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Global5G.org White Paper on Small cells

How Europe can accelerate network densification for the 5G Era

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Executive summary

Very high-capacity networks like 5G will be a key asset for Europe to compete in the global market. Network densification through the deployment of next-generation of small cells helps deliver the necessary micro capacity and coverage. These deployments are key not only for increasing capacity, improving coverage especially indoors and energy efficiency but also for reducing radiation. Small cells also improve capacity in rural areas, thereby helping to reduce the digital divide by bringing much needed coverage to agricultural communities and small businesses. As such, small cells are a critical component of 5G networks.

From 2020 onwards, IoT, industrial services across diverse vertical markets will be key drivers to meet the need for far greater coverage in-building and in remote areas. According to the Small Cells Forum, most non-residential indoor small cells will be in the business space. 5G will also be a strong driver in the outdoor market, especially from 2021 onwards as 5G serves the needs of industry with vertical-specific cells deployed outdoors.

Neutral hosts will also become an important enabler of densification, with most demand from enterprise and IoT. Another important trend is edge compute nodes, especially in the period 2022-2025 with an increasing focus on applications and industries that need compute capacity close to premises and users. This will bring a natural convergence with small cells for advanced connectivity.

Beyond the many private rollouts expected, the shift towards 5G for vertical industries is also evident in Europe's 5G PPP (5th Generation Public Private Partnership) in the drive to put European research and innovation at the forefront of EC and private investments. 63 use-case experiments are already taking place across Europe within 5G PPP phase 2 (launched in June 2017). Phase 3 projects are bringing to Europe large-scale pilots to empower vertical industries alongside advanced test infrastructures and cross-border automotive trials.

National and European programmes geared towards 5G leadership are also important catalysts for regulators and governments to lower deployment barriers, including smart cities and verticals industries. Many national initiatives and trials captured in the Pan-EU Trials Roadmap V4.0 (November 2018), while 5G PPP phase 2 use-case experiments feature in Global5G.org's web-based Verticals Cartography (September 2018) with on-going expansion to phase 3 projects.

The 5G Action Plan (5GAP) is closely related to the new European Electronic Communications Code as they are both aimed at fostering the competitiveness of European industry in the Digital Single Market. They both support the deployment and take-up of 5G networks, notably through the timely assignment and availability of radio spectrum, as well as more favourable conditions for small cell deployment, investment incentives and favourable framework conditions alongside measures to lower sectorial barriers to service deployment. In addition, the rules on Open Internet provide legal certainty regarding the deployment of 5G applications.

With 5G being a catalyst for network densification, Europe needs to take steps to enable the deployment of very high-capacity networks that enhance mobile broadband experience and support high device densities.

To lower barriers to 5G rollouts and the deployment of small cells, Europe has taken an important policy measure through the European Electronic Communications Code. The EECC marks an essential step towards harmonising telecoms regulation across the EU in view of 5G rollouts. 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.

This White Paper on Small Cells for 5G investigates the evolving small cell ecosystem, showing how network densification can be accelerated with new, practical approaches to 5G rollouts based on a lightweight regulatory regime applicable and workable across the EU.

The white paper draws on an in-depth study conducted by Global5G.org, which was submitted to the European Commission in early 2018 as D3.1 - Study on Small Cells and Dense Cellular Networks Regulatory Issues.

The study 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. Updates to the Study findings include interactions with key stakeholder groups. Chief among these are the Small Cell Forum and its international venues such as the SCF World Summit 2018 and Flip Book.

Intended Audiences

This white paper is primarily intended for national regulatory authorities representing European Member States and policy makers as a practical guide to network densification with the aim of implementing lightweight regulatory regimes as key to lowering barriers to small-cell deployments and accelerating 5G rollouts also across diverse EU vertical industries.

