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SERIES K: PROTECTION AGAINST INTERFERENCE

The impact of RF-EMF exposure limits stricter than the ICNIRP or IEEE guidelines on 4G and 5G mobile network deployment

ITU-T K-series Recommendations – Supplement 14

ITU-T

Supplement 14 to ITU-T K-series Recommendations

The impact of RF-EMF exposure limits stricter than the ICNIRP or IEEE guidelines on 4G and 5G mobile network deployment

Summary

Radio frequency electromagnetic field (RF-EMF) exposure limits have become a critical concern for further deployment of wireless networks, especially in countries, regions and even specific cities where RF-EMF limits are significantly stricter than the International Commission for Non-Ionizing Radiation Protection (ICNIRP) or Institute of Electrical and Electronics Engineers (IEEE) guidelines.

This problem currently affects several countries such as China, India, Poland, Russia, Italy and Switzerland, regions of Belgium or cities such as Paris.

Supplement 14 to the ITU-T K-series of Recommendations provides an overview of some of the challenges faced by countries, regions and cities which are about to deploy 4G or 5G infrastructures. This Supplement provides information on a simulation on the impact of RF-EMF limits that was carried out in Poland as an example of a wider phenomenon, which is applicable to several other countries, which have set limits that are stricter than those contained in the ICNIRP or IEEE guidelines.

The results of the simulation indicate that where RF-EMF limits are stricter than ICNIRP or IEEE guidelines, the network capacity buildout (both 4G and 5G) might be severely constrained and might prevent addressing of the growing data traffic demand and the launching of new services on existing mobile networks.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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4G, 5G, deployment, exposure limits, infrastructures, power density limit, RF-EMF.

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1 Scope

This Supplement discusses the impact on mobile networks of RF-EMF exposure limits that are more restrictive than the ICNIRP [b-ICNIRP 1998] or IEEE [b-IEEE C95.1] guidelines. This Supplement investigates the impact on 4G and 5G deployment and suggests that there is an urgent need to begin a process to harmonize electromagnetic field (EMF) standards worldwide. In this regard, it should be noted that the World Health Organization (WHO) commenced a process of harmonization of EMF standards worldwide [b-WHO EMF].

2 References

[ITU-T K.52] Recommendation ITU-T K.52 (2018), *Guidance on complying with limits for human exposure to electromagnetic fields*.

[ITU-T K.70] Recommendation ITU-T K.70 (2018), *Mitigation techniques to limit human exposure to EMFs in the vicinity of radiocommunication stations.*

[ITU-T K.91] Recommendation ITU-T K.91 (2018), *Guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields*.

[ITU-T K.100] Recommendation ITU-T K.100 (2018), *Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into service*.

[ITU-T K.121] Recommendation ITU-T K.121 (2016), *Guidance on the environmental management for compliance with radio frequency EMF limits for radiocommunication base stations*.

[IEC 62232] IEC 62232:2017, *Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure*.
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https://webstore.iec.ch/publication/7340

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

3.1.1 antenna [ITU-T K.70].

3.1.2 electromagnetic field (EMF) [ITU-T K.91].

3.1.3 exposure [ITU-T K.52].

3.1.4 exposure level [ITU-T K.52].

3.1.5 exposure limits [ITU-T K.70].

3.1.6 power density (S) [ITU-T K.52].

3.1.7 radio frequency (RF) [ITU-T K.70].

3.2 Terms defined in this Supplement

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

AR/VR Augmented Reality/Virtual Reality

CAGR Compound Annual Growth Rate

eMBB Extreme Mobile Broadband

EMF Electromagnetic Field

FDD Frequency Division Duplexing

FWA Fixed Wireless Access

MIMO Multiple-input and multiple-output

NIR Non-Ionizing Radiation

PDL Power Density Limit

RF Radio Frequency

5 Conventions

None.

6 EMF exposure limits should be harmonized worldwide based on international guidelines

6.1 Current status on EMF exposure limits worldwide

International RF-EMF exposure guidelines refer to the guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [b-ICNIRP 1998], or of the Institute of Electrical and Electronics Engineers (IEEE) [b-IEEE C95.1]. These limits are currently under review [b-ICNIRP].

