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D3.4 WHITE PAPER ON SMALL CELLS

Work Package	WP3, Global 5G ecosystem: standards and support to consensus building
Lead Author (Org)	Trust-IT Services
Contributing Author(s) (Org)	AALTO
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Dissemination Level

X	PU: Public
	PP: Restricted to other programme participants (including the Commission)
	RE: Restricted to a group specified by the consortium (including the Commission)
	CO: Confidential, only for members of the consortium (including the Commission)

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1.0	24/06/2019	John Favaro, Stephanie Parker, Trust-IT	Final version for delivery

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Table of Contents

List of Tables

List of Figures

Executive Summary

Small cells are a critical component of 5G networks, helping to deliver the micro capacity and coverage. The success of Global5G.org Deliverable 3.1 – *Study on Small Cells and Dense Cellular Networks Regulatory Issues* prompted a recommendation to create a White Paper suitable for wide public distribution. To profit from reviewer recommendations and from a broad public consultation before final publication and distribution, the contents of the prospective White Paper are first delivered in the form of a standard project deliverable, and only after public consultation in the form of a graphically typeset, high-quality White Paper.

Dissemination of the White Paper will occur along several dimensions: through the Small Cells Forum, through the Advisory Board, through events such as the Small Cells World Summit. A webinar on small cells will be hosted. New articles will be produced on a dedicated area on the website. SMART-based campaigns will be performed, drawing also on the essential guide to help newcomers navigate this complex environment.

The White Paper covers the following:

- **Background and deployment considerations**. What are Small Cells? Their differentiation from macro cells. The motivation for small cell deployments: concepts of network densification, improving coverage, enhancing spectrum efficiency, meeting aesthetic requirements, lower energy consumption.
- **Typical small cell deployment scenarios.** An overview of the most important scenarios, including residential, urban, enterprise, rural, transport corridors, aerial.
- **Considerations for the deployment of small cells.** The most important include availability of sufficient spectrum, high-capacity fixed links to small cells, powering of small cells, sharing, and safe operation.
- **Small cell deployment trends and projections.** An overview of observed trends, including the transition from domination of residential deployments to enterprise deployments, and the domination of certain areas of the world in deployments.
- **Stakeholders.** A critical overview of both supply-side stakeholders (e.g. standards organisations and manufacturers) and demand-side stakeholders (consumer, commercial, and governance).
- **Barriers to small cell deployments.** An examination of the primary obstacles, including inconsistent classification of small cells across jurisdiction, and overly restrictive limits on EMF exposure.
- **Small Cells Deployment Showcase.** The City of Amsterdam and its innovative partnership with JCDecaux to create an effective small cells deployment environment with a win-win result for all stakeholders was selected for highlighting.
- **Lessons learned from the field**. A set of lessons learned from concrete deployment cases around the world.
- **Conclusions**. Takeaways for the reader of the White Paper in conclusion of the document.

1 Introduction

1.1 Purpose and Scope

Network densification is a way of increasing capacity and improving coverage particularly indoors. It can also improve energy efficiency and reduce radiation. Improving capacity in rural areas is a good measure to decrease the digital divide.

The purpose of D3.4 is to present the Global5G.org White Paper on Small Cells as the basis for an Open Consultation prior to the publication of the final, graphically designed version. It builds on D3.1 - *Study on Small Cells and Dense Cellular Networks Regulatory Issues*, which describes deployment scenarios, the issue with high bandwidth, both backhaul and fronthaul. It also discusses radio network sharing and network slicing covering different business models, as well as RF exposure.

The white paper zooms in on the main findings of the study with selected updates while aiming for brevity. Its main target audience is national regulatory authorities and policy makers, with the aim of showing how the ecosystem is evolving and therefore requires new, practical approaches to 5G rollouts based on a lightweight regulatory regime applicable and workable across the EU.

1.2 Methodology

The study resulting in D3.1 was based on a multi-pronged approach, spanning desk research, questionnaires and engagement with relevant stakeholders and experts. Liaison was also undertaken with the EU Communications Commission (COCOM), Working Group 5G[1] to help ensure perspectives of the Member States.

The White Paper uses a different approach, which is:

- Zooming in on the main findings of D3.1 alongside an Essential Guide mostly targeted at non-technical stakeholders.
- Presenting a first full draft designed to profit from reviewer recommendations for further enhancements.
- Running a broad public consultation with a dedicated campaign to help build consensus on the main findings across the broad set of stakeholders that are part of small-cell ecosystem.
- Integrating results of the reviewer recommendations before final publication and distribution.

1.3 Dissemination Plan and Open consultation

The Consultation process will draw on previous experiences of creating user-friendly online questionnaires and network access to relevant stakeholders to ensure relevant inputs are received. The Dissemination Plan draws on past engagement with stakeholder engagement, such as the Small

[1] The COCOM is a committee composed of representatives of EU Member States. Its main role is to provide an opinion on the draft measures that the Commission intends to adopt, https://ec.europa.eu/digital-single-market/en/communications-committee.

Cells Forum and other stakeholders studying or interested in aspects that facilitate dense small cell deployment.

The newly formed Advisory Board includes experts on the topic to support the Open Consultation of the White Paper, such as multi-stakeholder perspectives for analysis and inclusion in the final graphically designed version, its publication and dissemination across the 5G community.

The Global5G.org dissemination plan will build on the presentation of the main findings at venues such as the Small Cell World Summit (SCWS) in May 2018, as showed in the figure below.

