	TECT- LA # Doc 00X **Radio Access Network Deployment Guideline for Latin America**
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EXECUTIVE SUMMARY

As wireless connectivity comes to underpin every work and leisure activity, the demands on radio access networks (RANs) are intensifying. There is a growing need for mobile data capacity, and for ubiquitous coverage with rapid response times and high reliability, to support high levels of quality of experience for users. For mobile network operators (MNOs), this means building networks in a new way, so that they can enable new services and user experiences, but also reduce costs and improve profitability.

This quest for cost-effective mobile capacity is leading to rising operator interest in densification – using small cells to provide capacity and coverage just where they are needed, complementing the macro network while also supporting new types of services, such as those enabled by location awareness.

There are strong drivers for operators, and for governments and regulators, to deploy more macrocells, support small cells and densification programs in Latin America. The region has a rising reliance on wireless connectivity for broadband access in many environments from congested urban centers to far-flung rural communities. The impact of deploying vast capacity in a simple, scalable and affordable way will be transformational and help governments achieve many of the social and economic aims of their broadband programs.

However, while the drivers are strong, there are still challenges to the deployment of large numbers of small cells and new macrocells. Some of these have deterred operators and other stakeholders, such as municipalities, enterprises and web providers, from embarking on densification. However, solutions are emerging to many of these challenges, provided all the parties which can benefit from densification can cooperate to implement it.

Many of the most important challenges are not purely technical, but relate to regulation (of spectrum or equipment), to rules for acquiring and using sites, to deployment processes and to cooperation mechanisms between all the stakeholders (regulators, operators, vendors, neutral host providers, landlords, local authorities, fiber owners, public works organizations and so on).

This report will identify the main challenges which could hold back large-scale deployment of small cells and new macrocells, and so limit the socio-economic impact of densification. It will suggest solutions in each case, and ways in which operators and regulators, as well as other parties such as municipalities, can work together to accelerate adoption.

1 Scope

The document is intended to detail the technical considerations that both Operators and Governments should take into account in the Radio Access Network deployment in the Latin American region.

It describes the background related to mobile networks densification, the drivers, the technologies involved, the challenges to deploy that networks and how to address them.

2 Introduction

Mobile networks are going through a phase of rapid evolution in technology and service capability. They are no longer just connectivity pipes, but are becoming IT, services and multimedia platforms. This trend is being driven by broad changes. Businesses, government and society are going through digital transformation programs, as most aspects of life are becoming increasingly digital. Within that context, connected activity is increasingly mobile-first. And a new dimension is added by the emergence of the Internet of Things (IoT).

The mobile technologies are developing rapidly to adapt to these new global realities. Key trends include densification, virtualization, IoT networks and the road to 5G.

Critical requirements for new mobile networks:

If harnessed effectively, these new-look networks have the potential to enable social and economic transformation. But this will only happen if they can be deployed:

- cost-effectively, so that operators can provide affordable services while making a profit themselves
- almost ubiquitously, so that all citizens and businesses can share in the benefits and emerging M2M applications such as smart grid can be supported, among others
- optimally, so that different services with different traffic patterns can all be supported, especially in vertical markets where mobile broadband will have the most impact
- scalably, so that capacity can be increased in line with rising usage, without causing unacceptable pressures on spectrum, operator budgets or quality of experience
- flexibly, so that systems deployed now will be smoothly upgradeable to or interoperable with future generations, including 5G, Cloud-RAN and software-defined networking (SDN).

Dense, flexible heterogeneous networks (HetNets) are importante to all of those goals, supporting a new approach to network economics, deployment and usage.

Macrocells are needed also for coverage using low frecuencies bands, for spectral efficiency by refarming. Then sites and spectrum are also levers for RAN deployment.

2.1 The dense networks

The wider impact on business and society will be felt quickly once operators start to roll out these networks. Many projects will be led by established MNOs, since they control most of the spectrum, but the flexibility of the HetNet, and the rising use of unlicensed and shared spectrum, will also enable new service providers in future, boosting competition. These may build out their own networks or more commonly, they may use a 'slice' of a shared or wholesale network to deliver their services.

