Technical Report / Teaching Material

Nominal Planning of a LTE700 PPDR Network in Germany

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1. Abstract

In Germany, 2 x 8MHz spectrum was assigned to Public Protection and Disaster Release (PPDR) services in the 700MHz frequency band. Currently public authorities operate for blue light services a national TETRA network using approximately 4,700 base station sites. This technical report examines the site portfolio for a national PPDR LTE network in 700MHz based on planning parameter for a PPDR network in Spain as published in [1]. Furthermore, the resulting planning margins are analysed using a common methodology for the nominal site count planning. Both planning approaches show that the number of sites given by TETRA is sufficient for a high quality LTE-based PPDR network in Germany.

The following chapter shows the assumptions taken for the network planning. In chapter 3, the planning approach in Spain is summarized and applied for the site layout in Germany. In chapter 4, a common method for the nominal planning is used. However, in this case this method was applied not for obtaining the number of required sites, but for calculating the power budget margins if using the existing number of sites. Chapter 5 summarises this technical study.

2. Planning assumptions

Following planning assumptions are used for this technical study.

a) Site layout
Existing TETRA sites for blue light services will be equipped with LTE technology (eNodeB) and 700MHz antennas. LTE with the distributed eNodeB design allows the installation of radio heads (remote radio units) close to the antenna. Such a design reduces the feeder cable loss, anyway being relatively small in the 700MHz frequency band, even further.

b) Services
The study [1] assumes a network, which is capable to deliver HD videos in the Uplink even from the coverage edge. In this study a typical LTE planning criterion of 64 kbit/s at the cell edge as used in [2] and [5] is considered. This is assumed to be sufficient for the planned PPDR services in Germany, i.e. messaging and data base access. Due to overlapping cell and planning margins the obtainable data rates in networks designed to this criterion are typically much higher.

c) LTE technology and antennas

The LTE air interface is designed for broadband services. SC-FDMA Single Carrier Frequency Division Multiple Access in uplink (pre-coded OFDMA with dynamic bandwidth) and adaptive OFDMA Orthogonal Frequency Division Multiple Access in downlink lead to high spectral efficiency. Furthermore, MIMO schemes and carrier aggregation (CA) contribute to high data throughputs. Therefore, the use of MIMO antennas in the initial network design is assumed for future-proof networks. A 4x4 MIMO base station antenna (e.g. Kathrein 4-Port Xpol 80010902) with 16dBi gain is assumed for the LTE700 network planning. The CA-feature of 700MHz band with other frequency bands is not considered in this study. For the LTE base station receiver a noise figure of 2dB is assumed, same as in [2].

d) Devices

3GPP has defined a high power class for devices especially for the extension of coverage of PPDR networks. The power class 1 with 31dBm transmission power is defined in 700 MHz bands. For the future-proof network design this power class is used in this study. However, this study considers also a use of commercial devices by blue light officers with power class 3 which are limited to 23dBm transmission power. Possible antenna gains for user devices are not considered here.

3. PPDR planning approach

3.1 Interpretation of the planning approach in [1]

The planning approach used in [1] is based on an outdoor planning with high planning margins. One planning margin in this approach is connected to a very high modulation scheme of 16QAM being the highest mandatory modulation scheme in the uplink. Another margin results from the assumption of using all available resource blocks (25 in 5MHz channel) at the cell edge. Further, an HD video transmissions in the uplink with a resolution of 1920 x 1080 pixels is assumed also at the cell edge. This results in the minimum requirement for the Signal-to-Interference and Noise Ratio (SINR) at the cell edge of 5dB and an eNodeB sensitivity of -100dBm.

In real network large cell overlapping exists for continuous radio coverage leading to a low probability of locations with cell edge properties. Furthermore, the assignment of all available resource blocks to one user only at the cell edge is very unlikely. In such a case all other active users in the cell are not served. With the assignment of a lower number of resource blocks the actual achievable SINR value increases due to the lower noise power, thus higher modulation and coding schemes providing higher bit rates per resource block are possible in principle. This adaptive mechanism, of course, only works up to the defined highest modulation and coding scheme. Therefore, the assumed SINR (for 16QAM) and the use of all resource blocks can be both interpreted as planning margins.

