Improving wireless connectivity through small cell deployment

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1 Introduction

Growing demand for mobile network connectivity associated with increased smartphone ownership, greater mobile usage indoors and higher data rates is driving the evolution of mobile networks. One approach to facilitating connectivity is the use of small cells. Small cells are low-powered radio access nodes or base stations (BS) operating in licensed or unlicensed spectrum that have a coverage range from a few meters up to a few hundred meters. Small cells are deployed to increase the mobile network capacity and coverage in localized areas. They can be used to provide in-building or outdoor wireless service.

50% of global connections are via smartphones.[1]

As shown in Figure 1, higher data rates are typically available closer to the base station antenna due to the higher quality connection.

Mobile data traffic has grown over the past

10 years **4,000X**

15 years **400 million X**[2]

1. GSMA Intelligence, Global cellular market trends and insight — Q2 2016
2. Cisco, Visual Networking Index (VNI) Global Mobile Data Traffic Forecast Update, 2016.

Figure 1

Higher data rates are generally possible closer to the network antenna

Today over 80% of mobile usage occurs inside buildings in developed markets and this is predicted to increase to greater than 90% in the next few years.[3]

Modern buildings are increasingly designed to meet stronger energy efficiency targets. However, some building materials used for energy efficiency purposes (for example, energy-efficient windows and aluminium-based polyurethane sheets) cause significant attenuation to radio signals, especially at higher frequencies. Measurements by the Tampere University of Technology, a Finnish university, found that radio signal penetration inside new buildings is on average twenty times weaker, and can be up to 100 times weaker, compared to buildings that are 10 years older. Potential solutions include using lower frequencies for mobile services, changes to building design and facilitating in-building small cell deployments[4].

In-building environments such as tall buildings and underground public transport infrastructure can only be effectively provided with coverage by small cell installations.

14 million small cells have been shipped to May 2016. There was a 78% growth in non-residential shipments from Q1/2015 to Q1/2016.[5]

3. Real Wireless Ltd, Options for Improving In-Building Mobile Coverage. Report for Ofcom, 18 April 2013.
4. Ministry of Transport and Communications, Mobile network reception problems in low energy buildings: working group report, publication 31/2013.
5. Small Cell Forum, Small cell deployments: Market status report, May 2016.

Their low visual impact also means that small cells can be an effective solution in outdoor areas near monuments and iconic buildings. However, the costs of deployment may be significantly higher due to the civil works needed to provide power and data back-haul connections to the small cell installation.

Example:
Indoor small cells have been installed in and around the Giza pyramids, Abu Simbel and other temples of Egypt to provide high quality cellular coverage and greater security.

Low power radio frequency (RF) transmitting equipment are addressed in different ways through existing national regulations and international standards. This paper proposes a harmonized approach in order to simplify the authorization regimes for equipment with low transmitted RF power, such as small cells.

Future mobile networks are expected to consist of a mix of macrocell sites to provide wide area coverage and small cells to improve localised coverage and increase capacity. These are termed heterogeneous networks or 'hetnets'. Figure 2 illustrates the concept of a hetnet.

Figure 2

Representation of a heterogeneous network - hetnet

Image: Real Wireless

The regulatory framework for mobile network antenna deployments needs to evolve to support the growth in small cells so that industry and governments can deliver on the digital connectivity expectations of citizens and pave the way to 5G.

The fact that small cells have a relatively small volume and are visually unobtrusive means that it is important that local planning laws allow for small cell deployments with minimal administrative hurdles or delays.

2 What is a small cell?

'Small cells' is an umbrella term for operator-controlled, low-powered radio communications equipment (base stations) that provide mobile and internet services within localised areas. Small cells typically have a range from ten metres to several hundred metres. Mobile network macrocells typically serve larger areas.

2.1 Small cell deployment scenarios

The term 'small cells' covers femtocells, picocells, microcells and metrocells that are used in residential (Home BS), enterprise (Local Area BS), urban and rural environments (Medium Range BS). Small cell deployments that are interconnected are also termed distributed antenna systems (DAS) or in-building systems (IBS) where they provide service within an existing structure.