However, the initial impetus will come from the existing MNOs, which need dramatic changes to their network economics in order to deal with a range of pressures:

- The rise in usage of mobile broadband networks for services which are heavy on bandwidth (e.g. mobile video) or signalling (IP voice, social media). According to Cisco VNI, mobile data traffic will grow eightfold between 2015 and 2020, reaching 26 exabytes per year, with 75% of that traffic being video.
- In addition, user expectation of quality of service is rising, as mobile connections become the primary way to access the Internet. This puts pressure on operators to support ubiquitous coverage with acceptable levels of capacity everywhere. This is particularly important indoors, where 80% of mobile data consumption takes place, and where high quality coverage remains challenging with a macro network only.
- All this places new demands on the network, at a time when consumer ARPU is falling in most parts of the world, and former revenue generators like voice and messaging are often offered as 'free' elements of service bundles.
- Most operators are also facing severe pressures on their capex budgets at a time when many markets are saturating and they are involved in price wars and consolidation.
- As well as narrowing the growing gulf between capacity requirement and revenue, operators also need to generate new revenue streams, and to implement networks which will readily enable that.

Densification is a way to reduce the cost of delivering vast quantities of data, using traditional Macro Sites and new Small Cells to fill coverage gaps and support ubiquity, which will be even more essential for IoT applications. All this equipment together will allow operators to extract more capacity and value from existing spectrum by enabling higher levels of reuse, and by harnessing high frequency bands.

2.2 Economic and social impact of dense networks

The economic benefits of mobile networks are significant – multiple studies have found that higher levels of mobile broadband penetration equate to increased GDP per head.[1]

Mobile networks drive direct economic contributions through service revenues and through the operators' investment in network equipment and services, which affects a long value chain. They also enable indirect economic and social benefit by allowing businesses and consumers to engage in new activities, to increase productivity and to communicate more effectively.

This impact will be increased if the costs of deployment can be reduced at the same time as enabling new services to be launched. These have the potential to enhance the MNOs'

[1] World Economic Forum http://www3.weforum.org/docs/GITR/2013/GITRChapter1.62013.pdf

business case, encourage new entrants, and provide businesses and consumers with a wider choice of cost-effective services.

There is also a profound potential impact on other sectors' productivity and service revenues, enabled by the Industrial IoT, and in many cases this will require the scalability, cost-effectiveness and ubiquitous coverage of the HetNet.

The enterprise is particularly important when considering economic benefits of dense networks. In a survey of 516 enterprises conducted by Nemertes in Q415, 94% of respondents said in-building cellular performance had an impact on their business, with 42% giving it a seriousness level between 8 and 10. This was driving high levels of interest in small cells, particularly in industries such as retail, transport and healthcare, and in the Latin America region.

The primary societal impact of a dense network is digital inclusion. A network which can deliver coverage and capacity to everybody, even in remote locations, at affordable cost, can have a significant impact on society. Key benefits include:

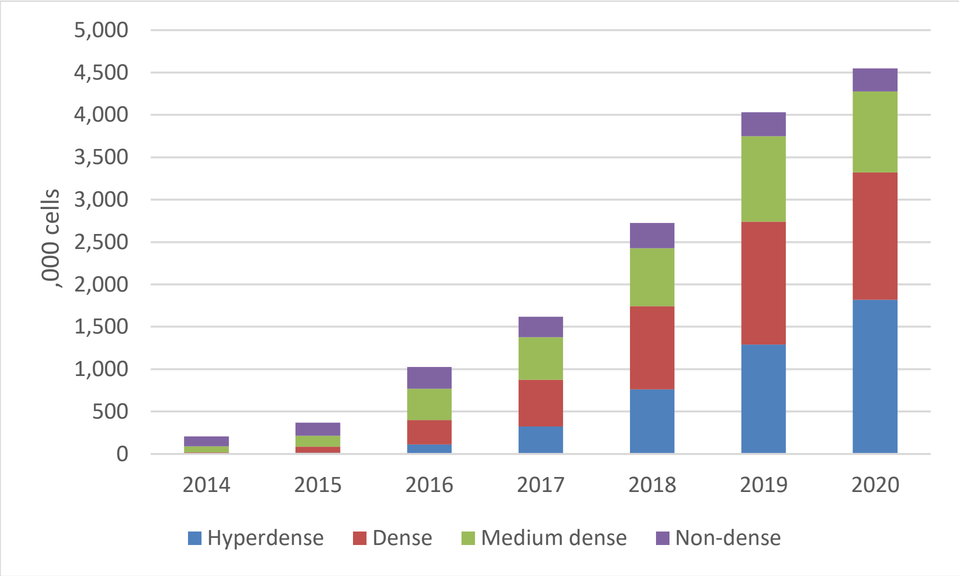
- Bridging the digital divided, especially by enabling rural and remote mobile broadband access at lower cost to the operator and consumer than macro or satellite solutions
- Connecting underserved communities in order to drive:
  - Micro-businesses
  - Improved participation in society (social media discussion of current affairs, voting, citizen services)
  - Monitoring of far-flung but critical assets such as farm animals
  - Remote working
  - Remote education
  - Assisted living and remote healthcare
- Small cells are well suited to rapid deployment of temporary networks in emergency situations such as earthquakes. Techniques like 'network in a backpack' are important to public safety services among others.
- Mobile connections are the only broadband link for many users, which has a significant effect on social interaction, working practices and consumer behaviour. Shopping, conversation, TV viewing etc increasingly takes place in all locations and on the move – but only if the network is sufficiently ubiquitous and dense to enable that.