The LTE planning approach in [2] and in [5] assumes the use of two resource blocks at the cell edge. Furthermore, an SINR value of -7dB for 64kbit/s is assumed in this approach. Compared to the approach used in [1] the margin for SINR is 12dB (5dB - (-7dB)) and a further margin in sensitivity arise due to use of two blocks instead of 25, i.e. 10xlog(25/2) = 11dB. In summary, different cell edge properties use in [1] and in [2] and [5] lead to the total margin of 23 dB.

For the LogNorm fading with a standard deviation of 6dB a cell edge availably of 90% (95% cell area availability) shall be ensured by the definition of the planning level. This requirement leads to a planning margin of 7.7dB.

The authors of [2] interpret planning margins for high area location probability as a contribution to the indoor coverage.

This means, that margins for high location probability derived from the standard deviation of LogNorm fading also help the indoor penetration. In accordance to [2] the area location probability of 95% as assumed in [1] is experienced by the user as a "fair indoor" coverage. Following this interpretation of planning margins a further margin of 23dB due to different cell edge properties as derived above will finally change the subjective coverage experience from the "fair indoor" to at least "excellent indoor".

Another small margin is connected to the assumed base station antenna with 15dBi in the study [1]. For the future prove network design the use of state of the art antennas with 16dBi can be assumed. Other planning parameters like 2dB noise figure of the base station receiver and the use of high power devices with 31dBm Effective Isotropic Radiated Power (EIRP) are in line with assumptions listed in Chap. 2.

3.2 Application of PPDR planning approach [1] to Germany

In the following analysis ,the approach as used in [1] is applied for the planning of a PPDR LTE700 network in Germany. The only difference to the assumption [1] is the change of antenna gain from 15dBi to 16dBi which is motivated by the use of state of the art antenna (e.g. Kathrein 80010902). All other margins mentioned above are not applied for the following site count planning. Therefore, the value of the maximum allowable path loss changes by 1dB from 136.3 to 137.3 dB. The value of the maximum allowable path loss is responsible for the cell range and consequently for the number of required sites.

The value of the maximum allowable path loss can be used for the calculation of the cell range using a model for the propagation loss (i.e. modified Hata model) in different environments [3]. The classification of Germany in different morphology classes used by modified Hata-Model can be found for example in [7].

The number of required sites in Germany is calculated in the following Table 1.

	Unit				Comments
Frequency	MHz	700	700	700	
Morphology		Urban	Suburban	Open	
Max. allowable path loss	dB	137.3	137.3	137.3	from [1] +1dB for higher antenna gain
BS antenna height	m	30.0	35.0	35.0	Typical BS heights, see 3GPP
Cell range	km	2.43	4.84	16.10	Calculated with mod. Hata model
Cell area	km²	15.3	60.8	673.8	Hexagon
Morphology classes	%	5%	28%	66%	
Morphology classes	km²	18,000	102,000	238,000	German area 358k km²
Number of sites		1,175	1,679	354	
Percentile of sites per morphology class		36.6%	52.3%	11.0%	
Resulting number of LTE700 sites			**3,208**		

Table 1: Resulting site count based on the planning approach for PPDR in [1]

In result, the application of the planning approach from for PPDR Network in Spain [1] with a small correction of 1dB for the antenna gain leads to approximately 3.200 sites required for a nationwide LTE700 network in Germany. This is much lower number than the existing 4,700 PPDR site from TETRA. This planning does not consider margins for the chosen [1] cell edge properties. With these power margins of 23 dB the subjective coverage can be assumed as excellent indoor.

A further consideration based on this approach is the calculations of the additional coverage margin assuming the implementation of LTE700 at all available PPDR sites. In the following Table 2 it is shown that the maximal allowable path loss of uniformly 134.4dB for all morphology classes leads to app. 4,700 sites. That means the planning based on [1] contains app. 3dB additional margin if the LTE700 network would be implemented on all available sites.

	Unit				Comment
Frequency		700	700	700	
Morphology		Urban	Suburban	Open	
Max. allowable path loss	dB	134.4	134.4	134.4	Calculated max. path loss for app. 4,700 Sites
BS Antenna height	m	30.0	35.0	35.0	Typical BS heights, see 3GPP
Cell range	km	2.01	3.99	13.29	Calculated with mod. Hata model
Cell area	km²	10.5	41.4	459.0	Hexagon
Morphology classes	%	5%	28%	66%	
Morphology classes	km²	18,000	102,000	238,000	German area 358k km²
Number of sites		1,716	2,464	519	
Percentile of sites per morphology class	%	36.5%	52.4%	11.0%	
Resulting number of LTE700 sites			**4,699**		

Table 2: Maximum allowable path loss for 4,700 sites

Together with the calculated margins for cell edge properties the total planning margin is about 26dB in case of using 4,700 sites in Germany.