Local Areas BS are typically deployed in indoor environments accessible to the general public such as stations, airports, commercial centres. Medium Range BS are typically deployed in outdoor environments. They are often embedded in street furniture such as lighting fixtures, advertisement panels, bus shelters or street signs as shown in Figure 3. They can also be deployed to extend the mobile network coverage and capacity on a localized area, such as isolated villages, industrial sites or emergency situations.

Figure 3

Typical installation of small cells in urban furniture

Credits for pictures of bus stop and advertisement panel with integrated Small Cells : ©JCDecaux

This paper focusses on stationary small cell installations, however, they have also been proposed for deployment in modes of transport such as aircraft, ships and trains.

In the following sections topics for administrative simplification that would support small cell deployments are identified. Practical implementation of simplified administrative procedures should also extend to electronic filing and shortened forms to be completed.

2.2 Small cell power classes

The technical forum for standardisation of mobile technologies defines small cells in terms of their transmitted power. Medium Range small cells typically transmit at power levels between around 0.25 and 6 watts per transmit connector (i.e. up to 12 W per access point). The equipment size is typically in the range of 5 to 15 litres. (see annex 1 for further technical details).

3 Small cell deployment permits

The existing process for obtaining permits for mobile network antenna sites is often based on the requirements of physically larger and higher powered macrocell sites. These administrative processes generally cover both the civil aspects of building permits and the compliance with radiofrequency exposure limits.

In determining what constitutes a small cell for permit requirements the US Federal Communications Commission (FCC)[6] in 2015 clarified that it includes the antenna, feeder, transmission equipment and associated power equipment, including backup power.

In Brazil three fronts were developed in deploying small cells. The first was the installation in indoor environments. The second was the integration of small cell radio equipment in public phones, and these devices were energized by line powering solutions. The third work front was hiring sharing companies with small cell integration solutions to various urban furniture of the city. All responsibility for this integration from the point of view of infrastructure is the responsibility of the company that proposes the integration solution, including the equipment mounting so that the installation will be as simple and agile as possible.

Small cell installations especially within buildings, should be exempt from requirements for registration of transmitter positions. These requirements sometimes exist for larger and higher powered radio transmitters.

6. Federal Communications Commission (FCC) 47 CFR Parts 1 and 17, Acceleration of Broadband Deployment by Improving Wireless Facilities Siting Policies, Federal Register, Vol. 80, No. 5, 8 January 2015.

3.1 Building permits

Small cell antennas for outdoor applications are hard to see by design or through visual integration with the installation site (facade or urban furniture). In order to cover an area many small cells of similar characteristics (radio parameters, size) will often be deployed at the same time. So it is good practice to provide for simplified approval for small cells to avoid administrative delays.

The FCC[7] has adopted rules exempting small cells from environmental assessments where they are mounted on existing telecommunications towers, buildings and other structures as well as inside buildings and meet certain limitations on size and visibility. The FCC also clarified that the existing shot-clock reasonable time frames for decision making (90 days for collocation and 150 days for new installation) also apply where small cells require permit applications, for example, where light poles are to be replaced to accommodate small cell installations.

Where it is determined that a building permit is required, an effective approach to building permits is to provide umbrella approval for deployment of small cell installation meeting certain specified area or volume, as well as radio characteristics (e.g., equivalent isotropic radiated power – EIRP) and installation requirements on nominated physical infrastructure (e.g., minimum installation height). All small cell installations meeting these requirements would be exempt from further permit requirements.

As a general principle small cell infrastructure installed within existing buildings should be exempt from specific notification or other permitting requirements. Any concerns about a specific installation are likely to be addressed by existing local building and safety regulations.

3.2 Permitting costs

In some countries there are permit fees or taxes for antenna installation applications. In order to encourage the deployment of small cells governments should consider a fee structure that reflects the small size and low power of such installations.