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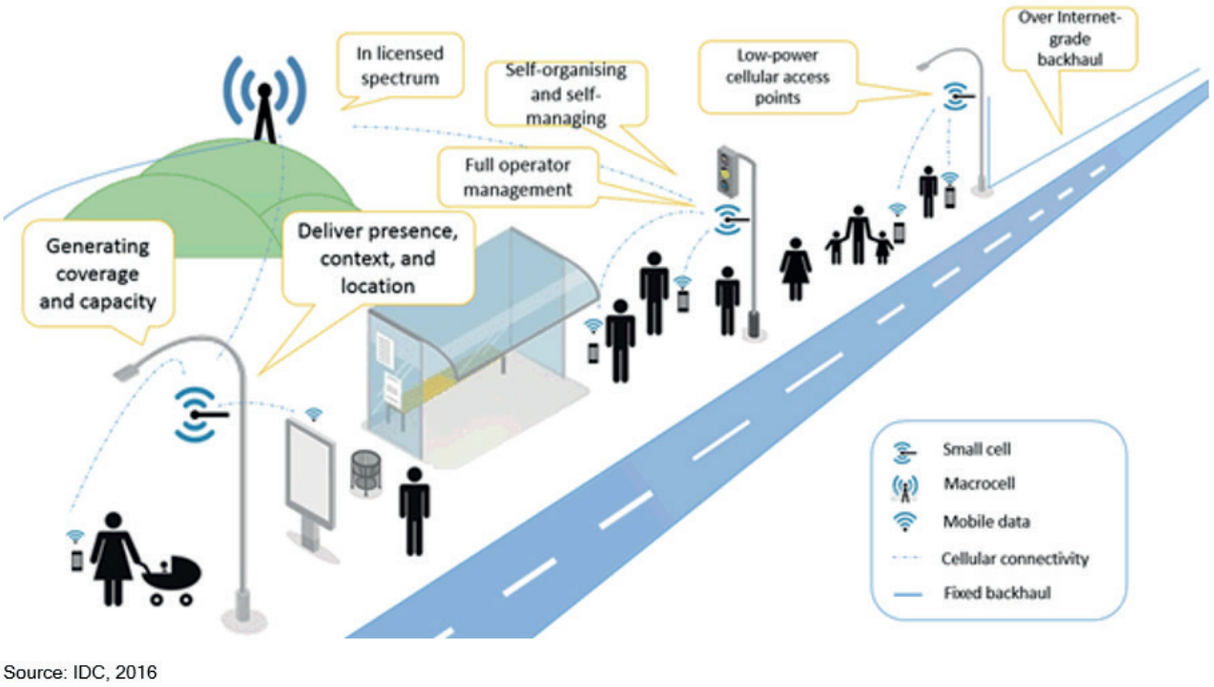
1 The Global5G.org Small Cells White Paper

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 a radio coverage range between a few kilometres and tens of kilometres and are served by a high-powered cellular base station. However, the 1000x scaling in mobile data traffic volumes in recent years 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 the dense deployment of small cells to complement existing macro cellular networks[1].



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). 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 that might periodically become closed access).

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

2 Key drivers behind dense small cell deployments

Mobile network operators face the continuous challenge of upgrading their networks in response to ever-growing traffic volumes stemming from the increased adoption of smart devices (e.g., smartphones, mobile virtual reality platforms etc.) and bandwidth-intensive services (e.g. 4K/8K video streaming).

One way of tackling traffic growth is for mobile operators to upgrade their networks to radio technologies that provide higher network capacities and user throughput. A good case in point is maintaining multi-standard radio access networks that include both fourth-generation (4G) technologies and those of earlier generations.

The deployment of small cells has been a critical part of the 4G network upgrades and expansion but will become even more critical in 5G networks because of the introduction of higher spectrum bands that necessitate denser network deployments to support larger traffic volumes per unit area.

This process of adding new cell sites, typically called small cell sites but also referred to as network densification, is quantified by the site density (site/km2) or inter-site distance (ISD). Network densification is ongoing in legacy 4G networks with site densities of 10-30 sites/km2 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.

While 4G network enhancements and/or expansions are ongoing, mobile operators, equipment vendors and other industry stakeholders are already aggressively developing and trialling 5G network technologies. These technologies will support emerging connectivity needs for the next decade and beyond.

5G is envisioned as 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), including use cases yet to be envisioned today.

The first commercial 5G deployments started in 2019, mostly driven by needs for enhanced mobile broadband (eMBB) in dense urban areas. It is projected that by 2024, 5G will constitute 17% of the global mobile subscriptions with the fastest adoption expected in North America, North East Asia and Western Europe[2].

From a small cell perspective, there will be several waves of 5G. The early phase is mostly based around macrocells and advanced MIMO antennas. There will then be a rapid move towards selective densification in areas of high usage and to support low latency services in cities or industrial locations.

In enterprise, where densification has accelerated earlier than outdoors, there will

2 https://www.ericsson.com/en/mobility-report/reports/november-2018.

be a greater tendency to enhance LTE further and achieve Return on Investment (RoI) before moving to 5G at scale.

The *Small cells market status report* (December 2018) by the Small Cell Forum[3] is based on Rethink Technology Research's small cell forecasting model. It describes best and worst-case scenarios for network densification by 2025 globally. The core forecast anticipates growth in new deployments and upgrades of 24% CAGR between 2017 and 2025, reaching a total of 8.4 million small cell radios deployed in 2025 across residential, enterprise, urban and rural/remote markets. The best-case scenario sees a GAGR of 29% in the same period, reaching a total of 11.4 million by 2025 while the worst case sees a CAGR of 22% and a total of 7.1 million by 2025.