Whilst most countries adopted these scientifically based RF-EMF guidelines, a small group of countries, regions or even cities within the same country, especially in Europe (e.g., Poland, Russia, Italy, Switzerland, Paris city and regions in Belgium), use limits that are ten to a hundred times lower. Limits below the ICNIRP guidelines are not limited to Europe however, China and India, amongst others, also adopted limits below ICNIRP guidelines. In addition, some countries (e.g., Poland and Italy) apply a very strict measurement methodology, resulting in even stricter RF-EMF requirements. Worldwide limits may be consulted at:

http://apps.who.int/gho/data/node.main.EMFLIMITSPUBLICRADIOFREQUENCY?lang=e.

Because disparities in EMF standards around the world have caused increasing public anxiety about EMF exposures from the introduction of new technologies, WHO commenced a process of harmonization of electromagnetic fields (EMF) standards worldwide [b-WHO EMF].

6.2 Impact of the more restrictive RF-EMF exposure limits on existing networks

A report published in 2014 [b-GSMA 2014] concluded that EMF exposure limits stricter than the ICNIRP guidelines were a strong limiting factor for the deployment of 4G networks.

The strict power density limits result in "waste of spectrum" and "less flexibility in the network deployment", i.e., access to and optimal location of sites. Other consequences were reduced coverage, reduced opportunities for site sharing and an increased number of sites needed for delivering the same level of service.

Based on the findings, this report:

– called on the European Commission to promote good practice by Member States through harmonization of RF-EMF exposure limit policies based on international guidelines;
– called on Member States to follow the European Council Recommendation 1999/519/EC [b-1999/519/EC] and latest SCENIHR (Scientific Committee on Emerging and Newly Identified Health Risks) opinion [b-SCENIHR] that exposure limit policies should be based on the international guidelines;
– called on the European Commission and Member States to adopt evidence based policies that enable the deployment of mobile broadband and other wireless technologies.

As of today, the EMF exposure limits have not been harmonized globally, nor on a European level. The consequences described above still apply. Going forward, the strict EMF exposure limits in a number of countries will further harm future network deployments, in particular 5G, as will be shown in the analyses outlined in this Supplement.

6.3 RF-EMF exposure limits below the ICNIRP or IEEE guidelines will further restrict upcoming 5G network deployment

EMF exposure limits that are more strict than the ICNIRP or IEEE guidelines negatively affect all potential levers to enhance the wireless infrastructure and deployment of 5G: *spectrum*, *technology* (determining the spectral efficiency) and *network topology* (number of sites and sectors). The capacity of a wireless site is a direct function of the amount of spectrum (MHz) combined with the spectral efficiency (bit per second per Hz) and with the site's number of sectors.

For example, the unfavourable effects of different EMF exposure limits on network roll-out, i.e., deployment of spectrum, technology and sites, have been simulated in Poland. The results are shown in the following analyses. They also serve as an illustrative example for other countries with power density limits stricter than the ICNIRP or IEEE guidelines, e.g., Russia, India, China, Italy, Paris city, Switzerland, and regions of Belgium.

6.3.1 Lever 1: Spectrum cannot be fully deployed

Additional radio frequencies, e.g., 60 MHz (FDD – 2x30 MHz) in the 700 MHz spectrum band, 100 MHz in the 2300 MHz band and 400 MHz in the 3.4-3.8 GHz spectrum range have or will become available for 4G and 5G mobile communications in the near future. This would double the available spectrum and capacity in mobile networks for example as shown in Figure 1 for the case of Poland.

However, deploying additional spectrum and consequently increasing the transmitted power, on an existing site increases the EMF exposure and hence the power density levels. In dense urban areas and urban areas [b-BCG], where distances between antennas and people are short already, the strict Polish EMF exposure limits do not allow mobile network operators to use the additional spectrum on most sites. In dense urban areas already some of today's spectrum cannot be used anymore and is wasted.