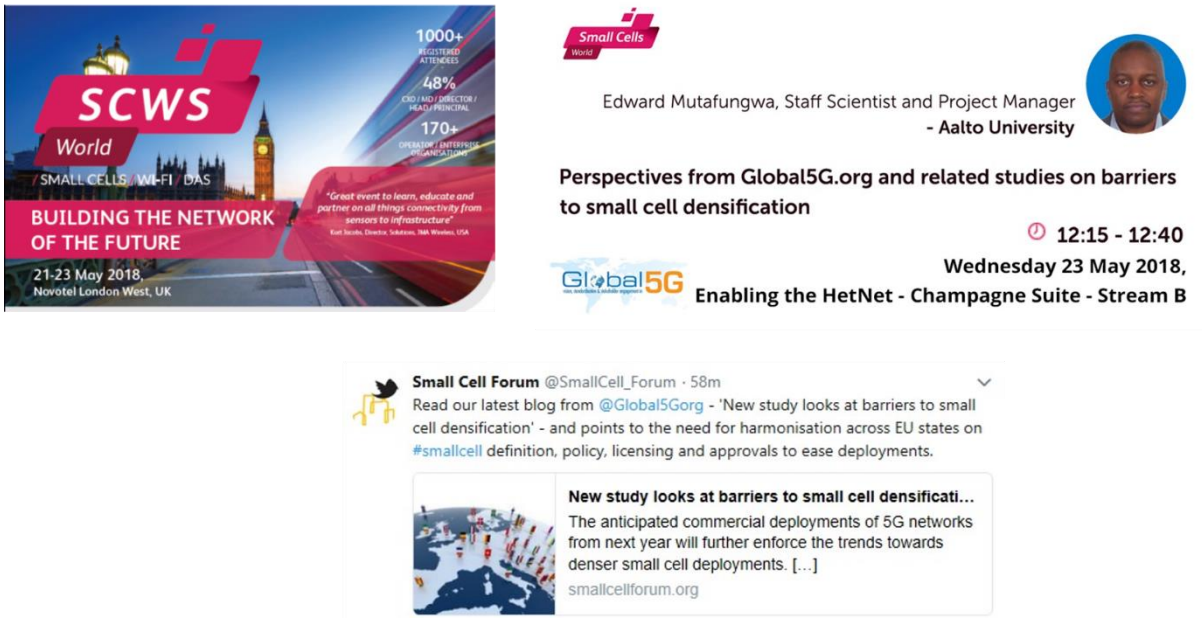


Figure 1: SCWS 2018 - Global5G.org Dissemination of Main Findings

The blog post in question, "New Study Looks at Barriers to Small Cell Densification", is also published in *Partnerships, Platforms and Protocols – A collection of insights from the Small Cell Forum, October 2017-December 2018*, a Flipbook of the Small Cells Forum (December 2018)[2].

Global5G.org also participated in the SAWAP Stakeholder Workshop (SMART 2018/0017) in November 2018[3]. The workshop explored a light deployment regime for small area wireless access points (SAWAP) from four perspectives: operational, technical, environmental and aesthetic, legal and regulatory. The outcome is an insightful overview of the main takeaways from the workshop as an input for this White Paper[4]. Another outcome of the workshop is an initial analysis of standardisation work on small cells. Global5G.org can build on this through the Verticals Standards

[2] https://www.smallcellforum.org/partnerships-platforms-protocols/?utm_source=linkedin&utm_campaign=industry_insights_from_SCF_2018#fb0=43.

[3] https://ec.europa.eu/digital-single-market/en/news/workshop-light-deployment-regime-small-cells-across-eu.

[4] https://www.global5g.org/news/outcomes-sawap-stakeholder-workshop.

Task Force with 3GPP market representation partners since the Small Cell Forum also counts among the partnership.

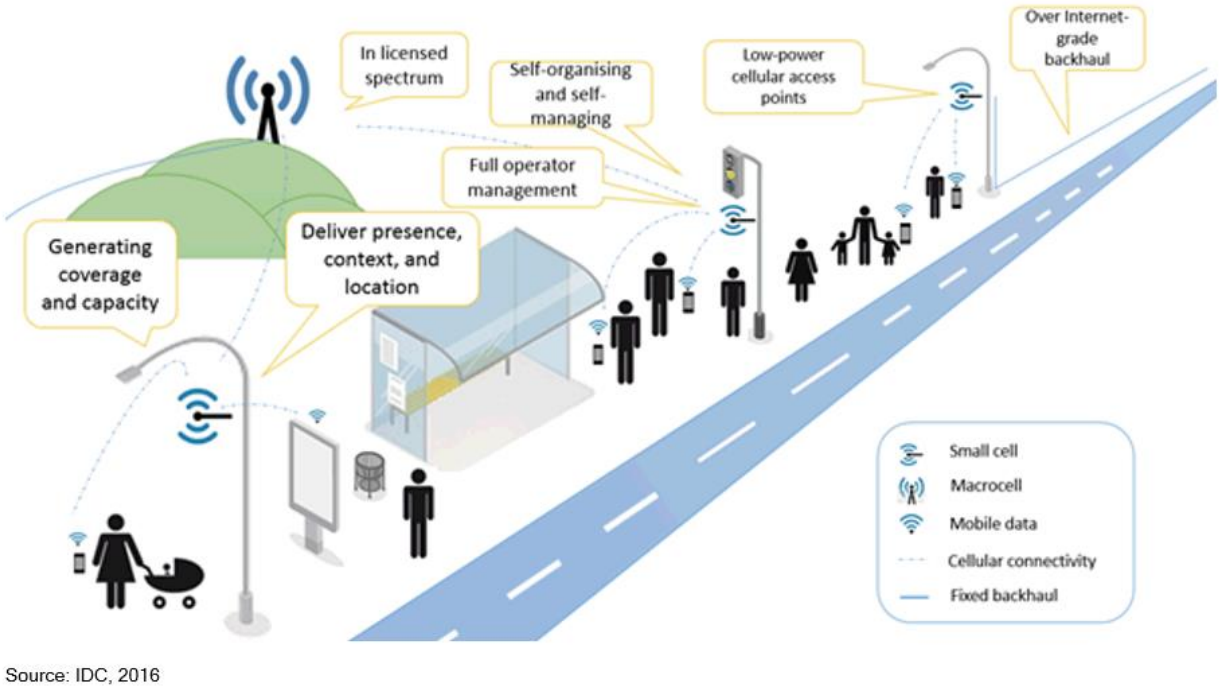
The Global5G.org dissemination plan for the White Paper will run from July to December 2019 and includes the following actions:

- Creating a dedicated web page for the Open Consultation as described in Section 1.3.
- Promoting the Open Consultation across the 5G community and with the support of the Small Cells Forum, the project's Advisory Board and the 5G PPP.
- Hosting a webinar on small cells to disseminate the main findings and collect feedback from participants through a short poll. The expected timeline for the webinar is early September 2019.
- Producing new articles for the dedicated area on the Global5G.org website, feeding in the main findings and updates from relevant articles and reports to create a mini competence centre on the topic.
- Performing SMART-based campaigns on the White Paper, webinar and website, measuring impacts through quantitative measures (KPIs) and a quality assessment looking at audiences effectively reached.

2 The Global5G.org Small Cells White Paper

What are small cells?

Legacy mobile networks are dominated by *macro cells*. These are large cells typically mounted on a mast or roof top in cities and towns, alongside motorways or on rural hills. Macro cells have radio coverage range of a few kilometres to tens of kilometres and are served by a high-powered cellular base station. However, the 1000x scaling in mobile data traffic volumes over the current decade has obliged operators to upgrade their network capacity. To that end, one of the most effective approaches is to enhance the spatial reuse of limited spectrum through dense deployment of small cells to complement existing macro cellular networks (see Figure 2)[5].