If the drivers to densify are stronger than current assumptions or if barriers holding back deployment are lowered more rapidly, there is a potential upside of 3 million units. By contrast, if the worst case proves correct, there will be a downside of 1.3 million compared with the base case.

The decisive factors in play would therefore accelerate or expand deployment plans and push the forecast towards the best case if appropriately tackled. Differences important to note are between indoor/enterprise and outdoor/urban environments. Key factors for indoor/enterprise are related to the total cost of ownership (TCO), shared risk and ease of deployment or management. For outdoor/urban environments, key factors relate to TCO but also site issues, approvals and deployment processes. In both environments, capex costs are at the bottom of the top 10 factors.

The regions that are already addressing such issues seriously are currently seeing the fastest growth, illustrating how critical it is that regulators everywhere follow their lead. These regions are North America (driven by the U.S.) and south-east Asia (driven by China and Japan). In these countries, significant effort has been made by authorities to simplify approvals and deployment processes and lower barriers in cities, in particular. Operators have also been active in working with partners, and lobbying regulators, to make it easier for them to deploy small cells at scale.

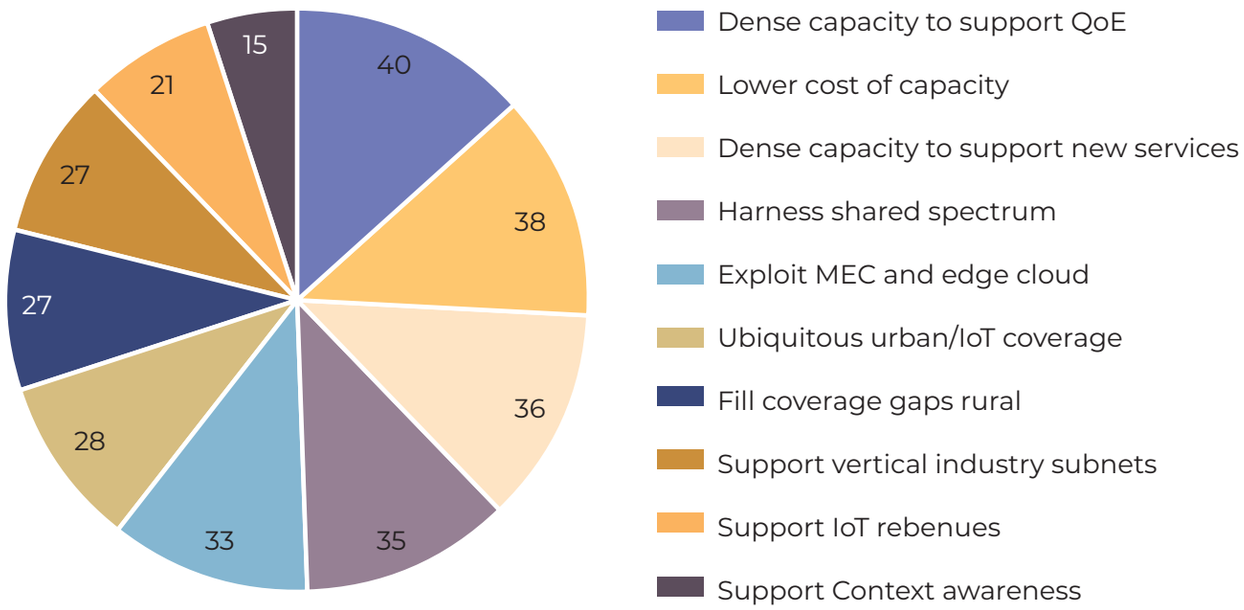
These areas of early, at scale densification will build a strong basis for 4G and 5G expansion, which will continue to generate growth in the early 2020s. By 2022-23, it is expected that Europe and Latin America will experience a higher rate of deployment and with higher levels of new deployments by 2025.

3 https://scf.io/en/documents/050_-_Small_cells_market_status_report_February_2018.php.

3 Stakeholders of small cells in the 5G Era

Networks must, and will, change and evolve as small cells play a pivotal role in both the emerging 5G ecosystem and continuing LTE rollout and as new spectrum and revenue models drive densification[4].

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).