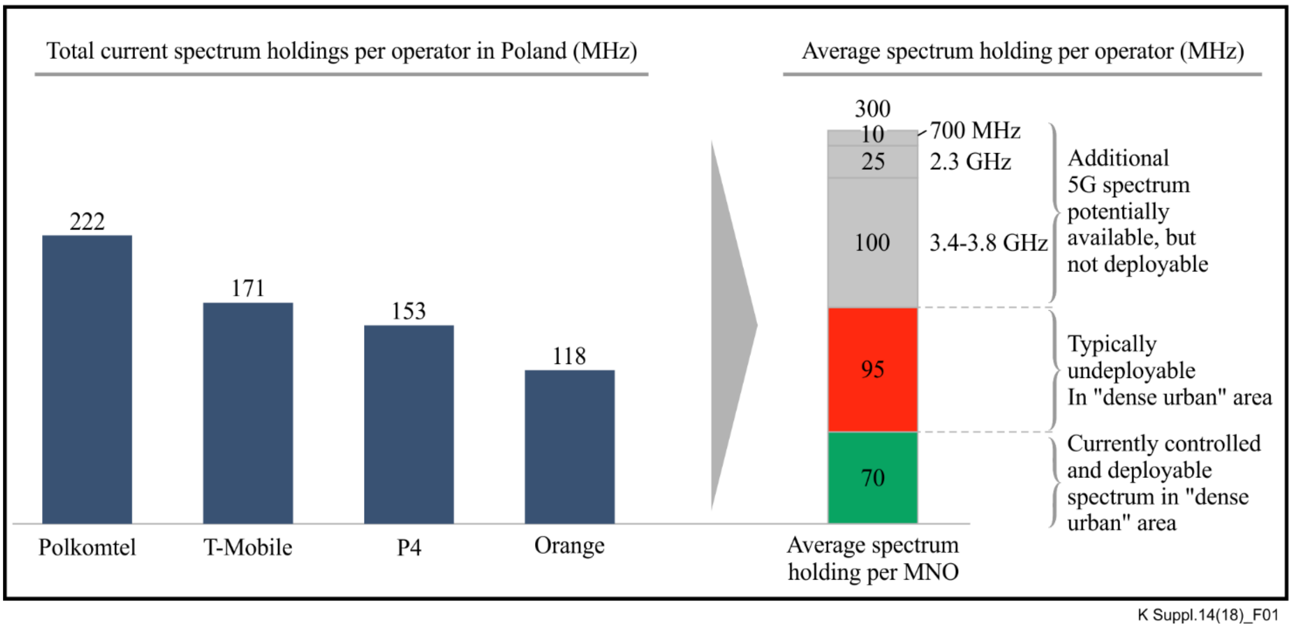

Figure 1 – Average spectrum holding (source Office of Electronic Communications, Poland)

Large blocks of spectrum are critical for the deployment of 5G technology and thereby increasing speed and capacity. For example, harmonizing the Polish EMF exposure limits in line with ICNIRP guidelines would remove the spectrum roadblock. All current spectrum plus the spectrum bands available in the near future could effectively be used by mobile network operators, including critical dense urban and urban areas, see Figure 2. Deploying new spectrum is an effective and efficient way of adding capacity to mobile networks quickly, before large capacity gaps can even occur.