4. Calculation of planning margins

A different way for the evaluation the available site portfolio for LTE700 network is the application of a common nominal site count methodology for the calculations of planning margins. These planning margins can be later used for taking into account other losses like building penetration losses, body losses if using handheld devices or lower power devices (e.g. power class 3 devices with 23dBm transmission power). Similarly to the approach in the chap. 3 only uplink is considered which is typically weaker than the DL for the calculation of maximum allowable path loss.

The SINR requirement of -7dB at the cell edge is taken from [2] or [5]. Furthermore, the use of two resource blocks is assumed which is sufficient together with the SINR requirement for 64kbit/s at the cell edge in accordance to [2] and [5].

Further assumptions in line with Chap. 2 are: gain of the base station antenna 16dBi, feeder losses 1dB, noise figure of BS receiver 2dB, interference margin in the uplink 1dB, handover gain 2.5dB [4] and different standard deviations $\sigma_{LogNorm}$ for LogNorm fading for urban 8dB, suburban and rural areas 6dB.

For other losses a standard deviation σ_{other} of uniform 6dB is chosen. Both slow fading and standard deviation of other losses contribute to the planning margin for higher availability than 50% at the cell edge. With the assumption of two independent statistic processes the resulting standard deviation is:

$$\sigma_{total} = \sqrt{\sigma_{LogNorm}^2 + \sigma_{other}^2}. \qquad (1)$$

The resulting margin necessary for 95% location availability i.e. 1.28 x σ_{total} (12.8dB for urban, 10.9dB for suburban and rural) is taken into account for the nominal planning (see Table 3). For the application of the common nominal site count planning method it is assumed that other losses in urban areas are 2dB higher than in suburban and 2 dB lower in rural than in suburban areas. In the following table the average resulting losses are determined in the way that the resulting number of sites is 4,700 (as shown in the Table 4).

	Unit	LTE700			Comments
		UL	UL	UL	
		Urban	Suburban	Open	
Device EIRP	dBm	31	31	31	3GPP, high Power UE with 0 dBi Antenna
Antenna gain	dBi	16	16	16	Kathrein 80010902
Cable losses	dB	1	1	1	Short feeder cable
NF	dB	2	2	2	State of the art BS receiver
SINR	dB	-7	-7	-7	[2], [5] 64kbit/s at the cell edge
#RB		2	2	2	[2], [5]
Sensitivity	dBm	-123.4	-123.4	-123.4	Calculated from SINR und NF and white noise power
Standard deviation of slow fading	dB	8	6	6	assumption
Standard deviation of other losses	dB	6	6	6	assumption
Aggregated standard deviation	dB	10.0	8.5	8.5	See equation (1)
Location availability at the cell edge	%	90	90	90	95% location availability
Margin for slow fading and other losses variances	dB	12.8	10.9	10.9	Aggregated margin
Interference margin	dB	1.0	1.0	1.0	see [2]
Handover Gain	dB	2.5	2.5	2.5	see [4]
Resulting other losses	dB	**26.14**	**24.14**	**22.14**	Resulting losses for building penetration, body loss and lower terminal powers
Max. allowable path loss	dB	132.0	135.9	137.9	

Table 3: Calculation of the resulting other losses for the nominal planning with approximately 4,700 sites

The resulting other losses differ among environments because of the different assumptions regarding the standard deviation of LogNorm fading and assumed differences in average losses in different environments. The resulting nominal planning of approximately 4,700 sites with the calculated other losses is proven in Table 4. This table shows that the coverage is given with the service location availability of 95% with the following other losses 26dB for urban, 24dB for suburban and 22dB for rural.