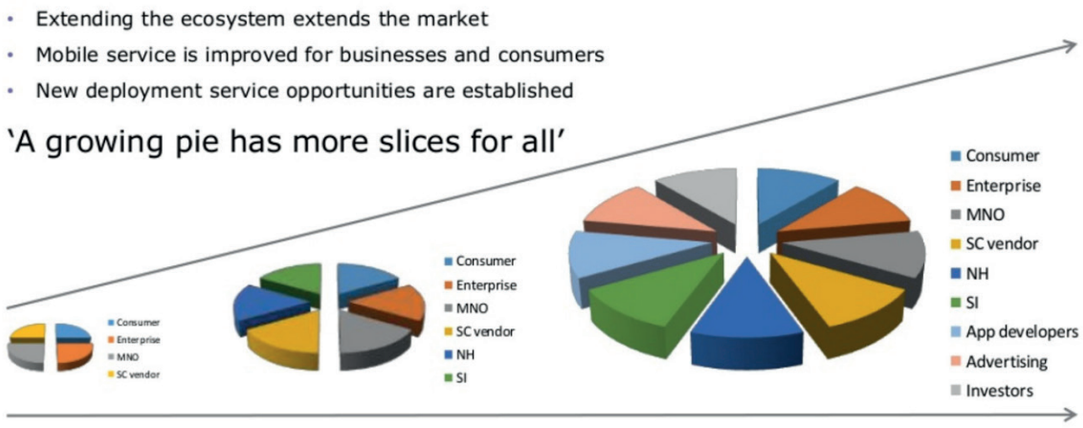
Projections from Small Cells Market Status Report (*Source: Small Cells Forum*)

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 current homogeneous macro cellular network deployments and clearly defined roles within the ecosystem. The transition to 5G will therefore call into play new wireless strategies, partnerships and a light regulatory regime, all geared towards lowering deployment barriers that are key to unleashing the full benefits of 5G.

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[5]. Zooming in on the new opportunities for this "growing pie", we can assess the role and responsibilities of four major stakeholder groups, namely, **supply**, **demand**, **advocacy** and **governance**.

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

5 http://scf.io/en/documents/050_-_Small_cells_market_status_report_December_2017.php.



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): can increase /retain subscribers through service and performance differentiation, reduce network capital and operational costs. They can enhance network capacity/coverage through small-cell deployments. Regulatory compliance is important 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.
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.

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).

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.

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 promoting 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.

Advocacy Stakeholders

4 Typical small cell deployment scenarios

Typical small cell deployment scenarios are outdoor deployments in urban and rural areas, and mostly indoor deployments in enterprise spaces as outlined in the table below.

Deployment scenario	Main purpose	Targeted users	Where/how	Deployment density
Residential	Improve service quality in domestic environments.	Individuals or families.	Indoor walls, ceilings, table tops.	High (per dwelling unit per room) Medium (sharing by multiple dwelling units).
Enterprise	Enhance customer experience (e.g. airports, malls, stadiums) or improve productivity (e.g. offices, factories, hospitals).	Customers, enterprise users.	Indoor walls or ceiling Indoor / outdoor canopies and other building fixtures.	Medium/High (depending on the venue and, typical user densities)
Urban	Fill in coverage gaps 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 and other street furniture, advertisement boards etc.).	High.
Rural	Fulfilling obligations for universal access broadband services.	Rural communities.	Outdoor on rooftops, cell towers.	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[6].	Passengers, travelers, drivers, transport infrastructure owners and/or operators.	Lampposts, traffic signs, ground stations, tunnels, bridges, pylons.	Medium/high (linearly along transport corridors.)

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

Deployment scenario	Main purpose	Targeted users	Where/how	Deployment density
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, ambulances).	Mounting on unmanned aerial vehicles (UAVs or drones).	Low/Medium (depending on the use case).

Small cell deployment scenarios

5 Key factors for small cell deployments

Availability of sufficient spectrum: Legacy 4G networks have utilised licensed spectrum bands typically in the sub-3 GHz bands, which provide wide area coverage. However, the availability of spectrum in these bands is limited due to a multitude of other wireless systems that operate in the same range. Future 5G New Radio systems will require even larger amounts of spectrum to support small cell densification as key to meeting 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)[7] 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 of 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 realise the capacity enhancements of 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.) connect the cellular base stations to each other and to the core network. As such they are known as *backhaul* links. Furthermore, the evolution towards 5G is triggering 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 small cells. Any limitations on backhaul or fronthaul link capacity or delays would create capacity bottlenecks or contribute to the end-to-end latency experienced by any service provided by the small cells. The relatively higher capacity requirements and stringent latency requirements of 5G services would therefore determine 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 requiring powering) implies an overall increase in network-wide energy or power consumption. 5G small cells will consume energy for both power transmission and computation purposes (e.g. signal processing, edge cloud processing etc.) These growing energy requirements put a constraint on possible densification due to unsustainable site powering costs and increases 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 are 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 (e.g. masts, utility poles, advertisement panels, fixed-plant for backhauling etc.). The *active sharing*

7 The term centimetre wave (cmWave) is sometimes used to refer to the 6-30 GHz, whereas the mmWave band is for the 30-100 GHz band. However, in this white paper, mmWave is synonymous with high bands above 6 GHz (up to 100 GHz).

mode means that multiple MNOs share some or all active elements of the 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 organisations that use 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 as part of an active sharing solution. The neutral host service is a Small-cells-as-a-Service (SCaaS) model that significantly lowers the entry barrier for some MNOs that need to deploy dense small cells 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.