France: A 2015 report[8] estimated that about 10 medium range small cells would be deployed per macro base station site and, therefore, recommended that in France the tax regime for small cells subject to light notification administrative process be set at 10% of the tax for macro sites subject to detailed approval administrative process. This recommendation was then adopted in the French Law of Finance at the end of 2015.

7. ibid
8. French Industry Strategic Plans – Small Cells White Paper (see Further Resources)

Brazil: In the lead-up to the 2014 World Cup in Brazil and the summer Olympics in 2016, the authorities recognised a need to increase mobile network capacity. Small cell installations were recognised as a key part of the infrastructure needed within stadiums. In order to facilitate these deployments the authorities in 2013 adopted regulations that exempted certain classes of small cell equipment from telecommunications monitoring fees that are charged by Anatel to the operators on a per base station basis.

3.3 Electrical Power

Small cell antenna installations need access to reliable electrical power to operate. In general this will involve grid connections though renewable energy sources such as solar may be suitable for isolated installations operating in remote areas. Venezuela has proposed that small cells using renewable energy be tax exempt.

Authorities should support small cell deployments by facilitating siting on or near existing sources of electrical power, such as buildings, street and traffic lights, advertisement panels or bus shelters.

3.4 Data backhaul

Small cells need to be connected via data links back to the core mobile network in order to connect voice and data traffic. Due to the increased consumer demand for mobile data small cells require 100-200 Mbps of capacity per cell. If the traffic is aggregated by macrocells, these will require backhaul capacity of hundreds of Mbps, even 1 Gbps per site[9]. Backhaul connectivity can be provided by point-to-point microwave links where line of sight is available or Internet-grade broadband connections, in particular optic fibre connections. Installing fibre links is disruptive and expensive. This means that small cell deployments can proceed efficiently in areas that already have the data backhaul infrastructure.

Globally base station backhaul is about 40% wireless and 60% fibre.[10]

Authorities should support small cell deployments by facilitating access to existing data backhaul connections and should consider preferential access for small cell infrastructure.

9. http://www.aglmediagroup.com/backhaul-for-mobile-networks-has-a-place-for-wireless-links-2/
10. ibid

4 Compliance with radiofrequency limits

Many countries have followed the recommendation of the World Health Organization (WHO) and the International Telecommunications Union (ITU) and adopted the limits for radiofrequency exposures developed by the International Commission for Non-Ionizing Radiation Protection (ICNIRP). The main conclusion of the WHO and many independent expert reviews is that there are no established health risks where antennas comply with these limits. Further information is available in the GSMA brochure Small Cells and Health listed in the resources section.

A Belgium study[11] found that in a 3G network with average macrocell coverage using a small cell resulted in total exposures that were 20-40 times lower, mostly due to the significant reduction in the mobile phone output power.

Small cells typically allow mobile phones to work at very low powers, increasing their battery life and reducing interference as well as reducing exposure of the phone user.

4.1 Simplified installation requirements

The proposed harmonized approach does not preclude national authorities from adopting further simplified criteria, as they have already been implemented in some countries.

No building permits are required for small cell deployments in Egypt. The only regulatory approval required after installation is measurement of RF exposure. This occurs only once for the lifetime of the site whereas for a macrocell inspections are conducted at least every two years.

11. Assessment and comparison of total RF-EMF exposure in femtocell and macrocell base station scenarios, Aerts et al., Radiation Protection Dosimetry, 162(3):236-243, December 2014.

In general, where small cell antennas are mounted above human body height they will comply with the recommended exposure limits. The International Electrotechnical Commission (IEC) has developed detailed classes of small cell products and installations, which are also reflected in ITU recommendations. These can be found in Annex 2. Where small cell installations comply with the power and installation parameters shown in Annex 2 they should be deemed to comply with the exposure limits without further requirements.

France: A 2015 report[12] has proposed that existing regulations are amended to provide an exemption from administrative processes for small cells with an EIRP less than 2 W. In addition the report proposed that for small cells with an EIRP between 2 W and 25 W only a light notification process is required while detailed approval administrative process applies above 25 W EIRP. This approach is consistent with the table in Annex 2 and would allow up to four devices to be installed at an E100 class site.