Source: IDC, 2016

Figure 2: Heterogeneous deployment of small cells and macro cells

Various small cells product types exist generally depending on, among other attributes, their targeted coverage range (transmit power) and provided capacity. These small cell variants include (but are not limited to) femtocells, picocells and microcells/metro cells – broadly increasing in cell range from femtocells (the smallest) to metro cells (the largest). The small cells can also be categorised according to their access model, including *open-access* (all subscribers of a particular operator can connect), *closed access* (connectivity restricted to certain users, for instance in an enterprise environment), and *hybrid access* (open access small cells which might periodically become closed access).

What is motivating dense small cell deployments?

Mobile network operators face the continuous challenge of upgrading their networks in response to

[5] Figure reproduced from M. Collier, "Small Cells, Big Opportunities" IDC Insight - DOC #AP40400116, June 2016.

ever-growing traffic volumes attributed to the increased adoption of smart devices (e.g., smartphones, mobile virtual reality platforms etc.) and bandwidth-intensive services (e.g. 4K/8K video streaming).

In view of this traffic growth, mobile operators may upgrade their networks to radio technologies providing higher network capacities and user throughput. A currently common scenario is for operators to maintain multi-standard radio access networks that include fourth-generation (4G) technologies and preceding technology generations. However, 4G network enhancement and/or expansion is ongoing. Mobile operators, equipment vendors and other industry stakeholders are already aggressively developing and trialling the fifth generation (5G) network technologies, which will support emerging connectivity needs for the next decade and beyond. To that end, 5G is envisioned to be a unifying connectivity fabric that will connect virtually everything around us — from enabling enhanced mobile broadband services and mission-critical communications to connecting the massive Internet of Things (IoT) — as well as support for use cases yet to be envisioned today. The earliest commercial 5G deployments have already begun in 2019, mostly driven by needs for enhanced mobile broadband (eMBB) in dense urban areas. It is projected[6] that by 2024, 5G will constitute 17% of the global mobile subscriptions with fastest adoption expected in North America, North East Asia and Western Europe regions.

The deployment of small cells has been a critical part of the 4G network upgrades and expansion. This process of adding new cell sites (typically small cell sites), also referred to as *network densification*, is quantified by the site density (site/km^2) or *inter-site distance* (ISD). Network densification is ongoing in legacy 4G networks with site densities of 10-30 sites/km^2 becoming increasingly commonplace. The main drivers behind this preference for small cells are:

- Improving network coverage: small cells can ensure connections indoors, outdoors in rural areas, on aircraft, ships, and trains (over 80% of all mobile usage occurs inside buildings).
- Enhancing spectrum efficiency, exploiting existing spectrum in a more efficient way, allowing spectrum license holders to derive more value from their existing spectrum assets.
- Improving network capacity: small cells can increase cellular capacity in a given area more efficiently than placing more macro cells.
- Meeting aesthetic requirements. The compact, unobtrusive form of small cells is suited for widespread deployment without creating unwanted visual impact on urban structures, including monuments and iconic buildings.
- Lowering energy requirements. The relatively lower energy consumption of small cells may lessen the carbon footprint of mobile networks and increases possibilities to leverage renewable energy sources for network operations.

The need for small cells will become even more critical in 5G networks due to the introduction of higher spectrum bands, which necessitate denser network deployments to support larger traffic volumes per unit area.

[6] https://www.ericsson.com/en/mobility-report/reports/november-2018.

What are the typical small cell deployment scenarios?

The typical small cell deployment scenarios are outdoor deployments in urban and rural areas, and mostly indoor deployments in enterprise spaces. **Errore. L'origine riferimento non è stata trovata.** provides an overview of the different deployment scenarios, their rationale and typical (or envisioned) small cell deployment densities.

Deployment scenario	Why?	For who?	Where/how?	Deployment density?
Residential	Improve service quality in home environment	Individuals or families	Indoor walls, ceiling, table top	High (per dwelling unit per room) Medium (sharing by multiple dwelling units)
Enterprise	Enhance customer experience (e.g. airport, malls, stadium) or improve productivity (e.g. offices, factory, hospitals)	Customers, enterprise users	Indoor walls or ceiling Indoor / outdoor canopies and other building fixtures	Medium/High (depending on venue, typical user densities)
Urban	Fill in coverage holes in urban macro coverage areas. Provide additional capacity in permanently (or routinely) densely populated areas with large traffic density volumes (street cafes, market squares bus stops etc.).	Urban dwellers, commuters and visitors to different urban hotspots	Street-level on side of buildings or street furniture (lampposts, advertisement boards etc.)	High
Rural	Fulfilling obligations for universal access broadband services	Rural communities	Outdoor on rooftops, cell tower	Low
Transport corridors	Ensure service continuity on transport corridors (highways, railroads, public transit etc.) improving efficiency and safety of transport systems and enhancing overall travel experience[7]	Passengers, travelers, drivers, transport infra owners and/or operators	Lampposts, traffic signs, ground stations, tunnels, bridges, pylons	Medium/high (linearly along transport corridors)
Aerial	Rapidly respond to unplanned or temporarily high service demands (traffic surge from crowds, emergency incidents etc.).	Attendants or organisers of large events (e.g. festivals); Emergency first responders (e.g. firefighters)	Mounting on unmanned aerial vehicles (UAVs or drones)	Low/Medium (depending on use case)

[7] "Cooperative Intelligent Transport Systems (C-ITS)" has come to be the commonly used term to refer to transport systems that leverage wireless technologies to for effective data exchange and connectivity of vehicles to each other, transport infrastructure and users, https://ec.europa.eu/transport/themes/its_mt.

Table 1: Small cell deployment scenarios

What should be considered when deploying small cells?

Availability of sufficient spectrum: Legacy 4G networks utilised licensed spectrum bands typically in the sub-3 GHz bands that provide wide area coverage. However, availability of spectrum in these bands is limited due to a multitude of other wireless systems that operate in the same range. Future 5G NR systems will require even larger amounts of spectrum to support the small cell densification needed to meet performance targets for enhanced mobile broadband (eMBB) services. To that end, newly allocated spectrum bands for 5G include spectrum allocations in the mid-bands between 3 and 7 GHz. Furthermore, high band allocations in the millimetre wave (mmWave)[8] bands between 24 and 28 GHz will provide even wider contiguous bandwidths (as high as 3 GHz) needed to deliver eMBB services. However, the radio propagation characteristics at mmWave bands are challenging due to the higher path losses and stringent line-of-sight (LOS) requirements. These characteristics limit the possible cell range, particularly in urban areas due to presence of multiple obstructions in the signal path, such as irregular building infrastructure, foliage and even random blockages from humans, vehicles and so on. Another limitation at mmWave bands is the inability to provide indoor coverage from outdoor sites, due to the high outdoor-to-indoor penetration losses as the signal propagates through building walls. These limitations inherently necessitate the massive deployment of small cells (in both indoor and outdoor environments) to fully realize the capacity enhancements 5G mmWave networks.