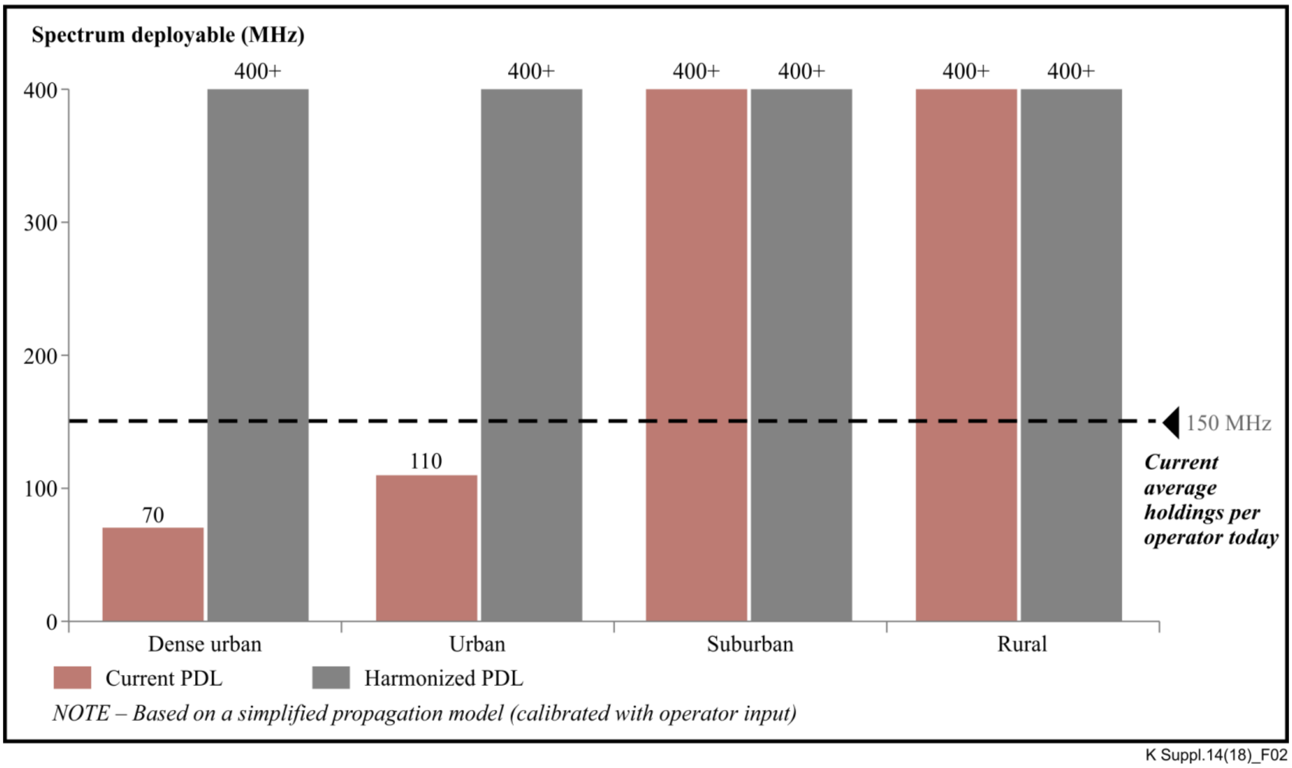

Figure 2 – Spectrum deployable on average with current and harmonized power density limits (PDLs) (source adapted from Polish mobile network operators [b-BCG])

6.3.2 Lever 2: Technology innovation is restricted

New antenna technologies, such as Massive MIMO and beamforming, or small cells are a key element of future 5G mobile networks.

The EMF exposure limits below INCIRP or IEEE guidelines (as shown in the case of Poland), do not in most cases allow mobile network operators to fully leverage these new technologies.

– Applying beamforming, i.e., further narrowing an antenna beam, would easily exceed the current EMF exposure limits;
– Deploying small cells in hot spot areas will not be feasible as the current EMF exposure limits prevent placing a large number of small cells due to the short distance between antenna and people, see Figure 3.

Both technology examples, beamforming and small cells, would be essential to provide more capacity in dense urban and urban areas.