2.3 HetNet technologies

The increase of mobile data described will result in a wave of deployment of dense networks.

Small cells will be very important in this densification. Figure xxx indicates the rising percentage of enterprise and urban small cells which will be deployed worldwide in dense configurations in the years to 2020.[2]

[2]



Percentage of small cells deployed at various levels of density (enterprise and urban)

Low density small cells	<20 per square km
Medium density	20-75 per square km
Dense	75-200 per square km
Hyperdense	>200 per square km

But the dense HetNet is about more than large numbers of small cells. It incorporates a wide variety of technologies which can be mixed and matched by operators according to their business case and targeted services. In order to achieve the benefits outlined above, it is critical that a robust, future-proof, flexible and standardized platform is readily available to operators round the world, supported by a favourable regulatory environment in the areas of spectrum, network services and site planning.

The Small Cell Forum defines the HetNet as a "multi-x environment – multi-technology, multi-domain, multi-spectrum, multi-operator and multi-vendor. It must be able to automate the reconfiguration of its operation to deliver assured service quality across the entire network, and flexible enough to accommodate changing user needs, business goals and subscriber behaviours." The foundations of this dense multi-x HetNet are:

- Wide variety of cell sizes and access point form factors from macrocells to tiny embedded radios.
- Seamless use of many spectrum bands – TDD and FDD, licensed, shared and unlicensed - with hand-off and aggregation to maximize flexibility and overall capacity.
- Integration of different architectures including macrocells, smallcells, DAS, Wi-Fi, vRAN.
- High levels of automation via SON and orchestration.
- The new economics and flexible resource management of virtualization.

- Rising importance of IT/cloud platforms and APIs to provide an efficient and open approach to service delivery.

Even these foundations are not all available today, the ecosystem is working in order to make them real in the near future.

There are many challenges to achieving this dense HetNet in a fully open, automated, cost-effective and scalable manner. Many have been addressed by the industry and the Small Cell Forum in recent years, but the HetNet is a moving target – as it becomes more dense and mission critical, new challenges emerge. The Small Cell Forum recently adopted two new work programs, one of which is entitled 'Deploying Hyperdense Networks'.

The critical enablers which this identifies, based on operator input, and which it will address in its work over the coming few years, are:

- **Interoperability** – ensuring that enabling technologies, such as NFV, management and orchestration, and automation are fit for 5G purpose and fully interoperable.
- **Backhaul –** delivering affordable gigabit backhaul to meet next generation capacity requirements everywhere.
- **Site acquisition** – defining an efficient repeatable process for acquiring sites in order to remove one of the biggest barriers to urban densification.
- **SON –** identifying how self-optimizing network technology can simplify the deployment and management process.
- **Internet of Things** – identifying the market drivers for small cells to deliver IoT services, especially indoors.
- **Unlicensed spectrum** – integrating many spectrum bands and licensing schemes within a single network to maximize flexible capacity, including coexistence, policy management, traffic shaping and authentication issues

It is essential for operators, regulators, consumers and national broadband programs that there is a smooth continuum from 4G to 5G, not an abrupt network upgrade.

2.4 Towards 5G

Another important reason to encourage rapid deployment of dense networks now is that they effectively enable operators and nations to get an early foothold in 5G. Whatever the detailed standards which get defined for 5G, some of its broader characteristics are already agreed, including its reliance on ever-denser networks to deliver affordable capacity, as operators target a 1000-fold increase. Elements of the current HetNet program, including virtualization, mixed-mode backhaul, unlicensed and shared spectrum, automation and SON, and many others, will also be cornerstones of 5G.