High-capacity fixed links to small cells: Mobile networks are not only wireless access networks, but also include fixed links, which connect base stations to a mobile core or public internet network. These wired or wireless links (based on fibre, microwave links, satellite, etc.) that connect the cellular base stations to each other and the core network are known as *backhaul* links. Furthermore, the evolution towards 5G is prompting a migration towards cloud-based virtualised radio access architectures, whereby *fronthaul* links are used to connect remote radio heads distributed at cell sites to a common baseband unit. The technology selection and design of the backhaul or fronthaul links is critical for the achievable performance of the overall service provided over the mobile network via the small cells. Any limitations on backhaul or fronthaul link capacity or delays introduced would create capacity bottlenecks or contribute to the end-to-end latency experienced by a service provided by the small cells. The relatively higher capacity requirements and stringent latency requirements of 5G services would therefore influence strongly the type and cost of backhaul and fronthaul link implementations.

Powering of small cells: Small cells products consume much lower power compared to macro base stations due to a reduced coverage area (e.g. less transmit powers) and fewer requirements for site support infrastructure (e.g. cooling systems). However, the increased network densification in 5G (more sites that require powering) implies an overall increase in network-wide energy or power consumption. The 5G small cells will consume power transmission purposes and for computation purposes (for signal processing, edge cloud processing etc.) These growing energy requirements put a

[8] The term centimetre wave (cmWave) is sometimes used to refer to the 6-30 GHz, whereas, mmWave band is for 30-100 GHz band. However, for this report, mmWave will be synonymous with the high bands above 6 GHz (up to 100 GHz).

constraint on possible densification due to unsustainable site powering costs and increase in the carbon footprint with site density. Therefore, green or energy-efficient small cell product designs are critical to overcome this "powering barrier" to densification.

Sharing of small cells: The sharing of network infrastructure is a well-established practice in the mobile industry. In general, there have been two ways of practically implementing sharing in mobile networks: *passive* sharing and *active* sharing. In passive sharing, multiple MNOs share physical space and site infrastructure (masts, utility poles, advertisement panels, fixed-plant for backhauling etc.). Whereas in the active sharing approach, multiple MNOs share some or all active elements of network (e.g. base station hardware, backhaul interfaces, or even elements of the core network). Infrastructure sharing is even more critical for small cell networks due to the required density of deployment and the wider diversity of deployment scenarios. This has seen the emergence of *neutral hosts* as key players in small cell deployment. Neutral hosts are companies that leverage their existing infrastructure (e.g. buildings, utility poles, advertisement panels etc.) to deploy and provide small cells for exclusive or shared use by other MNOs using active sharing solutions. The neutral host service is a Small-cells-as-a-Service (SCaaS) model that significantly lowers the entry barrier for some MNOs who intend to have dense small cell deployments in both indoor and outdoor areas.

Safe operation of small cells: The deployment and operation of radio frequency (RF) transmitters, such as small cells, raises safety considerations due to human exposure to electromagnetic fields (EMF). Therefore, small cells as a source of RF radiation may undergo assessment of EMF compliance at various phases (product certification/acceptance, installation or operation phase) to ensure safe operation. This compliance assessment requirements may follow local or international guidelines.

A lightweight regulatory environment: The European Electronic Communications Code (EECC) marks an essential step towards harmonising telecoms regulation across the EU in view of 5G rollouts[9]. The Directive, which is set to take effect by the end of 2020, defines new rules on issues such as the rights to install new telecoms equipment and the use of radio spectrum. Specifically, Article 57 sets out the EECC concept for Small Area Wireless Access Points (SAWAP) for both fixed and mobile radio, essential to future wireless networks and their regulation.

Small cell deployment trends and projections

Mobile network operators in Europe and other regions are now compelled to deploy small cells to alleviate capacity exhaust. Furthermore, the entry of third-party site facility providers that have access to assets like street furniture or buildings will positively affect the deployment pace of small cells in a way that was not possible with macro cell deployments. Moreover, the commercial deployment of 5G networks will further drive the need for densification, to effectively transmit the value of 5G upgrades to the subscribers. The key architectural trend will be the rise of small-cell clusters attached to a controller or other device running virtualised network functions. These are expected to significantly gather pace when part of larger scale densification.

As the number of deployed small cells is expected to increase sharply over the next several years,

[9] http://data.consilium.europa.eu/doc/document/PE-52-2018-INIT/en/pdf.

several trends are projected[10].

1. ***While in the early phase small cell deployments have long been dominated by residential small cells, new small cell deployments will be dominated by enterprise and urban small cells***.

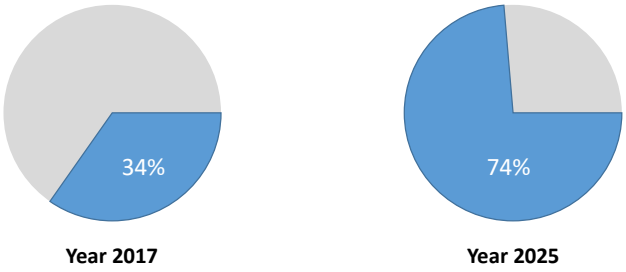


Figure 3 Urban and enterprise small cell deployments as a fraction of all new small cell deployments (Source: *Rethink Technology Research*)

2. The new small cell deployments will be increasingly dense as operators target urban and enterprise scenarios and 5G network upgrades intensify.

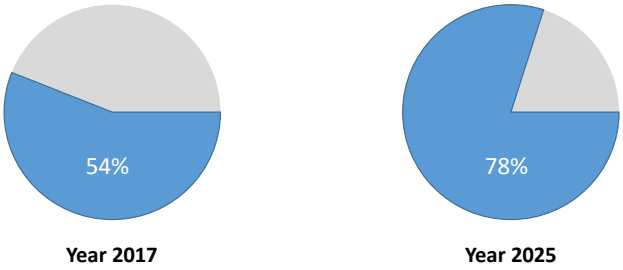


Figure 4 Dense or hyperdense small cell deployments as a fraction of all new small cell deployments (Source: *Rethink Technology Research*)

3. ***The Asia Pacific Region (APAC) will continue to dominate in terms of numbers of new small cell deployments, followed by Europe and North America*** *(note: CALA – Central and Latin America, CIS – Commonwealth of Independent States)*.