Manufacturers of small cell equipment must ensure that they conform to relevant technical standards and to any essential requirements in terms of health and safety. It is the responsibility of the organisation deploying the small cells to ensure that once brought into operation, the small cell complies with any additional spectrum authorisation requirements or national exposure limits. Evidence of compliance with the exposure limits may be provided either by declaration of conformity or by a certificate issued by the authority or third party. The declaration of conformity approach is recommended.

Routine post installation measurements or site inspections are not required for small cell installations. Of course permitting authorities may consider inspections of a sample of sites or investigations on a case-by-case basis to confirm compliance. In order to build public confidence the costs for such auditing procedures should be borne by the authority and not the small cell operator.

4.2 Signage

If the small cell installation is in compliance when the radome is touched then there should be no requirement for signage. When determining whether a warning sign is needed consideration should be given to the likely access to the area near the small cell. For example, small cells installed on street lights are only likely to be accessed by authorised maintenance personnel who can be provided with awareness and safe working procedures training. Where a sign is implemented the size, position and visibility of the sign should be appropriate to the installation location and accessibility of the small cell.

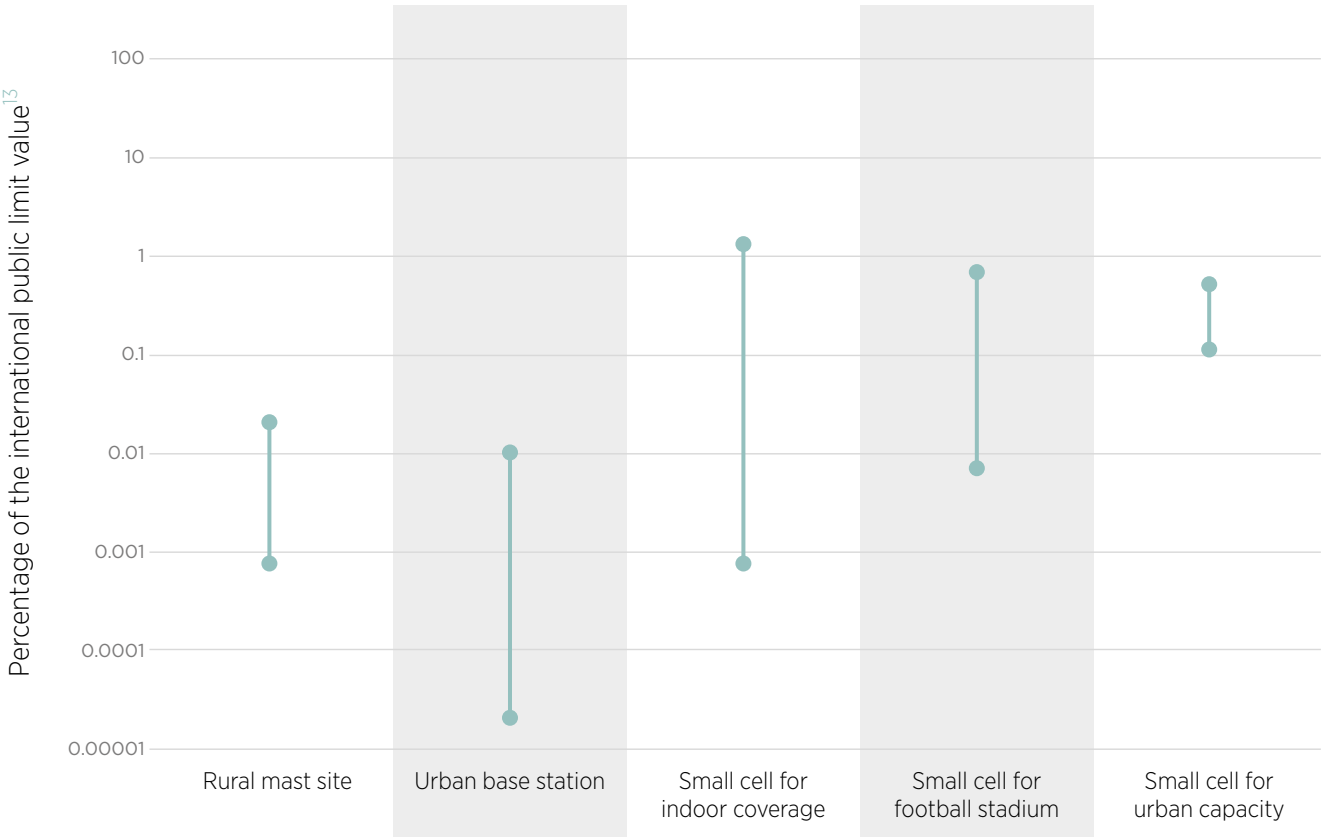
12. French Industry Strategic Plans – Small Cells White Paper (see Further Resources)