This means that, with the appropriate regulatory environment, operators can begin to deploy dense networks now, in their existing spectrum, confident that they will have more spectrum and a smooth migration path to future air interfaces, enabled by a set of interfaces and frameworks which are common to 4G and 5G.

Investment in dense networks now requires future-proofing, in the shape of a core framework. This will ensure that there is interoperability at every layer of the multi-x network, so that innovation in technology and business cases can continue, but without the danger of fragmentation or technology dead ends.

Overwhelmingly, these frameworks must support a flexible migration, so that service providers can move to new platforms in their own time according to their business case; can maintain old and new technologies together for as long as makes sense; can enter new markets and services flexibly and with agility.

These foundations of 5G include elements which underpin first generation HetNets and will continue to do so in the 2020s.

3 Market drivers for network densification

Reports show that Android 4G smartphones use more than double the monthly cellular data of Android 3G smartphones, confirming that new and better technologies lead to higher data use. In 2014, more than 3GB of cellular data per user per month was recorded on average in several developed markets. In particular, among younger users, 5-10 GB/month is commonplace.

The most data-hungry application today is video streaming, because mobile video content has higher bit rates than other mobile content. Mobile video will grow at a CAGR of 66 percent between 2014 and 2019. Comparing such figures to TV consumption, the amount of time spent watching TV typically ranges to 100 – 300 minutes per day with a European average of close to 4 hours per person per day. If we assume that the consumption of video is 100 minutes per day per person and we assume a conservative throughput of 1.5 Mbps (high definition video needs about 5 Mb/s and 4k HD video would need 16 Mbps), the data usage based on just video would be 1.1 GB/day. With higher video quality and other applications, the total amount of traffic will be even higher.

For most Latin American MNOs, intelligent densification will help to address:

- User experience improvement because resources are targeted where required.
- Better use of spectrum assets through reuse
- Assured coverage and service quality for customers, e.g. with in-building networks and street cells
- Macro off-load.
- Support for special use cases such as public safety, IoT

The key commercial drivers for investing in dense networks will proliferate between 2016 and 2020. For the short term (2016-2018), the most commonly cited use cases (based on a survey of 72 Tier 1 and 2 MNOs worldwide, conducted by Rethink Technology Research) are dominated by enterprise services (a top three priority for 36%). These are followed by various services driven by consumer video, including the rise of multiscreen viewing and multiplay bundles (see Figure 1).

By 2020, the use cases for dense networks are expected to be more diverse and driving brand new revenue streams. For incremental revenues, there will be a shift to connected ‘things’ as well as people, to wholesale models and to a new generation of video-based services and user experiences.

Enabling new revenue streams

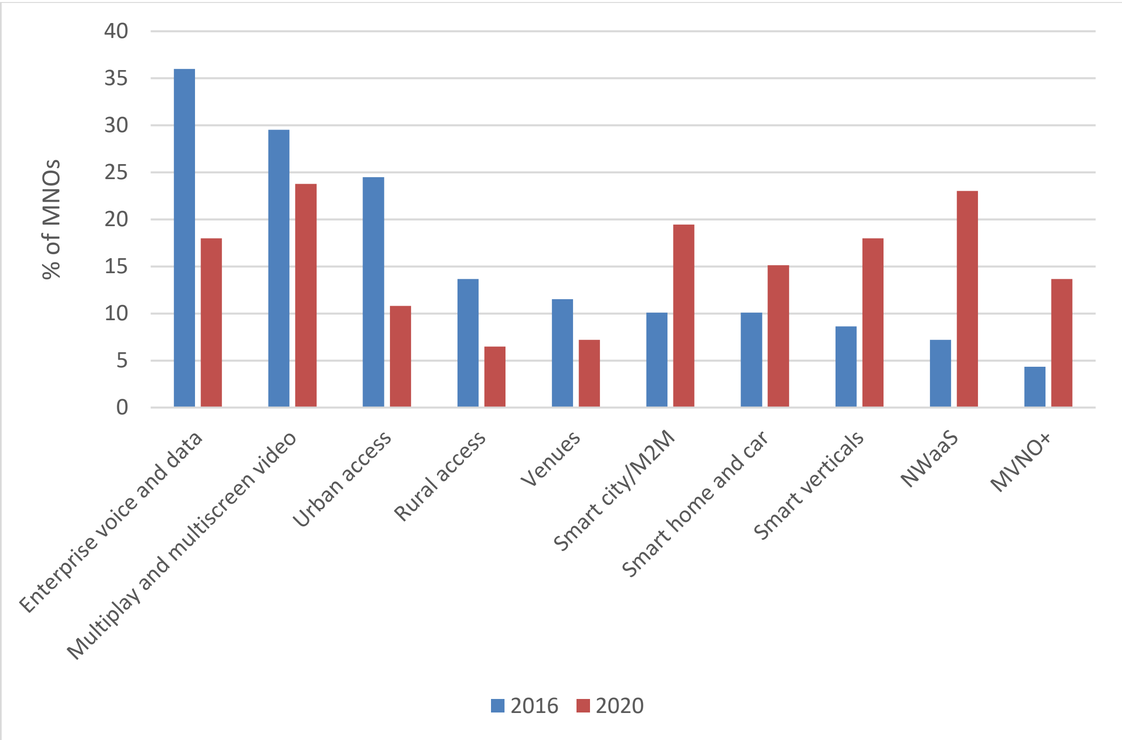
Combined with the need to reduce spending, MNOs need to generate new revenue streams to justify their investments in spectrum and infrastructure for 4G and, soon, 5G. Many of the most promising opportunities, such as connected cars and smart cities, involve very different network topologies and behavior, compared to consumer broadband.