LTE700	Unit			
Morphology		Urban	Suburban	Open
Max. allowable path loss	dB	**132.0**	**135.9**	**137.9**
BS antenna height	m	30.0	35.0	35.0
Cell range	km	1.72	4.41	16.78
Cell area	km²	7.6	50.6	731.7
Morphology classes in %	%	5%	28%	66%
Morphology classes in km²	km²	18,000	102,000	238,000
Number of sites		2,354	2,015	326
Resulting number of sites for the LTE700 network			**4,695**	

Table 4: Resulting number of sites for the maximum path loss based on other losses taken from Table 3.

The resulting other losses can be used for taking into account various effects like building penetration, body loss etc. The variance of these effects is already considered while calculating the service location availability.

Since the measured building entry loss in 700MHz band in Germany is in average 8.5dB [6] and there are lots of margins left for other losses, lower devices transmission power or higher service location availability. After the subtraction of the average building entry loss there is still additional 17.64dB left for other losses in urban areas. For suburban and rural areas this value is 15.64dB respectively 13.64dB.

If considering low power devices with 23dBm transmission power (i.e. power class 3) and no additional antenna gains instead of PPDR devices with 31dBm EIRP the margins will be 8dB lower. But also in this case margins for other losses or higher availability remain positive (9.64dB in urban, 7.64dB in suburban und 5.64dB in rural areas).

Another possibility of coverage surplus use is a growth of the location availability. If increasing the cell edge location availability from 90% to 95% the area location availability increases from 95% to 99% assuming the propagation exponent of 3.5. This high location availability can be achieved with an additional margin of app. 1.4dB which is shown in the Annex. However, it should be mentioned that PPDR users besides the higher availability will experience higher bitrates if adding margins for increased availability due to technology inherent adaptive adjustments of modulation and coding schemes.

In both cases e.g. for lower device power or for higher availability or even taking into account both cases there are still remaining margins left for consideration of other losses. This margins if not consumed extreme penetration losses like deep indoor usage will always be used by the LTE system for the provision of higher throughputs and thus for better user experience.

5. Summary

This technical report studies two approaches for LTE700 network planning for PPDR application in Germany using the existing 4,700 sites. The first one transfers PPDR planning approach for a very demanding service e.g. HD video links in uplink published in [1] to German antenna site grid.

The second approach is a nominal site count planning which is commonly used in order to estimate the number of required antenna sites for an assumed service. Since the number of sites is known this approach was used here for the calculation of potential other losses. Different assumptions have been made for other losses in urban, suburban and rural areas in order to take into account differences in building penetration in various areas. The calculated other losses can be further used for consideration of various use cases: building penetration, body losses, lower transmission power of devices or higher service location availability.

Both approaches show that LTE700 network for PPDR use built on 4,700 sites provides highly available in building coverage with high bitrates. Furthermore, both approaches provide some additional margins, which can be used for better user experience.

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Annex

Calculation of the maximum path loss for an area location availability of 99%:

	Unit	LTE700		
		UL	UL	UL
		Urban	Suburban	Open
UE EIRP	dBm	31	31	31
Antenna gain	dBi	16	16	16
Cable losses	dB	1	1	1
Noise figure	dB	2	2	2
SINR	dB	-7	-7	-7
#RB		2	2	2
Sensitivity	dBm	-123.4	-123.4	-123.4
Standard deviation of slow fading	dB	8	6	6
Standard deviation of other losses	dB	6	6	6
Aggregated standard deviation	dB	10.0	8.5	8.5
Location availability at the cell edge	%	95	95	95
Margin for slow fading and other losses variances	dB	16.4	14.0	14.0
Interference margin	dB	1.0	1.0	1.0
Handover gain	dB	2.5	2.5	2.5
Resulting other losses	dB	**22.77**	**20.77**	**18.77**
Max. allowable path loss	dB	131.7	136.2	138.2

Table 5: Resulting other losses for higher location availability

LTE700	**Unit**			
Morphology		Urban	Suburban	Open
Max. allowable path loss	dB	**131.7**	**136.2**	**138.2**
BS Antenna height	m	30.0	35.0	35.0
Cell range	km	1.69	4.50	17.10
Cell area	km²	7.4	52.6	760.1
Morphology classes	%	5%	28%	66%
Morphology classes	km²	18,000	102,000	238,000
Number of sites		2,436	1,940	314
Percentile of sites per morphology	%	51.9%	41.4%	6.7%
Resulting site count		**4,690**		

Table 6: Site count planning for resulting maximum path loss due to higher location availability

6. References

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