[10] The projections are based on data obtained from Rethink Technology Research operator's survey on small cell deployments (4th quarter 2017) https://rethinkresearch.biz/

Figure 5 Breakdown of global small cells deployment by region (Source: *Rethink Technology Research*)

Stakeholders

Networks must, and will, change and evolve with small cells playing a pivotal role in both the emerging 5G ecosystem and continuing LTE rollout and as new spectrum and new revenue models drive densification[11].

Network densification will drive a substantial number of small-cell deployments under 5G with the installed base of small cells reaching 70.2m in 2025, covering 5G's early deployment phases, according to the Small Cell's Forum "Small Cells Market Status Report" (December 2018, Document 050.10.03).

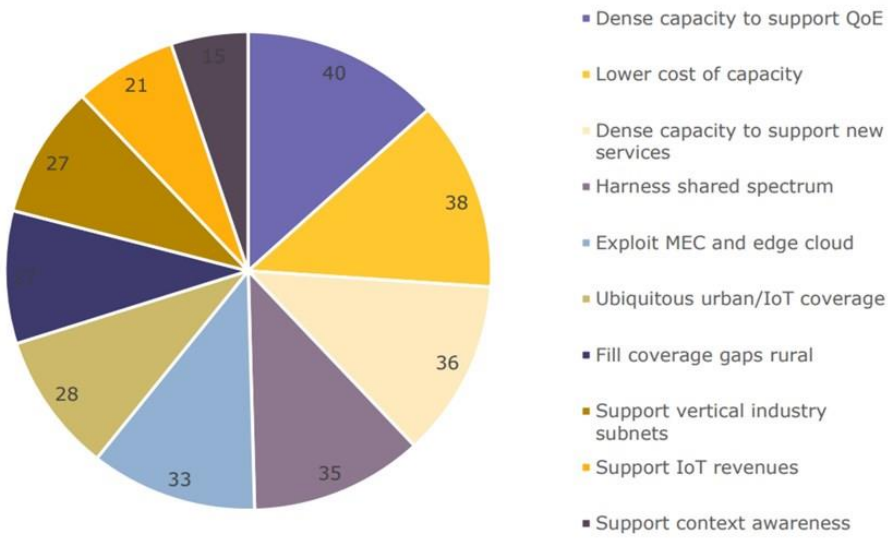


Figure 6: Projections from Small Cells Market Status Report (*Source: Small Cells Forum*)

Network densification will affect many stakeholders across deployment scenarios spanning urban, enterprise and rural. This will have different implications for a growing variety of stakeholders, each with their own drivers and concerns. Deployments will also be in sharp contrast with the present

[11] https://www.telecomtv.com/content/small-cells/small-cells-predicted-to-drive-5g-densification-16411/.

homogeneous macro cellular network deployments and clearly defined roles within the ecosystem, requiring new wireless strategies, partnerships and a light regulatory regime.

A 2017 report from the Small Cells Forum on the evolving small cells ecosystem gives a vivid illustration of the expanding range of stakeholders who will gain from small cell deployments[12]. The study helps zoom in on stakeholders in terms of **supply**, **demand**, **advocacy** and **governance**.

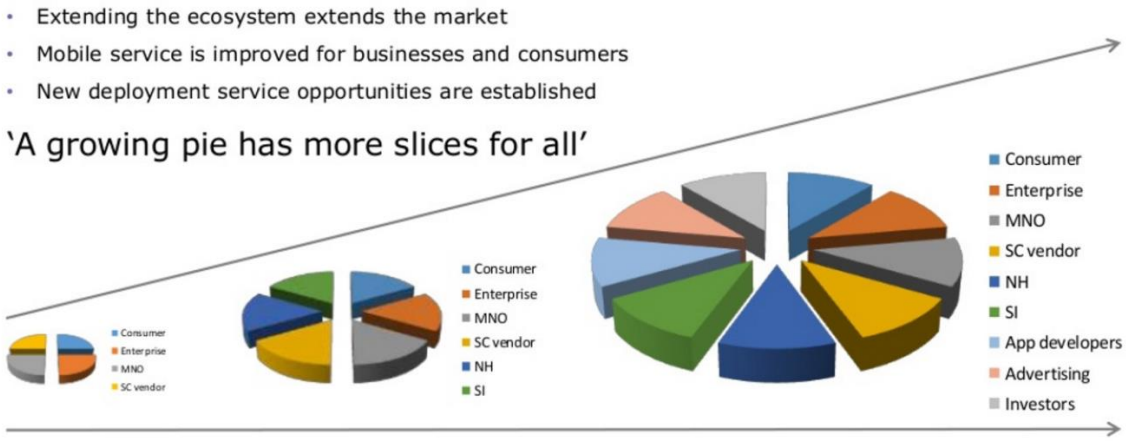


Figure 7: Evolving Small Cell Ecosystem (*Source: Small Cells Forum*)

Stakeholders can have a positive impact on small cell deployments, e.g. by lowering regulatory barriers, stipulating and/or certifying health or environmental aspects, thereby speeding up deployment. Conversely, they can negatively influence public opinion, by impeding or preventing deployments. In some circumstances, the same stakeholder category can exert both positive and negative impacts.

Supply Side Stakeholders
Mobile Network Operators (MNOs): Increasing/retaining subscribers through service and performance differentiation, reducing network capital and operational costs. Small-cell deployments to enhance network capacity/coverage. Regulatory compliance to ensure the required coverage and infrastructure sharing, including street furniture.
Manufacturers and vendors can increase the number of small cell shipments and help expand markets to new types of customers, e.g. building and fleet owners. They can ensure product compliance with local regulations, and develop new products for new scenario deployments or for simpler installation.
Site owners and site facility providers: can increase revenue from site rental fees and from the lease of site facilities. They can simplify procedures for rights of way and invest in site facilities ahead of demand. On the negative side, these stakeholders may charge overly high fees for sites or leased facilities.
Neutral hosts: can generate new revenue streams by leasing small cell infrastructure, increasing the value of existing assets, e.g. buildings. Neutral hosts can reduce the small cell deployment burden for MNOs and offer an appealing option for sharing small cell infrastructure compared with MNO deployments.