Dense networks do not just improve the economics of supporting rising levels of mobile data usage. By providing high levels of scalability, and a smooth migration path to emerging architectures for the 5G generation, they allow the MNO to consider entirely new revenue streams, from services which would be partially supported by a macro network alone.

These include:

- Many M2M/IoT services, especially those which require ubiquitous coverage such as smart transport
- Services which rely on granular location and presence awareness (often linked to big data)
- High value enterprise applications enabled by good indoor coverage and capacity
- Expanded wholesale models, and support for new MVNOs on an ‘as a service’ basis

This shows how dense networks will be better able to support diversity in the operators’ business models, because zones of capacity and coverage can be optimized to support certain locations or use cases. This flexibility, and ability to target network resources where they are required, will be enhanced further with the introduction of virtualization to the network.



Percentage of MNOs placing each HetNet use case into their top three in terms of potential to deliver additional revenue within 12 months of deployment. Source: Rethink Technology Research operator survey Q116.

The MNOs' challenge for 2020, if they are to reap healthy profits from their network investments, is to undergo digital transformation, which involves branching out from the homogeneous business model, as well as the homogeneous networks, of the past. They will become IT platforms, cloud providers, wholesalers and vertical market specialists as well as MNOs, and will be handling a huge diversity of devices with different demands on the network. All this will require dramatic change to their processes, partnerships, management systems and, of course, their networks.

3.1 Coverage enhancement and NFV

Network function virtualization (NFV) is an industry initiative that moves functions from specialised hardware to standard data centre infrastructure. Virtualization in the radio access network is often referred to as Cloud-RAN.

Until recently, Cloud-RAN and small cells have often been presented as alternatives. However, it is now clear that virtualization techniques can be re-applied to small cell architectures. This development means that in dense HetNets, small cells are fully interworking with other platforms to create the broadest pool of capacity and most efficient use of shared resources.This is important, because there will be better ROI if operators can plan virtualization across the entire HetNet, including small cells, rather than as a separate exercise.

Virtualization of the small cell functions, and more specifically, their centralization, which frequently goes with their virtualization, allows the more advanced physical layer performance enhancement techniques, typically found on large macro cells, to be used in small cell deployments. These techniques rely on the coordinated scheduling and the processing of information between multiple cells and multiple antennas within a cell, and are not normally usable on small cells which typically only support a single cell with only two or four antenna ports. Exactly which techniques can be used depends on the split point chosen between the centralized small cell function and the remote radio unit, which in turns also depends on the performance and capabilities of the fronthaul link between them.

The techniques which are enabled include:

- Carrier aggregation (inter and intra band)
- Cross carrier scheduling
- Higher order MIMO
- DL and UL CoMP, including beamforming/coordinated scheduling

All of these techniques can be used to increase coverage, capacity and general performance of the radio network. It is acknowledged that all of these techniques could be used in some way within a distributed small cell deployment. However, in all cases centralization increases the flexibility and options for how these techniques are utilized.

3.2 Value-added service opportunities

For the short term, the use cases for HetNets are dominated by the enterprise, both voice (still a ‘killer app’ in this environment as many organizations go mobile-first) and data. Achieving a more strategic role in enterprises through improved quality of service, and layering new added value revenue generators on top of that, is a key goal for many MNOs.