4.3 Typical signal levels

Though small cells operate at lower power they are often mounted closer to areas accessible by people. As a result the range of radiofrequency exposures measured from small cells are similar to those from other mobile network antenna installations. As can be seen in Figure 4 the range of measured levels from typical small cell installations is similar to that of macrocell installations. This is because even though the small cell operates at lower power, it is often mounted at lower heights so people can approach closer. For both macrocells and small cells the typical levels are a very small fraction of the international recommendations designed to protect human health.

Figure 4

Comparison of typical measured radio signal levels for differing types of 3G base station sites.[13]



In some countries small cell deployments have been suggested as a way to reduce the overall exposure from mobile networks antennas. However, technical studies demonstrate that the most efficient mobile network antenna infrastructure is a mix of macro and small cells according to coverage and capacity requirements. This illustrates the importance of allowing network operators flexibility with network design and not mandating technical solutions.

13. Adapted from data reported in Determination of the general public exposure around GSM and UMTS base stations, Bornkessel et al., Radiation Protection Dosimetry, 124(1):40-47, March 1, 2007.

A 2015 French report[14] has produced measurement results on operational small cell sites performed according to IEC 62232 protocols. In-situ exposure levels are well below ICNIRP exposure limits (0.1% or below relative to the power density limits).

Image: JCDecaux

It is important that authorities provide information based on WHO[15] recommendations to address stakeholder concerns.

Research indicates that small cell infrastructure can be successfully deployed in medical facilities without causing interference to sensitive equipment.

Indeed measurements show that mobile devices can operate at very low powers where there is an in-building system to improve coverage. It is important that the in-building coverage system should avoid coverage gaps due to building construction materials.

14. French Industry Strategic Plans – Small Cells White Paper (see Further Resources)
15. http://www.who.int/peh-emf/en/

5 Summary of Recommendations

Small cell deployment is an important option for mobile networks as they evolve to address the growing demand for mobile connectivity, improved capacity and coverage. In order to support efficient small cell deployments authorities should adopt the following policies:

1. Follow the internationally harmonised small cell power classes when developing regulations related to compliance with radiofrequency exposure limits.
2. Adopt simplified procedures for building permits for small cells (if required) based on standardised size, installation requirements and radio characteristics.
3. Accept declarations of compliance and do not require routine post-installation measurement.
4. Exempt small cell installations from location registration requirements.
5. Reduce permit costs for small cells relative to those for macrocells.
6. In respect of RF compliance provide information for consumers and local authorities based on WHO materials and recommendations.
7. Facilitate access to existing structures, electrical power and data backhaul.

Annex 1

Range of transmit powers for small cells

(extract from 3GPP 36.104)

3GPP BS class	3GPP PRAT* (Transmit power per carrier per connector)
Wide Area BS	(note)
Medium Range BS	< + 38 dBm (6.3 W)
Local Area BS	< + 24 dBm (250 mW)
Home BS	< + 20 dBm (100 mW, for one transmit antenna port) < + 17 dBm (50 mW, for two transmit antenna ports) < + 14 dBm (25 mW for four transmit antenna ports) < + 11 dBm (12.5 mW for eight transmit antenna ports)

Note: There is no upper limit for the rated output power of the Wide Area BS.