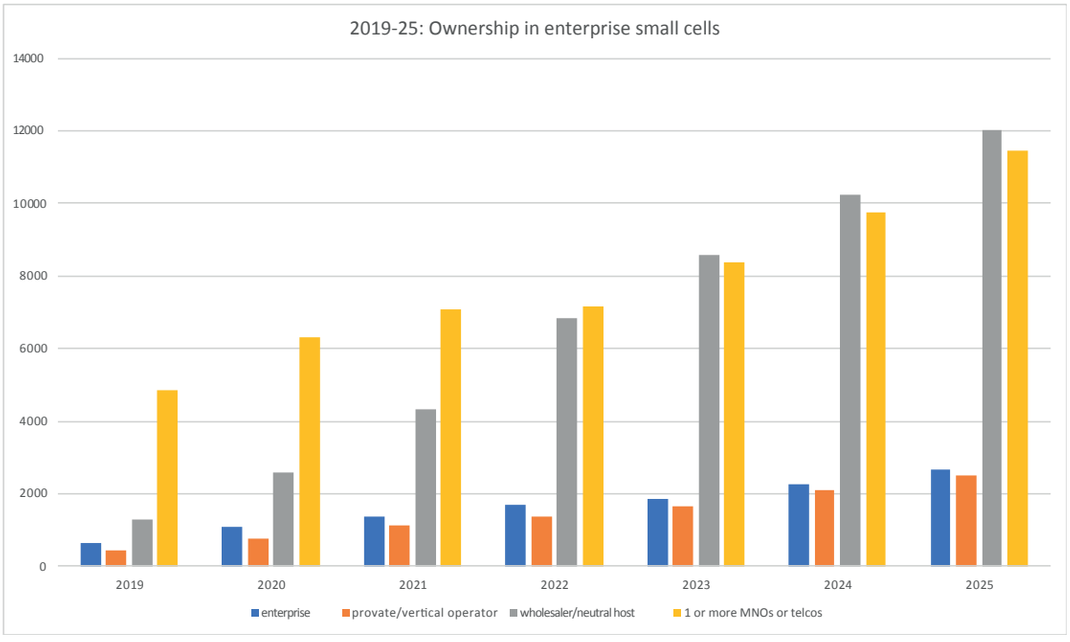
6 Small cell deployment trends and projections

Mobile network operators in Europe and other regions are now compelled to deploy small cells to alleviate capacity exhaust. The entry of third-party site facility providers with 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 rise of small-cell clusters attached to a controller or other device running virtualised network functions is a key architectural trend that is expected to gather pace in large-scale densification.

Several trends are forecast as the number of deployed small cells increases over the next few years and up to 2025. The main source cited here is the SCF's small cells market status report (December 2018), which describes key findings from the forecast modelling of Rethink Technology Research[8]. The report also provides best and worst-case scenarios depending how successful key stakeholders will be in addressing the issues that would accelerate or slow down small cell deployments for the 5G era. It is also important to note the increased demand from vertical industries and businesses as key factors for the European economy.

1. Densification Forecast 2017-2025

By 2025, SCF forecasts deployments and upgrades reaching 10.25 million radios. 8.4 million will be non-residential, with enterprise being the largest sector (5.5 million units), followed by urban (2.86 million deployments).



2017-2025 Densification Forecasts (Source: Small Cell Forum)

8 The projections are based on data obtained from Rethink Technology Research survey conducted in September and October 2018, published in Small Cell Forum., Small cells market status report, Document 050.10.03, Release 10.0, December 2018.

Early rapid growth up to 2020 in enterprise and urban markets is mostly due to very large projects in cities and enterprises in markets like China and the U.S. From 2022, a new higher growth curve is expected as 5G becomes more mainstream and as new capabilities emerge to support new or enhanced security architectures and edge compute platforms.

By 2025, deployments will add up to an installed base of about 40.2 million small cells across all environments, at a CAGR rate of 46% since 2017. The urban environment will see the fastest growth, reaching 11.2 million units by 2025, with 28.6 million enterprise units in the same year.