[12] http://scf.io/en/documents/050_-_Small_cells_market_status_report_December_2017.php

Standards organisations work towards globally harmonised technologies, and develop standards for interoperability and backward/forward compatibility. As a result, they help generate economies of scale for small cell products and enable the same product development for different markets. Technical standards are voluntary unless regulators make them mandatory by specifying them as legal requirements.
Systems integrators: can increase revenue through the number of small cell installations. This can enable scalable and rapid small cell deployments and installation compliance with regulations.
Application developers: can create new revenue streams from small cell apps, e.g. through usage fees and advertisements. This can increase the added value of small cells to end users beyond mere connectivity benefits and provide further incentives for deploying small cells around user surroundings.

Table 2: Supply Side Stakeholders

Demand Side Stakeholders
Individual mobile subscribers: Individuals that subscribe to communication services provided by the MNO via small cells (e.g. private residential small cells).
Businesses and Vertical Industries: Using small cell infrastructure deployed in enterprise environments (e.g. offices, retail spaces, warehouses etc.) for enhanced communications services to their staff, customers. Small cells may be deployed and operated either by the enterprise organisation or by third parties (e.g. MNOs, neutral hosts).

Table 3: Demand Side Stakeholders

Governance Stakeholders
EU Policy Makers: responsible for harmonising small cell deployments across the EU by adapting regulations to suit new/evolving landscapes and requirements, such as the lightweight regime under Article 57 of the EECC, which seeks to significantly reduce the administrative barriers for deploying small-area wireless access points (SAWAP) (Small Cells) that comply with a certain set of characteristics.
National Regulatory Authorities (NRAs): From a small cell perspective, NRAs are responsible for ensuring compliance with and enforcement of existing regulations related to small cell product compliance, installation and operation. The RF spectrum licensing functions vary in different countries, placing them under the NRA, or some other government agency or Ministry.
Local government (e.g. local authorities/councils) responsible for receiving and processing applications for deployment of small cells (by supply group stakeholders) on publicly owned land or infrastructure. They define the local rules but can also incentivise investments and accelerate 5G rollouts by updating these rules.

Table 4: Governance Stakeholders

Advocacy category stakeholders
Environmental and historic entities: typically committed to ensuring that small cell deployments and operations are implemented without adverse effects on human health, the environment or national assets of historical significance (e.g. buildings).
Industry alliances: Alliances of mobile industry stakeholders (supply side category) and/or vertical industries

advocating member interests. These alliances offer a platform for defining joint positions aimed at overcoming barriers to 5G rollouts and small cell deployments aimed at Governance stakeholders and promote the use of small cells to demand side stakeholders.
Consumer rights bodies: advocate member interests in terms of the quality of communications services provided by the MNOs via the mobile network (including small cells infrastructure).
Research communities: Researchers and/or research projects that investigate various aspects of small cells (e.g. technical, commercial, legal, etc.) to produce new scientific knowledge and innovations. These may inform or influence the small cell-related perceptions, decisions or developments by all other stakeholders.
Technology Analysts: Individuals or firms that provide expert advice on small cell technologies and trends to all other relevant stakeholders.

Table 5: Advocacy Stakeholders

Barriers to dense small cell deployments

The demand for network densification through use of small cells is contingent on an enabling environment that allows for deployment of a relatively large number of small cells in a short timeframe. This enables mobile network operators and service providers to progressively achieve service quality targets through network densification in a timely and cost-effective manner. However, the deployment of small cells at these envisioned rates is usually inhibited by a number of regulatory, commercial, or procedural barriers. These are reviewed briefly below.

- **Inconsistent or inexistent definition of Small Cells:** The differentiation in regulations for small cell and macro base stations is contingent on the explicit definition or classification of the different base station types in regulations. Lack of this distinction would place small cells under the same (more stringent) regulations as macro base stations. In the case that the classifications of base stations do exist, there may still be challenges due to differences in what would qualify as a small cell across different regulatory regimes. This fragmentation would complicate the process of deployment of small cells, particularly for operators who carry out nationwide or multinational network deployments. Furthermore, the ambiguity in the definition of small cells also reduces effectiveness of governance stakeholders in ensuring that only installations that qualify as small cell base stations are eligible for any regulatory concessions.
- **Limited sharing of small cells**: It has been previously noted that infrastructure sharing is critical for small cell networks due to the required density of deployment and the wider diversity of deployment scenarios in both indoor and outdoor areas. The prospect of multiple mobile network operators, neutral hosts and other venue owners deploying their own small cells to cover the same geographical footprint is aesthetically unacceptable and likely to be commercially unsustainable. To that end, the lack of incentives or regulations that encourage or even mandate sharing of small cell infrastructure would significantly limit network densification in any given area.
- **Conservative RF-EMF Exposure Limits**: The requirement for compliance assessment of

small cells in terms of RF-EMF exposure limits may present one of the most significant barriers for rapid and sustainable network densification. This is due to the relatively larger number of small cell sites (both outdoor and indoor) that may need to undergo the assessment. Typically, small cells have a relatively small coverage footprint and operate with aggressive interference management and energy saving mechanisms (e.g. putting idle small cells to sleep). All these factors mean that small cells usually operate well below their peak transmit powers. Therefore, RM-EMF compliance boundaries typically evaluated based on peak transmit powers create overly conservative RF-EMF limits that constrain the density of small cell deployments.

- **Complex or Prolonged Licensing and/or Approval Processes**: In a given service area, the small cell deployment density will typically exceed that of macro deployments by at least one order of magnitude. Therefore, the small cell deployment processes have to be relatively cheaper, simpler and faster compared to traditional macro site deployment processes. Furthermore, the diversity and number of stakeholders involved in or impacted by dense small cell deployments is much broader compared to macro deployments. This requires simplification and reduced fragmentation in several processes in small cell deployment, including product approval, spectrum licensing, and planning permissions.

Small Cells Case Deployment Showcase: Amsterdam

American Congressman Thomas P. "Tip" O'Neill famously said, "All politics is local." The same might be said of the issues surrounding the deployment of small cells in urban locations. While national regulations might be a model of harmonisation, local regulations can vary considerably from city to city even within a single country. As noted earlier, cities are particularly concerned with visual pollution of the urban landscape, and each local government has its own perspective on what that means, making the installation of small cells in public places a thorny matter of aesthetics. The problems are not only of a regulatory and aesthetic nature: there are numerous technical issues to confront, such as the availability of power sources for the equipment and access to backhaul network facilities.