*Definition: Rated output power, PRAT, of the base station is the mean power level per carrier for BS operating in single carrier, multi-carrier, or carrier aggregation configurations that the manufacturer has declared to be available at the antenna connector during the transmitter ON period.

Annex 2

Simplified installation requirements for base stations

(from IEC 62232)

Class	EIRP[a] (W)	EIRP (dBm)	Product installation criteria
E0	n/a	n/a	The product complies with IEC 62479 or the product compliance boundary dimensions are zero. No specific requirement for product installation.
E2	≤2	≤33	The product is installed according to instructions from the manufacturer and/or entity putting into service. Compliance with the exposure limits is generally obtained at zero distance or within a few centimeters.
E10	≤10	≤40	The product is installed according to instructions from the manufacturer and/or entity putting into service and the lowest radiating part of the antenna(s) is at a minimum height of 2.2 meters above the general public walkway.
E100	≤ 100	≤50	The product is installed according to instructions from the manufacturer and/or entity putting into service and: (a) the lowest radiating part of the antenna(s) is at a minimum height of 2.5 meters above the general public walkway, (b) the minimum distance to areas accessible to the general public in the main lobe direction is Dm[b] and (c) there is no pre-existing RF sources with EIRP above 10 W installed within a distance of 5Dm meters in the main lobe direction (as determined by considering the half power beam width) and within Dm meters in other directions. If Dm is not available, a value of 2 meters can be used or 1 meter if all product transmit frequencies are equal to or above 1500 MHz.[c]
E+	>100	>50	The product installed according to instructions from the manufacturer and/or entity putting into service and: (a) the lowest radiating part of the antenna(s) is at a minimum height of Hm meters above the general public walkway, (b) the minimum distance to areas accessible to the general public in the main lobe direction is Dm[b] meters, (c) there is no preexisting RF source with EIRP above 100 W installed within a distance of 5Dm meters in the main lobe direction and within Dm meters in other directions. Hm is given by Equations (6.1), (6.2) or (6.3) of IEC 62232.[d]

a. EIRP (equivalent isotropic radiated power) transmitted by the installed antenna(s) including all active bands.

b. Dm is the compliance distance in the main lobe of the antenna (from Clause 6.1 of IEC 62232).

c. When such condition is not fulfilled the installation is still compliant if the sum of the EIRPs of the product and nearby sources is less than 100 W. If the total EIRP is above 100 W then the product is still compliant if it is installed at a minimum height of Hm meters above the general public walkway and at a minimum distance from areas accessible to the general public in the main lobe direction of Dm meters, where Hm and Dm are obtained using Equations (6.1), (6.2) or (6.3) of IEC62232 for the sum of the EIRPs including those of nearby sources.

d. When such condition is not fulfilled the installation is still exempted from evaluations if the product is installed at a minimum height of Hm meters above the general public walkway and at a minimum distance from areas accessible to the general public in the main lobe direction of Dm meters, where Hm and Dm are obtained using Equations (6.1), (6.2) or (6.3) of IEC 62232 for the sum of the EIRPs including those of nearby sources.

6 Further Resources

Small Cells and Health is a brochure produced by the Small Cell Forum (www.smallcellforum.org), the GSMA (www.gsma.com) and the Mobile & Wireless Forum (www.mwfai.org).

French Industry Strategic Plans – Small Cells White Paper, Actions de Souveraineté Télécoms - Promouvoir le deploiement des petites cellules: leur utilité dans les réseaux mobiles, l'amélioration de leur cadre règlementaire, leur facilité de deployment, October 2015 (http://www.lemag-numerique.com/2015/10/4-nouveaux-livres-blancs-sur-la-souverainete-telecoms-7966)

IEC TC106: http://www.iec.ch/tc106

ITU-T EMF: http://www.itu.int/en/ITU-T/emf/

WHO EMF: http://www.who.int/emf/

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