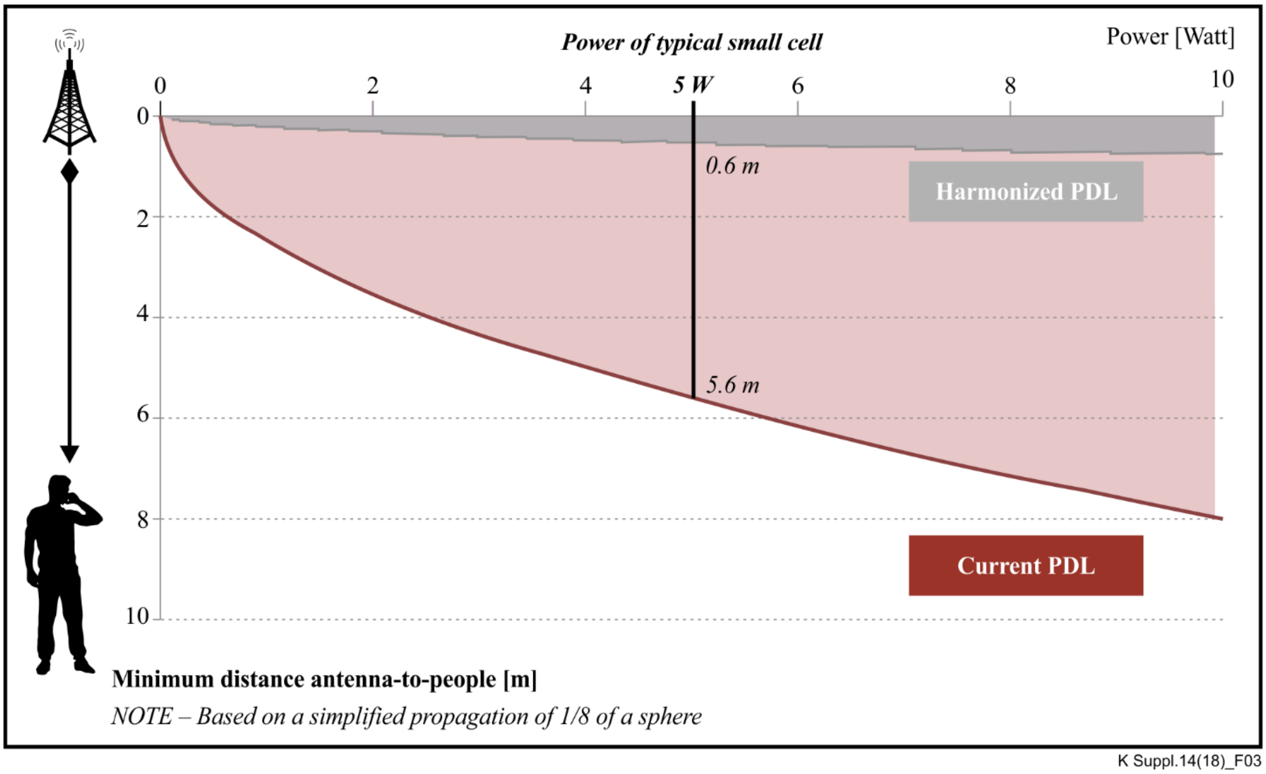

Figure 3 – Minimum distance antenna-to-people (source [b-BCG])

6.3.3 Lever 3: Possibility to densify site grid is limited

Densifying the mobile network grid by adding new sites would be the third, but most expensive and time-consuming lever to increase capacity in mobile networks. In order to cope with the data traffic explosion and assuming that spectrum and technology levers cannot be exploited, mobile network operators would have to have 3.5-fold the number of sites in urban areas by 2025 and almost sevenfold the number of sites in dense urban areas by 2025, see Figure 4.

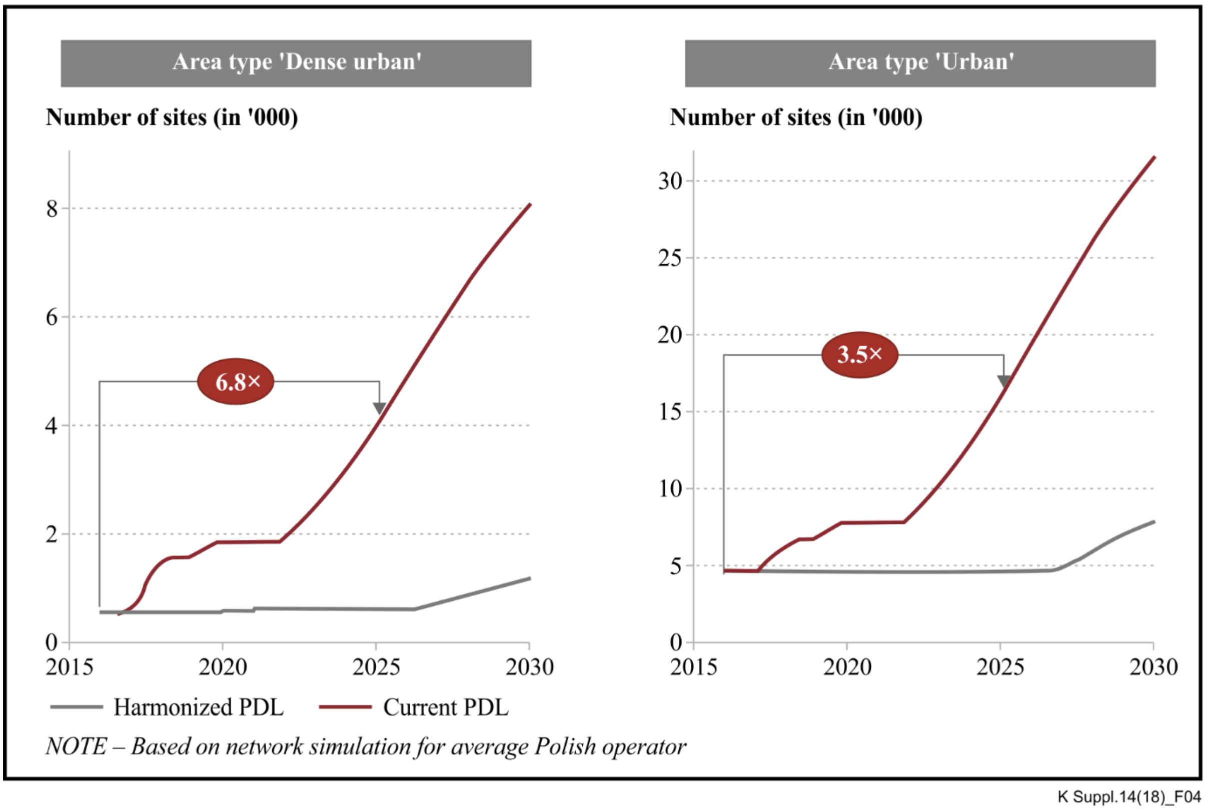

Figure 4 – Site evolution in dense urban and urban areas (source [b-BCG])