The city of Amsterdam was confronted with this problem as a part of their modernization initiatives, such as Amsterdam Smart City. At the same time, the city is striving to become one of the "greenest," most sustainable cities in Europe while continuing to attract businesses and maintain economic growth. Amsterdam is one of the oldest continuously inhabited European cities, with a renowned architectural heritage and numerous historical attractions (e.g. the 17th-century canals of Amsterdam) included on the UNESCO World Heritage List. Therefore, network densification projects in Amsterdam need to pay particular attention to the city's architectural, environmental and historical patrimony.

In 2014, Vodafone (one of the top two MNOs in the Netherlands by market share) embarked on a pilot project to deploy 200 small cells in Amsterdam. This was a case where out-of-the box thinking was called for, with a new kind of stakeholder: JCDecaux[13] is the leading global company for outdoor advertisements – those seen typically on billboards, lampposts, and bus stops. JCDecaux has over 100,000 street furniture assets across the markets in which Vodafone operates, including the

[13] http://www.jcdecaux.com/press-releases/jcdecaux-and-vodafone-sign-global-contract-roll-out-small-cells.

Netherlands. This turned out to provide the perfect set of unique, leading capabilities for successful small cell deployment:

- In these locations, JCDecaux already has existing agreements with the local authorities, with typical contracts of 10-20 years already in place, which could be exploited to streamline the onerous process of navigating local regulations;
- Bus shelters and roadside advertising panels could be used as sites for concealed installation of the Vodafone small cells, resolving the problem of visual pollution;
- Finally, the street furniture used by JCDecaux also includes facilities for powering the small cells and terminating fibres that were laid on the street, thus eliminating or reducing the need for additional civil works and providing future-proofed high-speed backhauling[14] capable of supporting upgrades to 5G.

This kind of partnership creates a win-win situation for both parties for their respective businesses: the MNO was able to acquire a superior deployment capability for its core 5G small cells business; and JCDecaux was able to leverage its unique relationships and assets to acquire a new target customer (5G small cells providers) in its own area of market focus. This case study represents an excellent showcase of the promise of 5G for stimulating new kinds of partnerships and evolving business models.

Figure 8: Small cell equipment concealment in bus shelters and roadside advertising panels[15]

Lessons Learned from the Field

The experience acquired in the Amsterdam case study and others around the world can be distilled in

[14] The is particularly useful as JCDecaux observed that fiber is needed for 95% of sites because of poor line-of-sight options for high capacity millimeter wave backhaul. https://www.thinksmallcell.com/Events/das-and-small-cells-congress-event-report-november-2017.html.

[15] JCDecaux presentation on "Addressing the multi-small cell challenge" at Small Cell Forum event at Mobile World Congress (MWC) 2017, February 2017 https://www.slideshare.net/SmallCellForum1/addressing-the-multismall-cell-challenge

a set of lessons learned on how to facilitate the complex task of small cell deployment in urban environment.

- **Collaboration**. Small cell deployment has to be framed as a win-win collaboration between stakeholders, both public and private, with each recognising and promoting the advantages for themselves, the others, and the public at large.
- **Transparency**. Public authorities can make the procedures for achieving deployment clear and straightforward, so that confusion and objections from potential applicants are avoided from the very beginning. Several nations, such as the UK and India, have now published excellent guidelines for small cell deployment procedures.
- **Consistency**. Particularly in applications for planning permits, consistency is essential to ensure rapidity, predictability, and repeatability of dense small cell deployments. Applicants need to know what their outlays will be, and inconsistent (or worse: unsustainable) fees across jurisdictions is an enormous damper on willingness to invest.
- **Competition and investment**. Public authorities need to take care that anti-competitive phenomena (like exclusive access to small cell sites) don't accidentally or intentionally occur, so that consumers can reap the benefits of a healthy competitive environment. Mobile operators such as BT are driving a vision of open-access, whereby industry and local authorities can work together to share street sites in an open and collaborative way. This approach marks a shift away from the present exclusive rights regime, where operators bid for contracts with local authorities for the exclusive right to deploy micro-infrastructure such as small cells on street furniture such as lampposts and bus shelters. Any operator wishing to use these assets must pay a wholesale charge to the rights holder. Such models are seen as unpractical for 5G since the market and regulatory landscape have changed, potentially stifling investments and slowing down 5G deployments. As an alternative, councils could grant access to street furniture on a fair and equal basis, thereby creating the right environment for long-term investment and innovation in future mobile networks[16].
- **Innovation**. Dense small cell deployments require a departure from "business as usual" approaches and methods used in larger deployment contexts. Case studies around the world have demonstrated that innovations such as streamlined planning application processes, integrated sharing, and design for minimising visual impact can be game-changers in the business of small cell deployment.

Summary of Takeaways

This white paper has highlighted some of the main barriers that impact dense deployment of small cells. A contextual overview of network densification landscape was presented by looking at the practical deployment considerations and overall small cell densification trends. This provided the basis for the discussion of the regulatory factors impacting small cell densification. The main takeaways can

[16] https://www.techradar.com/news/bt-wants-all-operators-to-have-equal-access-to-street-furniture.

be summarised across several perspectives:

- The regulatory interventions to facilitate dense small cell deployments **require definition or classification of base stations that provide a clear distinction of small cells from conventional macro cells**. These definitions or classifications **should be standardised and recognised not only across diverse stakeholder groups but also in different countries** to facilitate harmonisation of deployment rules and regulations.
- The increasingly dense small cell networks make the **sharing of small cell infrastructure even more critical than in macro cellular networks**. Overlapping dense small cell deployment by multiple operators and neutral hosts is commercially and environmentally unsustainable. The **need to encourage or mandate sharing** has been highlighted by policy and regulatory initiatives, including the proposed European Electronic Communications Code (EECC) directive.
- The RF-EMF compliance boundaries typically evaluated based on theoretical maximum transmit powers create **conservative EMF limits and may unnecessarily constrain the density of small cell deployments**. There are increased arguments for small cells to have **simplified assessments that reduce or eliminate the need for product installation compliance for individual small cell installations**. Further, scientific studies supported by measurements in real deployments could further enhance the validity of these arguments.
- The small cell deployment processes involve diverse stakeholders, which may result in **overly complex and prolonged processes for dense small cell deployments**. Some local authorities have already adopted measures (e.g. generic permits, exemptions, rule simplifications etc.) for **simplifying planning approval processes for small cells**. Further benefits of the interventions described could be amplified **by harmonising some of those procedures across different local authorities and indeed in different countries**. To create the right environment for long-term investment and innovation in future mobile networks, local councils could grant access to street furniture on a fair and equal basis, opening up to several operators rather than just one with exclusive rights.

