different operators should be used, i.e.200 kHz frequency spacing between channel edges.

Such arrangement is possible provided that deployment of these technologies is coordinated between operators.

In summary:

- 200 kHz separation between the GSM channel edge and Wideband UMTS/LTE/WiMAX channel edge, where LTE includes LTE-MTC/eMTC, In-band NB-IoT and guard-band NB-IoT, GSM includes EC-GSM-IoT;
- 200 kHz separation between the Standalone NB-IoT channel edge and Wideband UMTS/LTE/WiMAX channel edge, where LTE includes LTE-MTC/eMTC, In-band NB-IoT and guard-band NB-IoT;
- 200 kHz separation between the Standalone NB-IoT channel edge and the GSM channel edge, where GSM includes EC-GSM-IoT, subject to coordination between operators.

Regarding the deployment in 900 MHz and 1800 MHz bands, it is expected that the conditions of operation of guard-band and standalone NB-IoT with respect to adjacent services are similar to those of regular LTE. Regarding operation in the other harmonised MFCN bands (excluding SDL and TDD) it is expected that no additional interference is created by guard-band NB-IoT. Therefore the conditions of operation of guard band NB-IoT are expected to be similar to those of regular LTE, provided that currently existing BEMs are fulfilled.

6 CONCLUSIONS

The following M2M Cellular IoT technologies were studied in this report: LTE-MTC, LTE-eMTC, EC-GSM-IoT and NB-IoT. The technologies were described in Section 2. In particular, M2M Cellular IoT technologies can be deployed in standalone, in-band or guard-band mode. EC-GSM-IoT can be deployed in standalone, and/or in-band, LTE-MTC/eMTC can only be deployed in in-band mode, while NB-IoT can be deployed in all three modes.

EC-GSM-IoT is covered by the GSM harmonised standard and has the same parameters as those used for GSM in the previous CEPT compatibility studies. In consequence EC-GSM-IoT does not raise any regulatory or technical (coexistence) issue in the 900 and 1800 MHz band.

LTE-MTC/eMTC is covered by the LTE harmonised standard. LTE-MTC/eMTC is part of an LTE system, the BS and UE spectrum masks are the same as a normal LTE system and use the same LTE OOBE. There is no modification to the LTE SEM, either on the UE or BS side. LTE-MTC/eMTC does not raise any regulatory or technical (coexistence) issue and can be deployed in 900 MHz, 1800 MHz as standard LTE. Concerning the frequency bands where BEM are in force, the assumptions used for developing these BEM are also valid for the LTE-MTC/eMTC. In consequence, LTE-MTC/eMTC could be used in any harmonised MFCN band, except SDL and TDD bands, where BEM are in force without further consideration.

NB-IoT in-band is covered by the LTE harmonised standard. Embedding an NB-IoT in an LTE carrier does not change the power or the Spectrum Emission Mask (SEM), either on the BS or the UE side. In consequence, NB-IoT in-band does not raise any regulatory or technical (coexistence) issues with MFCN networks and can be deployed in 900 MHz, 1800 MHz and in any other harmonised MFCN band without further consideration. SDL and TDD bands have not been considered in this report.

As described in Section 5, interference caused by NB-IoT standalone will not be greater than that caused by GSM in the 900/1800 MHz bands. As such, the regulatory technical conditions applicable to GSM are also applicable to NB-IoT standalone; to reflect this, the ECC Decision(06)13 [37] would need to be amended, to include standalone NB-IoT.

Standalone NB-IoT operation is considered in this report only in the 900 and 1800 MHz bands, with the following minimum separation requirements:

- 200 kHz separation between the GSM channel edge and Wideband UMTS/LTE/WiMAX channel edge, where LTE includes LTE-MTC/eMTC, in band NB-IoT and guard-band NB-IoT, GSM includes EC-GSM-IoT;
- 200 kHz separation between the standalone NB-IoT channel edge and Wideband UMTS/LTE/WiMAX channel edge, where LTE includes LTE-MTC/eMTC, in-band NB-IoT and guard-band NB-IoT;
- 200 kHz separation between the standalone NB-IoT channel edge and the GSM channel edge, where GSM includes EC-GSM-IoT, subject to coordination between operators.

Guard band NB-IoT should operate in 900/1800 MHz frequency bands, provided that the NB-IoT RB band edge is placed at least 200 kHz away from the LTE channel edge. The usage of guard band NB-IoT within CEPT is foreseen only for LTE channel bandwidth of 10 MHz or higher. Operators may deploy guard band NB-IoT for smaller channel bandwidth in between their blocks, if agreed.

With regard to interference with adjacent services/applications no additional interference from guard band NB-IoT is expected compared to a LTE 5 MHz channel. Regarding operation in the other harmonised MFCN bands (excluding SDL and TDD) it is expected that no additional interference is created by guard-band NB-IoT if placed at least 200 kHz away from the block edge. Also the receiver characteristics of NB-IoT are similar to those of regular LTE receivers. Therefore the conditions of operation of guard band NB-IoT are expected to be similar to those of regular LTE, provided that the currently defined BEMs are fulfilled.