Two aspects are important in terms of densification landscape development: indoor and outdoor cells.

1. **Indoor and enterprise deployments**: most non-residential indoor small cells are in business environments, including public-facing (e.g. retail malls) and private enterprise activities. While currently deployed and operated by MNOs, more diversification of operating models is expected in the future. This will be most apparent in indoor and business environments.
2. **Outdoor and urban deployments:** mostly serve MNO-deployed, public networks in urban, suburban and rural environments with a subset of outdoor cells dedicated to a specific enterprise category, e.g. in remote areas, an oil rig or power station. 5G will bring the need for small cells for industrial and IoT services, with more vertical-specific cells deployed outdoors, sometimes managed by enterprise specialists. The increasing shift towards 5G for vertical industries is apparent in Europe's 5G PPP, with the Global5g.org Verticals Cartography currently counting 63 case experiments for phase 2 (2017-2020)[9] across 10 vertical industry clusters, including the integration of satellite in 5G as a key enabler and experiments targeting multiple vertical domains. More such cases are coming from the on-boarding of phase 3 (2019-2022) running large-scale pilots across diverse verticals.

The Pan-EU Trials Roadmap V4.0 (November 2018) also captures the growing momentum of 5G not only within the 5G PPP but also Member State programmes, including smart city trials and major sporting events in EU, as well as specific programmes like the European Space Agency (ESA) Satellite for 5G Initiative[10].

2 Increasing importance of Neutral Host

Neutral Host will be an important enabler of densification, especially for industrial and enterprise uses and IoT. By allowing multiple providers to roll out services on a single set of infrastructure, neutral host tackles many of the challenges of scalability, TCO, shared risk and ownership. The convergence of small cells with edge compute nodes will be one of the drivers for neutral host or private enterprise models. Convergence will support new use cases, especially in low latency IoT applications, while driving additional monetisation opportunities for dense networks.

The advent of 5G will thus bring further stimulus for densification, in tandem with further enhancement of LTE capacity and coverage. Outdoor deployments are prime examples of this. The upward trend in 5G small cell deployments will be inextricably linked to the availability of virtualised and disaggregated architectures, acting as a catalyst for 5G densification because of the greater cost efficiency and flexibility. Combined 4G/5G small cells will be very important in deployment patterns, especially in virtualised environments. While virtualised clusters of small cells will be slow to take off in 4G, they are expected to be the dominant architecture in 5G.

SCF forecasts show that shared and neutral host networks will be key in the densification landscape, with forecasts showing the largest section of the market from 2023 to be in business environments. The data points reveal that these networks will narrowly overtake the conventional MNO-driven model (including multi-MNO sharing) in 2023.

Other approaches likely to emerge range from businesses running their own network

9 https://www.global5g.org/cartography. Release 1.0 in September 2018; Release 2 in April 2019, with iterative releases and updates on results obtained planned between September 2019 and July 2021.

10 https://5g-ppp.eu/wp-content/uploads/2018/11/5GInfraPPP_TrialsWG_Roadmap_Version4.0.pdf.

(in shared or MNO spectrum) include private cellular operators providing a localised, self-contained network, often with its own local core.

In outdoor environments, MNOs are expected to retain ownership in most cases but their networks will feature a growing number of cells deployed by industrial players or vertically focused neutral hosts, typically supporting 5G industrial and IoT use cases.

3 Edge Compute Nodes

Edge compute will be an increasingly important driver of densification, especially in the period from 2022 to 2025. Initially, the focus will be on telco sites such as macro cell sites. The next phase will reflect the growing importance of diverse applications and industries that will need edge compute capability closer to their premises and users, leading to a natural convergence with small cells to provide advanced connectivity. From 2019[11], there will be a growth of almost 100% in the deployment of small cells collocated with edge compute nodes. Early drivers include conventional MNO use cases like improved video streaming, enabled by lower latency and localised caching. Key drivers will be supporting enterprise and industrial use cases with much more demanding latency requirements. The growing requirement for localised edge/connectivity resources will ensure high degrees of security and data privacy. The forecasts thus point to an increasing shift towards more enterprise, mission critical and ultra-low latency applications. Further evidence of this comes from 3GPP (3rd Generation Partnership Project) and the increasing focus of vertical applications and services that are being standardised, with Working Group SA6 on mission-critical applications being one example .