When strong coverage and capacity are achieved, operators will aim to generate additional revenue streams on top of that foundation. In a survey, the most promising urban and rural added-value business cases, enabled by HetNets, were perceived to be:

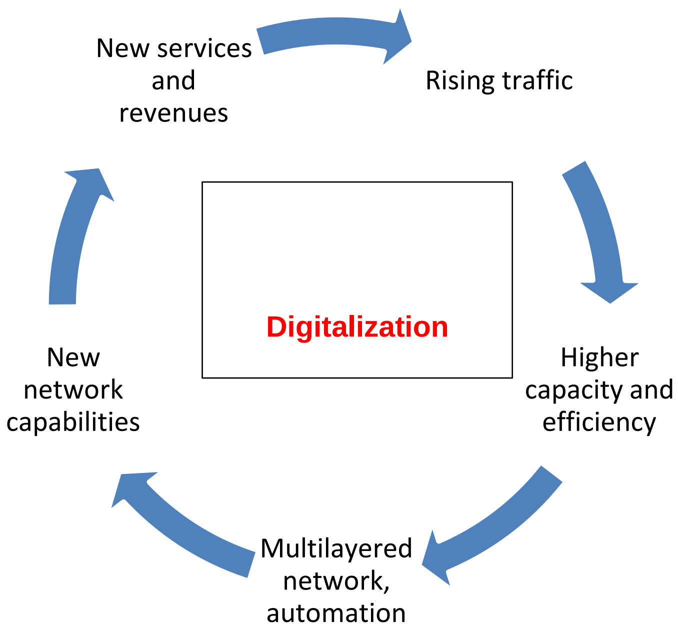
- Smart city/M2M
- Smart transport
- Smart farm
- Citizen access
- Public safety
- Remote working
- Digital divide

4 What technology delivers dense networks?

4.1 Background and technology architecture

There are many technologies involved in delivering a dense network. These include enhanced macrosites, with technologies like Massive MIMO and carrier aggregation; Distributed Antenna System; WiFi offload; Cloud-RAN; and small cells. The small cell itself can take many forms. Once the small cell becomes part of a dense zone of coverage and capacity, rather than being deployed in a one-by-one manner to fill individual gaps, it must be surrounded by many other enablers of density, macrocells included.

The technologies involved in creating an effective dense network change as the requirements of the HetNet change. New use cases will drive new technologies within the dense network, which in turn will enable yet further use cases.



The HetNet cycle: New business demands drive new network capabilities, which in turn enable new services and revenue streams.

4.1.1 The physical layer

The key attributes of the physical layer are:

- Multiple domains: Small cell, macro, Wi-Fi, NFV, transport and core network.
- Multiple spectrum bands: Sub-GHz, microwave, mmWave
- Multiple access point form factors: Macrocells, Smallcells, distributed antennas, distributed radios
- Multiple vendors: Enabled by open interfaces.