These might become very unrealistic targets in light of mobile network operators struggling already today in commissioning only a few new sites in urban and dense urban areas. Furthermore, the already dense network grids with low site-to-site and site-to-building distances prevent mobile operators from densifying within the current EMF exposure limits. Similar issues might also be faced by other countries such as Italy where a new market entrant is rolling out a fourth wireless infrastructure and may be struggling with available power budgets.

6.4 Future customer experience will suffer and true 5G is not possible

Given the limitations for deployment of new spectrum, technology and the very restricted growth of a number of sites (Assumption: 20% additional sites compared to the status quo), as a result of the strict EMF exposure limits, the gap between capacity supply and data traffic demand will grow very quickly. Polish data traffic growth with a CAGR of 36% until 2020, 29% until 2025 and 15% until 2030 (24x network data traffic in 2030 versus 2016).

For example, in the case of Poland, in 2020, already 22% of available total mobile data traffic demand cannot be served (thereof 31% of urban traffic demand and 63% of dense urban traffic demand will remain unserved). In 2025, this number would increase to 41% and in 2030 to up to 56%. In dense urban and urban areas with almost half of the Polish population, the numbers are even more dramatic, see Figure 5.

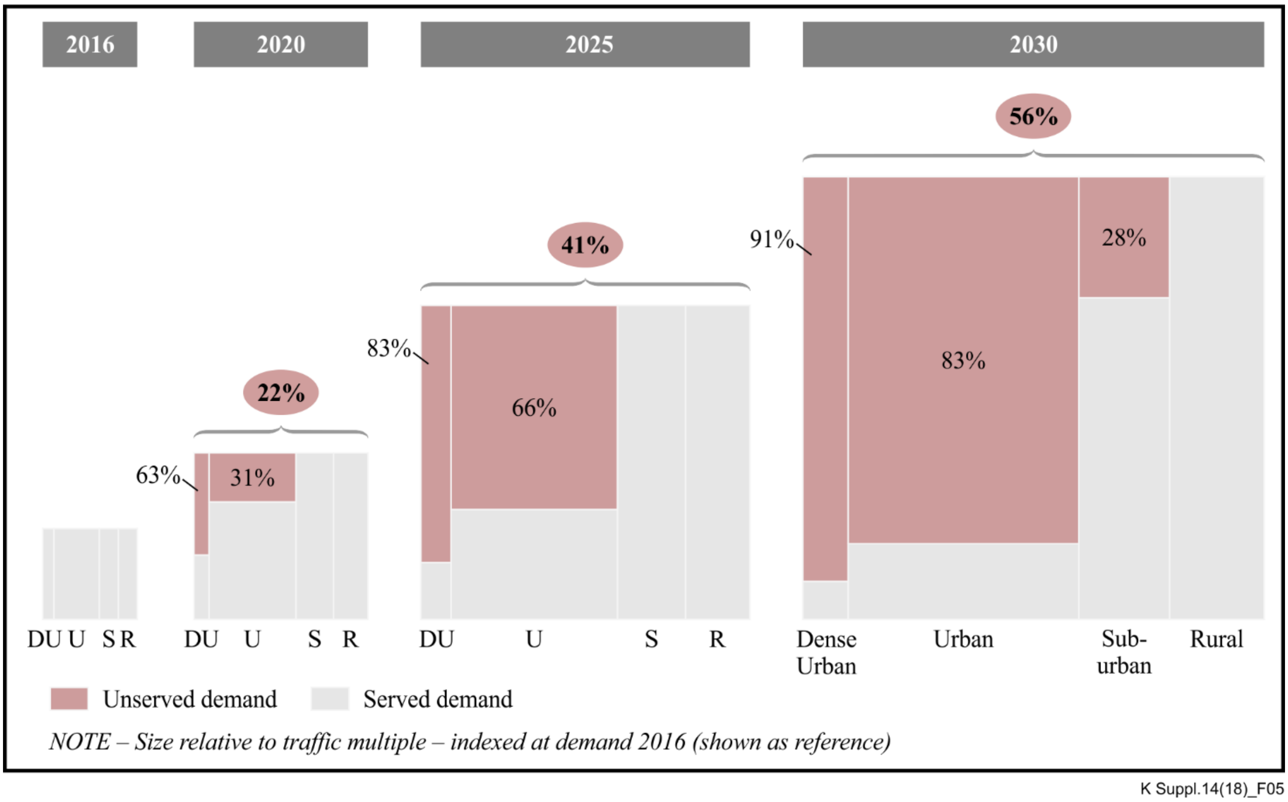

Figure 5 – Share of unserved data traffic (source [b-BCG])