In enterprise environments, neutral hosts will be the most common deployers of the connected edge compute nodes after 2021, due also to deployments in data centres and enterprise premises (non-telco locations), with the nodes connected by the MNOs cellular network or private cellular local RANs. In terms of RoI and business models, the decision of how much edge infrastructure to deploy or whether to rely on 3rd-parties is likely to be a key factor. Many operators expect to increasingly extend their edge virtually, especially in enterprise, through neutral host deployments of localised small cell plus edge networks, connecting these local zones via their wide area mobile network, and potentially offering added value services like end-to-end security, or virtualised connectivity between enterprises driven by software-defined network (SDN) technologies.

4 New Small Cell Architecture

The conventional all-in-one cell will be the dominant small cell architecture until late 2020. Thereafter, several trends, such as **more distributed** or **disaggregated designs** will drive new form factors. Examples include the need for **discrete** or **compact cells** for **urban** or **indoor environments**, and the emergence of '**mini-macro' products**, that is, macro equivalent cells in compact formats mountable on street furniture.

The **growing number** of **cells in small areas** will also drive **new architectures** based on **shared controllers**, thereby increasing flexibility while reducing cost and total footprint. 5G will bring a significant increase in the adoption of **virtualised small cell networks**, with clusters of radios supported by a central controller, with some or all baseband tasks running as a virtual network function. These virtualised systems will gain the highest CAGR (37%) in the period 2017-2025, with the largest category of new deployments from 2021 (4.8 million units, that is, radio heads, in 2025).

5 Factors influencing 2025 outcomes

Based on the models from Rethink Technology Research, the SCF has also analysed the impact of 10 key factors that could accelerate densification or slow it down in the next 3-5

11 https://www.3gpp.org/about-3gpp/about-3gpp.

years. These factors vary between indoor/enterprise and outdoor environments. For **indoor and enterprise**, key factors relate to **total cost of ownership (TCO), shared risk and ease of deployment/management**. The top three factors are: **lower operating costs (opex); a clear framework for sharing cost and risk between the operator and the enterprise and clearer RoI cases**. If these issues can be addressed in the coming years, network and service providers would have greater incentives to accelerate or expand their rollouts. Other factors include automated or outsourced network operations; clearer differentiation from Wi-Fi; plug and play deployment; low cost or shared spectrum; low cost backhaul; deep integration with Wi-Fi and lower capex equipment costs.

In outdoor environments, the key factors also relate to TCO but are more connected with **site issues**, **approvals**, and **deployment processes**. **Access to affordable sites is therefore the top factor for accelerating or slowing down deployment plans**. Factor number 2 is lower operating costs for the entire deployment or standardized processes for site and deployment approvals. Other factors deemed to be of lower importance include: affordable backhaul; shared cost of deployment (e.g. with other operators/cities); plug and play deployment process; affordable/shared spectrum; outsourced network operations (e.g. neutral host, cloud); network automation; lower capex costs of equipment, which comes last in both indoor/enterprise and outdoor environments.

The findings of SCF point to more potential for upside than downside, with operators unlikely to deploy at a radically lower rate than expected. A key finding is the **untapped potential** that would be realised if certain factors come into play. The **urban environment** has the **greatest potential upside/downside**. This is because of the **higher risks associated** with **sites** and **city regulatory issues**. Addressing these issues would release significant pent-up demand. However, there still remains a high risk that barriers will be slow to come down in some regions. In this case, operators could choose alternative approaches such as massive MIMO, which is much less relevant in indoor environments.

7 Barriers to dense small cell deployments

The demand for network densification through the 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 diverse regulatory, commercial, or procedural barriers. These are briefly reviewed 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 different types of base stations 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, ambiguity in the definition of small cells also reduces the effectiveness of governance stakeholders by stipulating 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 need 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.

8 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 modernisation 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 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[12] 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 Netherlands. This turned out to be the perfect setting of unique, leading-edge 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. These 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 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[13] 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.

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

13 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.

Small cell equipment concealment in bus shelters and roadside advertising panels panels (Source: JCDecaux 14

14 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

9 Lessons Learned from the Field

The experience acquired in the Amsterdam case study and others around the world can be distilled in a set of lessons learned on how to facilitate the complex task of small cell deployment in urban environment.

- **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.
- **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.
- **Competition and investment**. To ensure consumers can reap the benefits of a healthy competitive environment, public authorities need to avoid anti-competitive phenomena like exclusive access to small cell sites either accidentally or intentionally occur. It is important to drive 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. Retaining such models is impractical for 5G as both 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[15].
- **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. Inconsistent (or worse: unsustainable) fees across jurisdictions is an enormous damper on the willingness to invest.
- **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.

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

10 Overcoming the challenges

The European Electronic Communications Code (EECC) marks an essential step towards harmonising telecoms regulation across the EU in view of 5G rollouts[16]. The **EECC's SAWAP concept is a major opportunity to achieve harmonisation** by clearly defining a new type of access point for both fixed and mobile radio, essential to future wireless networks and their regulation.