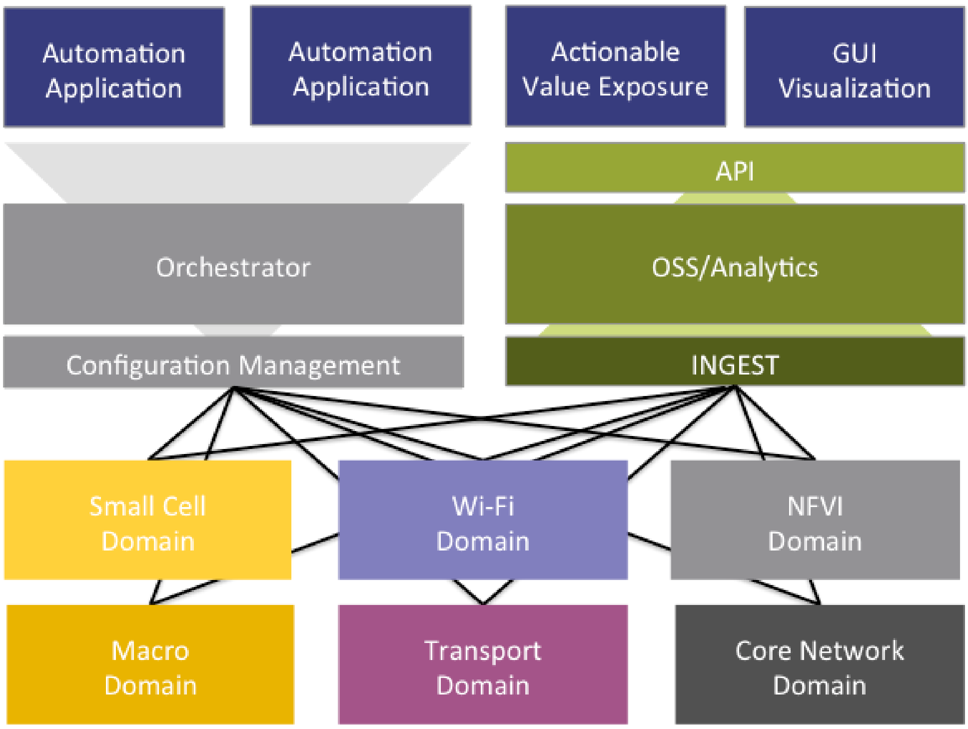
4.1.2 The overall architecture

The physical layer is only one aspect of a dense network. There is an entire architectural framework which supports the integration of services across multiple domains, using multiple technologies, from multiple suppliers.

Key elements of this framework are:

- Multiple radio technologies in licensed and unlicensed spectrum
- Virtualized RAN
- Automation and SON
- Management and orchestration (of virtual and physical networks)
- Open interfaces for interoperability (multivendor, multi-architecture)
- APIs and applications

The Small Cell Forum's HetNet Integrated Architecture Framework is explicitly designed to be relevant now, but also to pave the way to next generation networks.



This structure is also designed to support excellent service quality assurance architecture, with the ability to:

- Generate service quality information
- Automate and reconfigure HetNet domains
- Account for changing user needs, business goals and subscriber behaviors
- Use (self) optimization to consume service quality across the HetNet
- Algorithmically determine recommendations on how service quality metrics can be enhanced
- Prioritize multiple candidate optimizations according to policies

Importance of SON and automation in HetNet architectures

The management of hyperdense architectures will be greatly enhanced by leveraging the automation enabled by self-organizing/optimizing networks (SON). In a recent survey from analysts Rethink, MNOs concluded that automation and SON become entirely critical to the HetNet business case at a density level of about 10 cells per macro/50 cells per square km point, though SON was considered highly desirable beyond three cells per macro/15 per square km.

Use of SON can enable network management automation, network performance automation, improve network robustness and self-healing, as well as enhancing overall network agility. These enhancements can lead to significant reductions in implementation and deployment costs, as well as enabling more efficient siting and installation/setup/configuration. The efficient installation and plug-and-play setup/configuration can significantly reduce capex and the automated management, optimization, and self-healing can significantly reduce operational expenses (opex).

In addition to reduced capex and opex, the self-configuration, optimization, and self- healing offered by SON can lead to a greatly improved customer experience. SON networks can automatically download software updates, manage network traffic, manage interference, and other similar dynamic configuration aspects leading to an improved customer experience as well as lower costs to the operator.

4.1.3 APIs and applications

The dense network will be an IT platform as well as a communications enabler. A number of SDOs have been working on applications and open APIs to encourage new small cell-enabled services since its inception, and has enriched this work in recent years with industry collaborations. Important ones include:

- The Small Cells Forum
- The GSMA's OpenAPI program
- ETSI's Mobile Edge Computing (MEC) initiative
- The Open Mobile Alliance

MEC is particularly important for the road to 5G, distributing the operator's cloud platform right to the edge of the network where it can deliver services and QoS close to the user. This inherently marries with a HetNet vision, and the Small Cell Forum has already highlighted the alignment between the MEC aggregation platform and its own enterprise small cell architecture, enabling the latter to be revised in line with ETSI MEC. For instance, the MEC hosting platform can be delivered by the enterprise small cell concentrator, supporting MEC applications for traffic offload and enterprise unified communication services.

4.2 Backhaul technology

As we have seen, mobile data consumption has had a phenomenal rise over the last few years. This is set to continue for many years to come. Densification will play a central role in meeting this demand, allowing the same spectrum to be reused more to increase overall network capacity.

The total number of cells required may eventually become an order of magnitude greater than current numbers of macrocells. A key challenge is to provide extensive backhaul connectivity to the cells both economically and with sufficient performance. A wide range of different solutions has been proposed for the 'backhaul toolbox', each with their own individual characteristics.