Future 5G use cases that require high bandwidths such as Extreme Mobile Broadband (eMBB), Augmented / Virtual Reality (AR/VR) or 5G Fixed Wireless Access (FWA) would be very difficult to implement in such a scenario. The capacity gap would further create severe bottlenecks in the mobile radio access network and negatively impact latency and thus may inhibit future low-latency 5G use cases such as mission-critical emergency services or autonomous drone delivery.

7 Conclusion

Investigation shows that in the next three years up to 63% of mobile data traffic demands will not be served in countries, regions and even specific cities where RF-EMF limits are significantly stricter than the ICNIRP or IEEE guidelines. This hinders countries from taking into consideration new trends to shape smarter and more sustainable societies worldwide. This also impacts their ability to achieve the UN Sustainable Development Goals (SDGs).

From the analysis carried out in this Supplement, it should be noted that RF-EMF exposure limits should be harmonized worldwide. A framework for harmonization of RF-EMF standards is being developed by WHO to encourage the development of exposure limits and other control measures that provide the same level of health protection to all people.

Harmonizing the RF-EMF exposure limits should also take into consideration measurement methodologies (e.g., daily average versus maximum) and locations (e.g., indoor versus outdoor) and national compliance assessment standards should be harmonized with international Recommendations and Standards from ITU and IEC.

Appendix I

Modelling methodology and key input assumptions

I.1 Modelling methodology

The simulation presented in this Supplement is based on a general model of the impact of RF-EMF limits on the network capacity. The Hata radio propagation model was used to simulate the relationship between RF-EMF exposure limit, coverage and capacity.

All-specific inputs were provided by the Polish Chamber of Information Technology and Telecommunications and the four Polish mobile network operators. The simulation was based on the operators' actual wireless assets (i.e., detailed infrastructure inventory per site level with respective technology and spectrum configurations). Forecast data traffic determines the required network capacity buildout (e.g., new sites, site upgrades and small cells).

The simulation model compares mobile data traffic demand with supply in each year and triggers the network capacity upgrades accordingly. The capacity of a mobile network is a direct function of the amount of spectrum (MHz) combined with the spectral efficiency (bit per second per Hz) then with the number of sites and sectors.

The simulation assumes varied spectrum and network rollout strategies for (dense) urban, suburban, and rural area types. For example, small cells are rolled out only in (dense) urban areas, but not in suburban and rural areas.

The network capacity upgrades are modelled each year in the order of cost efficiency (i.e., the least costly upgrades to be realized first: new carriers and spectrum bands, antenna upgrades, new sites, new small cells). Capacity extension is only performed if RF-EMF exposure limits allow for that.

The capacity build-out was simulated for different scenarios of RF-EMF exposure limits: current Polish RF-EMF exposure limit versus ICNIRP guidelines.

I.2 Key input assumptions used in the model

Mobile data traffic forecast in Poland is derived from [b-CISCO]. Traffic growth was extrapolated until 2030, using a conservative growth assumption of declining annual growth rate, see Figure I.1. Another report estimated annual data traffic growth in mega-cities (e.g., London, Paris) will be of ca. 35% between 2017 and 2025, leading to an average traffic consumption of ca. 30 GB+ per month in 2025 [b-GSMA 2018]. The forecasts for the entire population of Poland are in line with these projections.