The new Directive addresses the rights of telecom companies to install telecom equipment on public or private property. However, its broad scope covers the activities of telecoms network and service providers as well as national regulators in the EU countries where they operate.

It also sets out high-level rules on the co-location or sharing of "network elements and facilities" for EU countries to expand upon with their own legislation. The directive also promotes strategic planning, coordination and harmonisation of the use of radio spectrum within the EU, and stipulates conditions on the rights of use for radio spectrum. It envisages that EU countries will coordinate with each other on their assignment of certain blocks of spectrum for the purposes of enabling new 5G services to be provided.

Security requirements and incident reporting rules for providers of public electronic communications networks or services are also set out in the directive. They include powers for regulators to require providers to submit to security audits.

The directive will also require national authorities to "conduct a geographical survey of the reach of electronic communications networks capable of delivering broadband".

In summary, the directive is one example of how the regulatory landscape continues to develop to help level the playing field for industry and support greater broadband penetration and consumer access and choice.

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

11 Summary of Takeaways

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.

Europe has a key role to play in its ambition, not to be the first, but the best in terms of 5G rollouts, with a high priority on vertical industries and smart cities. To fully realise the benefits of small cell deployments, steps need to be taken to lower the barriers highlighted in this white paper as the basis for assessing regulatory and other factors impacting densification.

To enable such steps this paper looks at the network densification landscape was in terms of practical deployment considerations, overall small cell densification trends and resulting economic growth.

The main takeaways can be summarised across several perspectives:

- The regulatory interventions to facilitate dense small cell deployments **require definition or classification of base stations with a clear distinction between small cells and conventional macro cells**. These definitions or classifications **should be standardised and recognised not only across diverse stakeholder groups but also in different countries** with a view to facilitating 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** is therefore 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.
- **Neutral host and edge are important drivers**. Reducing cost, risk and management effort by sharing the investment in small cells with others (e.g. between enterprise and service provider, or between multiple operators) would be an enabler of accelerated deployment. To achieve some of these aims, new deployment and ownership models are coming into play. Trends like **shared spectrum** and **the need to tailor networks to diverse vertical industries or use cases** could act as accelerators in this respect. Co-investments could also be the way forward as in the case of the 5G PPP and its private-facing 5G Infrastructure Association, with examples also coming from China and Japan.

Neutral host deployment of dense infrastructure and multi-operator small cells is a promising approach to lowering deployment barriers. Service providers, including MNOs and enterprise specialists can share the network to deliver different services, thereby significantly reducing the cost for each operator, with less pressure on sites and backhaul, and less risk of interference. Moving forward, **key drivers for edge compute** will be supporting **enterprise and industrial use cases** with much more demanding latency requirements. The growing requirement for localised edge/connectivity resources will ensure high degrees of security and data privacy. The forecasts thus point to an i**ncreasing shift towards more enterprise, mission critical and ultra-low latency applications**.

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.

12 Essential Glossary

Term	Overview
3GPP	3rd Generation Partnership Project, the main standards body for 5G standardisation, including vertical industries through technical specifications transposed by national and EU standards organisations like ETSI (EU). Significantly, 3GPP has a growing number of industry associations serving as market representation partnership with a Task Force aimed at lowering entry barriers across market sectors.
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, vertical industries, emergency services	Using small cell infrastructure deployed in enterprise environments (e.g. offices, retail spaces, warehouses, factories 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), among others.
Consumer rights groups	Consumer rights groups are typically responsible for ensuring the rights of consumers, fair competition, and accurate information about 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 Small Area Wireless Access Points (SAWAP)	Set to take effect by the end of 2020, the EECC sets out new rules on issues such as the rights to install new telecoms equipment and the use of radio spectrum. It marks an important attempt to harmonise telecoms regulation across the EU. The EECC's SAWAP concept defines a new type access point for both fixed and mobile radio, essential to future wireless networks and their regulation.

Term	Overview
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 such as 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 associations for the telecommunication industry are the GSM Association 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. In the context of small cells, local governments are responsible for receiving and processing applications for small cell deployments (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 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

Term	Overview
Research communities (e.g. individuals, groups and projects)	This stakeholder group investigates various aspects of small cells (e.g. technical, commercial, legal, etc.) to produce new scientific knowledge and innovations. These may inform and/or influence perceptions of small cells, decisions or developments (by some or 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	These stakeholders 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 manufacturer's instructions. System integrators may also be involved in site acquisition functions.
Technology analysts	Individuals or firms that provide expert advice on small cell technologies and trends to all other relevant stakeholders.

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