6.1 AREAS FOR CONSIDERATION WITH REGARD TO ECC REGULATORY FRAMEWORK

1. LTE-MTC/eMTC and EC-GSM IoT are implemented as intrinsic parts of existing LTE and GSM technologies respectively. Therefore no change to the ECC regulatory framework is needed to address LTE-MTC/eMTC and EC-GSM-IoT.
2. Revision of ECC Decision(06)13 to accommodate the use of guard band and standalone NB-IoT in 900/1800 MHz.
3. For the frequency bands other than 900/1800MHz bands, the current ECC regulatory framework allows mobile operators to deploy guard band NB-IoT anywhere in their blocks. The requirement of 200 kHz frequency separation between guard-band NB-IoT channel edge and operator block edge is not ensured by the current ECC regulatory framework where BEM are in force.

ANNEX 1: MAIN TECHNICAL PARAMETERS OF M2M CELLULAR IOT TECHNOLOGIES FOR COEXISTENCE STUDIES

Table 18: Main technical parameters of M2M Cellular IoT technologies for coexistence studies

Parameter	EC GSM	LTE-MTC/eMTC	NB-IoT		
			Standalone	In-band	Guard-band
BS BW	200 kHz	BW of support LTE carrier	200 kHz channel BW 180 kHz signal BW 180 kHz (adjacent to NB-IoT)	BW of support LTE carrier	BW of support LTE carrier + use of channel 'guard-band'
Minimum in-channel guard-band	Not applicable	Same as support LTE carrier 10 MHz => 500 kHz	10 kHz	Same as support LTE carrier	0 kHz
BS OOBE	GSM OOBE	LTE OOBE	New NB-IoT OOBE	LTE OOBE	LTE OOBE for emissions 165 to 245 kHz away from NB-IoT channel edge (see Table 3)
Min UE BW	200 kHz	180 kHz	[15/3.75] kHz	[15/3.75] kHz	[15/3.75] kHz
Max UE BW	200 kHz	1080 kHz	180 kHz	180 kHz	180 kHz
UE OOBE	GSM OOBE	LTE OOBE	New NB-IoT OOBE	LTE OOBE	LTE OOBE for emissions 165 to 245 kHz away from NB-IoT channel edge (see Table 3)
UE Tx power		23 dBm (class 3) 20 dBm (class 5)	23 dBm (class 3) 20 dBm (class 5)		

ANNEX 2: 3GPP BAND DEFINITION

Table 19: CEPT relevant 3GPP bands as defined in Table 5.5.1 of 3GPP TS 36.101 V14.1.0 (2016-09)

E-UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit F UL_low – F UL_high			Downlink (DL) operating band BS transmit UE receive F DL_low – F DL_high			Duplex Mode
1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	FDD
28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	FDD
31	452.5 MHz	–	457.5 MHz	462.5 MHz	–	467.5 MHz	FDD
32	N/A			1452 MHz	–	1496 MHz	FDD
33	1900 MHz	–	1920 MHz	1900 MHz	–	1920 MHz	TDD
34	2010 MHz	–	2025 MHz	2010 MHz	–	2025 MHz	TDD
38	2570 MHz	–	2620 MHz	2570 MHz	–	2620 MHz	TDD
40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
43	3600 MHz	–	3800 MHz	3600 MHz	–	3800 MHz	TDD
46	5150 MHz	–	5925 MHz	5150 MHz	–	5925 MHz	TDD
65	1920 MHz	–	2010 MHz	2110 MHz	–	2200 MHz	FDD
66	1710 MHz	–	1780 MHz	2110 MHz	–	2200 MHz	FDD (SEE NOTE 1)
68	698 MHz	–	728 MHz	753 MHz	–	783 MHz	FDD
69	N/A			2570 MHz	–	2620 MHz	FDD

NOTE 1: The range 2180 – 2200 MHz of the DL operating band is restricted to E-UTRA operation when carrier aggregation is configured.

ANNEX 3: LIST OF REFERENCE

[1] CEPT Report 40 - Compatibility study for LTE and WiMAX operating within the bands 880-915 MHz / 925-960 MHz and 1710-1785 MHz / 1805-1880 MHz (900/1800 MHz bands), November 2010

[2] CEPT Report 41 - Compatibility between LTE and WiMAX operating within the bands 880-915 MHz / 925-960 MHz and 1710-1785 MHz / 1805-1880 MHz (900/1800 MHz bands) and systems operating in adjacent bands, November 2010

[3] CEPT Report 42 - Compatibility between UMTS and existing and planned aeronautical systems above 960 MHz, November 2010

[4] ECC Report 242 - Compatibility and sharing studies for M2M applications in the 733-736 MHz / 788-791 MHz band, March 2016

[5] 3GPP TS 36.101, Rel. 13 - Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception

[6] 3GPP TS 36.104, Rel. 13 - Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception

[7] ETSI EN 301 908-13 V11.1.1 - IMT cellular networks; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive; Part 13: Evolved Universal Terrestrial Radio Access (E-UTRA)User Equipment (UE)

[8] ETSI EN 301 908-18 V11.1.1 - IMT cellular networks; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive; Part 18: E-UTRA, UTRA and GSM/EDGE Multi-Standard Radio (MSR) Base Station (BS)

[9] ETSI EN 301 502 V11.1.1 - Global System for Mobile communications (GSM); Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive

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