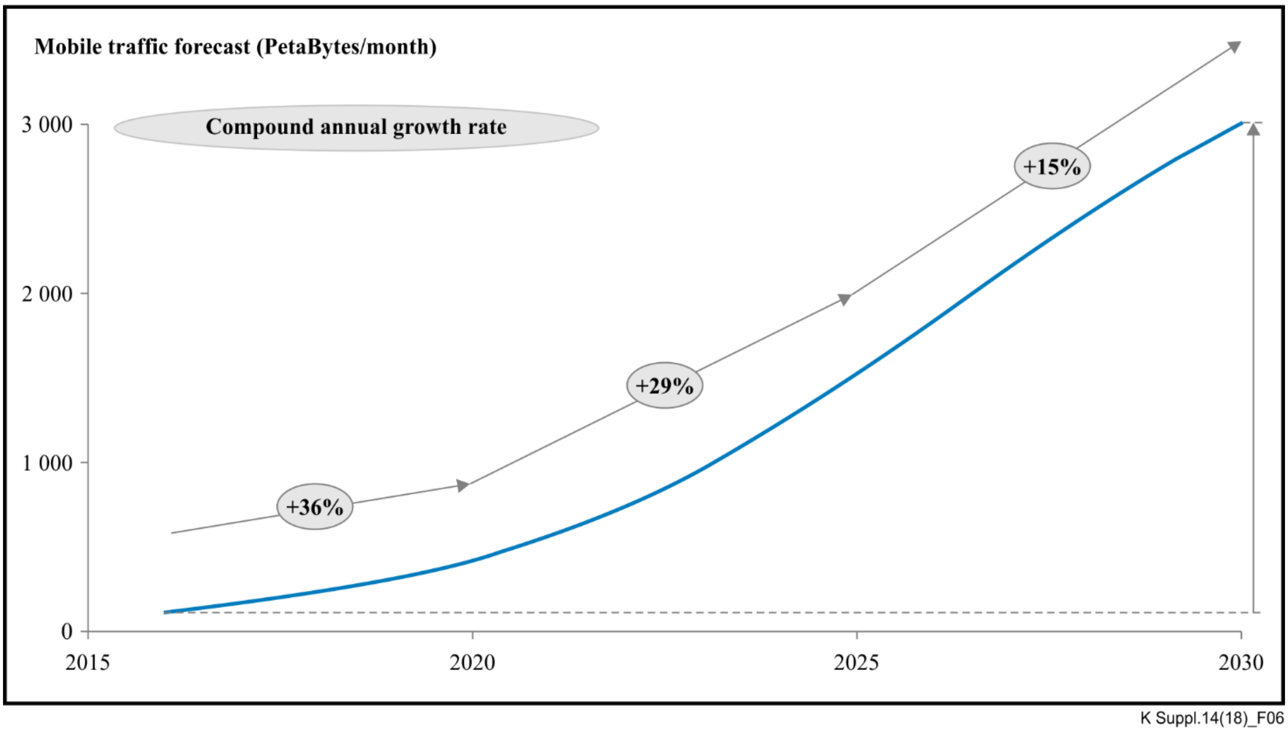

Figure I.1 – Polish mobile traffic increase until 2030

Downlink site capacity is based on average effective data rates (per 5 MHz and sector). Average of three sectors per site across was applied by all area types. Sectorization (e.g., upgrading from three to six sectors) is not modelled in the simulation. Table I.1 shows assumed average effective data rates.

Table I.1 – Assumed average effective data rates

Radio access technology	**3G**		**4G**				
Spectrum band (MHz)	900	2100	800	900	1800	2100	2600
Assumed MIMO	1x1		2x2				
Average effective data rate (Mbps per 5 MHz and sector)	4.7	4.9	8.0				

As additional radio frequencies will likely become available for 4G and 5G mobile communications in the near future, the availability of such spectrum bands and bandwidths for wireless use are assumed from 2021 onwards. For simulation purposes, the additional spectrum was (almost) evenly allocated amongst the operators. Spectrum refarming and phase-out of legacy radio access technology is considered in the simulation. Table I.2 shows assumed additional radio frequencies for wireless use.

Table I.2 – Assumed additional radio frequencies for wireless use

Spectrum band	**Availability**	**MNO 1**	**MNO 2**	**MNO 3**	**MNO 4**
700 MHz	2021	2x10 MHz	2x10 MHz	2x5 MHz	2x5 MHz
2300 MHz	2021	1x25 MHz	1x25 MHz	1x25 MHz	1x25 MHz
3.x GHz	2021	1x75 MHz	1x75 MHz	1x75 MHz	1x75 MHz

New technologies such as MIMO (4x4 or massive MIMO) or beamforming increase the spectral efficiency, see Table I.3. We did not assume any additional gains of 5G beyond antenna technology.

Table I.3 – Assumed spectral efficiency

Antenna technology	Spectral efficiency (index = 100)
2x2 MIMO	100
4x4 MIMO (deployed on bands below 2.6 GHz)	150
64x64 Massive MIMO (deployed on bands at 2.6 GHz and higher)	300

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