The transition towards hyper-dense 5G networks underlines the need for urgent regulatory and policy innovations backed by empirical evidence from early deployments to ensure timely dense small deployments with envisioned 5G rollout roadmaps.

3 Essential Glossary

Term	Overview
3GPP	3rd Generation Partnership Project, the main standards body for 5G standardisation, including vertical industries. Among other activities, 3GPP has a growing number of industry associations as part of its market representation partnership.
Application developers	Individuals or companies that use small cell application programming interface (APIs) or edge clouds to create and deliver new applications and services to individuals or enterprise customers.
Backhaul and Fronthaul	Backhaul is a wireless network that connects cell sites to central exchange. Key BH technologies include Ethernet, fibre and microwave. Fronthaul is when remote radio heads separate the radio deployment at the top of a call tower, increasing signal coverage range.
Businesses and vertical industries	Using small cell infrastructure deployed in enterprise environments (e.g. offices, retail spaces, warehouses etc.) for enhanced communications services to their staff, customers. The small cells may be deployed and operated either by the enterprise organisation or by third parties (e.g. MNOs, neutral hosts). 5G is expected to benefit diverse verticals spanning automotive, energy/utilities, farming, healthcare, industry/manufacturing, public safety, transportation and logistics. Key industry associations include the 5G Automotive Association (5GAA), 5G-ACIA (Industrial Internet of Things), the International Railway Union (UIC), the European Utilities and Telecoms Council (EUTC), the Critical Communications Association (TCCA) and Public Safety Communications Europe (PSCE).
Consumer rights groups	Consumer rights groups are typically responsible for ensuring the rights of consumers, fair competition, and accurate information of the products or services in the marketplace. In the context of small cells, consumer rights refer to the quality of service communications services provided by the MNOs via the mobile network (including small cells infrastructure).
Environmental and historic entities	Organisations or individuals responsible for ensuring that small cell deployments and operations are implemented without adverse effects on human health, the environment or national assets of historical significance (e.g. historical buildings).
European Electronic Communications Code (EECC) and concept for	The EECC sets out new rules on issues such as the rights to install new telecoms equipment and the use of radio spectrum. It represents an attempt to harmonise telecoms regulation across the EU. It is set to take effect by the end of 2020. The EECC's SAWAP concept defines a new type

Term	Overview
Small Area Wireless Access Points (SAWAP)	access point for both fixed and mobile radio, essential to future wireless networks and their regulation.
Individual mobile subscribers	Individuals that subscribe to communication services provided by the MNO via small cells (e.g. private residential small cells).
Industry alliances	Alliances of mobile industry stakeholders (supply side category) set up to represent; promote and advocate member interests. Industry alliances provide a platform for defining joint positions related to tackling issues related to dense small cell deployments, e.g. to governance stakeholders, and promoting the use of small cells, e.g. to demand side stakeholders. The main ones for the telecommunication industry are the GSM Alliance and the Next-generation Mobile Network Alliance (NGMN).
Latency	Latency is the time between an action being performed (such as clicking a video link) and a reaction occurring (the video playing), as data travels between two points. 5G has low latency, which means things happen more quickly. This is particularly useful for business applications.
Local government (e.g. town and city councils/municipalities; county/province etc.)	Local government is the public administration of towns, cities, municipalities, counties, districts, states and so on. Local governments are responsible for running local utilities, libraries, fire departments, public buildings, leisure facilities, parks, local law enforcement and many other areas of local everyday life. In this context, local governments are responsible for receiving and processing applications for deployment of small cells (by supply group stakeholders) in publicly owned land or infrastructure.
Mobile Network Operators (MNO)	Providers of communications services via deployed small cell infrastructure. The small cells may be owned by the MNO, or shared with (or leased from) 3rd-parties (e.g. local councils, other MNOs, neutral hosts etc.). The MNOs may own some of the sites and provide some of the site facilities needed for their own use.
National Regulatory Authorities (NRAs)	In general, NRAs are responsible for ensuring that the mobile sector is functioning properly and that stakeholder interests are protected in a fair and balanced manner. From a small cell perspective, NRAs are responsible for ensuring compliance with and enforcement of existing regulations related to small cell product compliance, installation and operation. The RF spectrum licensing functions vary in different countries, placing them under the NRA, or some other government agency or Ministry. However, for sake of simplicity, we assume that all spectrum licensing is done by NRAs.
5G Network slicing	Operators running multiple dedicated networks simultaneously using the same physical infrastructure. Different slices are used for different

Term	Overview
	services and allow each to work effectively without being affected by bandwidth. For example, network slices at a music concert could include: general internet access; live video broadcast to TV; broadcasting a 360-degree video experience to VR headsets; emergency services communication.
Neutral hosts	Entities that provide small cell infrastructure for exclusive or shared use by other MNOs. Neutral hosts are different from MNOs as they themselves do not provide the actual communications services. The term *small cell infracos* is sometimes used to refer to neutral hosts
Research communities	Researchers and/or research projects that investigate various aspects of small cells (e.g. technical, commercial, legal, etc.) to produce new scientific knowledge and innovations. These may inform or influence perceptions of small cells perceptions, decisions or developments (by all other stakeholders). Besides an increasing number of national programmes in EU member states, the 5th Generation Public Private partnership (5G PPP) is the largest funding scheme in Europe, with a public side (EC) and private side (5G Infrastructure Association, 5G-IA) over 3 phases (2016-2020).
Site owner and site facility providers	Provide suitable sites or locations (e.g. street furniture) for installation of small cells in outdoor or indoor environments. The sites may include additional facilities (e.g. power supply, backhaul) necessary for small cell operation. The site owner or 3rd-party utility companies are usually the providers of these additional facilities.
Small cell product manufacturers or vendors	Develop and/or sell standards-based and certified (type-approved) small cell products to specific target markets.
Standards development organisations (SDOs)	Responsible for specifying and maintaining (e.g. revising, promoting etc.) technical standards to harmonise the development of small cell product features and ensure interoperability. These technical standards are voluntary unless they become mandatory, for example if adopted by regulators as legal requirements.
Street furniture	Assets such as lampposts and bus shelters used to deploy micro infrastructures, whereby MNOs typically bid for access rights. New models and partnership agreements are required to ease and accelerate 5G rollouts.
System integrators	3rd-party engineering companies providing small cell installation services to MNOs and neutral hosts. These companies have the necessary expertise to install small cells at various types of sites according to the small cell manufacturers' instructions. System integrators may also be involved in site acquisition functions.

Term	Overview
Technology analysts	Individuals or firms that provide expert advice on small cell technologies and trends to all other relevant stakeholders.

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