There are many approaches to backhauling cells in a dense environment. The choice of backhaul solution depends on the original motivation to deploy small cells. There is a range of use cases for open access small cells, from targeted demand hotspots in city centres, through generalised capacity uplift, to serving not-spots in remote rural areas. In each case the emphasis on backhaul requirements shifts, and aspects that are critical to one type of deployment can be relaxed in others. Solutions include:

- Fiber and copper in some locations
- High capacity micro and millimetre wave where line-of-sight is available or non-line-of-sight wireless solutions where it's not.
- Satellite can address the remote rural or mobile scenarios that other solutions cannot reach.

Where multiple options are applicable, total cost of ownership will decide, as well as the primary business case, as these examples show:

- Small numbers of small cells can be connected into the existing macro transport network with minimal complexity in initial deployments. For longer term scalability, dedicated small cell core network nodes may be deployed, enabling the use of alternative backhauling solutions by utilizing functions specific to the small cells including transport security termination, traffic aggregation, synchronization, element management, SON, QoS support etc.
- Backhaul performance requirements vary with the operator's motivation to deploy, and relaxations on hard requirements are possible in different deployment scenarios: For capacity driven deployments, backhaul should be provisioned to match the capabilities of the small cells, for which data is provided for dedicated carrier small cells. Where small cells share carriers with the macro in a HetNet, we expect reduced backhaul capacity requirements compared to the dedicated carrier case.
- For coverage driven deployments, backhaul can be provisioned according to end use demand rather than the limitations of the small cell RAN.
- Remote deployments by definition are far from existing network infrastructure and thus are potentially expensive to backhaul with terrestrial links. Satellite becomes cost effective here and has proven suitability for backhaul.
- Rural deployments are not necessarily remote, and may be 'in the next valley' from a larger town with connectivity. Shorter range backhaul and copper connectivity can be used here. Backhaul to remote areas is likely to have limited performance: As little as 50kbps capacity is sufficient to provide a basic 2G voice and SMS service.
- Small cells deployed on ships, planes and trains require backhaul that can connect to a moving cell site. Non-LOS and satellite backhaul have been demonstrated for these applications.

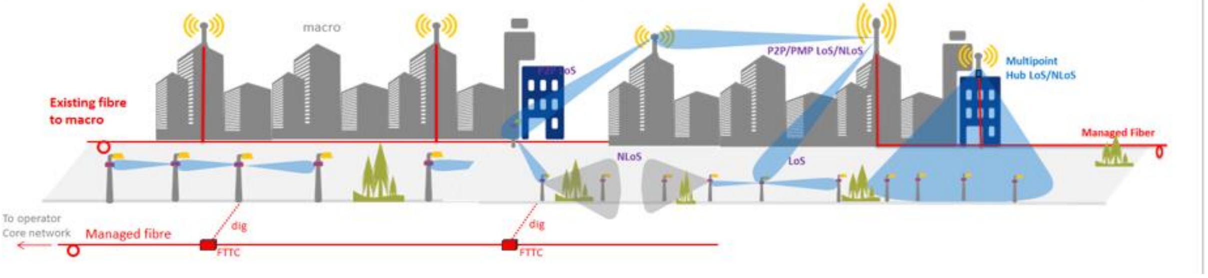


Figure xxx. Backhaul options in an urban environment

4.2.1 Low frequencies vs. high frequencies

The carrier frequency used by a particular wireless solution determines many of that solution's characteristics:

Propagation: line-of-sight, near-line-of-sight or non-line-of-sight
At lower frequencies, link obstructions are smaller compared to the wavelength, giving better penetration through or diffraction around them. Broadly speaking, and in the context of backhaul systems being discussed, systems using carriers below 6 GHz can support non-line-of-sight/near-line-of-sight propagation. Above 6 GHz, losses tend to be too high and only line-of-sight propagation is used. There is no hard cut-off frequency between line-of-sight and non/near-line-of-sight; it depends on the system link budget.

It is also worth noting that absorption of oxygen in the atmosphere becomes significant in the link budget at frequencies around 60 GHz. High propagation losses here can be exploited to reduce interference (this is described in more detail in the 60 GHz section).

Size of RF components

The size of RF components and, perhaps most importantly, antennas, is proportional to the wavelength for a given set of characteristics. Antenna gains are also related to their 'aperture' size in wavelengths.

We generally see higher antenna gains at higher frequencies because:

- They can be achieved in a compact form.
- High gains mean narrow beams, which extend the range of line-of-sight links.

We generally see lower gain antennas at lower frequencies because:

- High gain would require large physical sizes.
- For non-line-of-sight propagation, wider beams or omnidirectional patterns are better suited to match the scattered energy arriving over a range of angles.

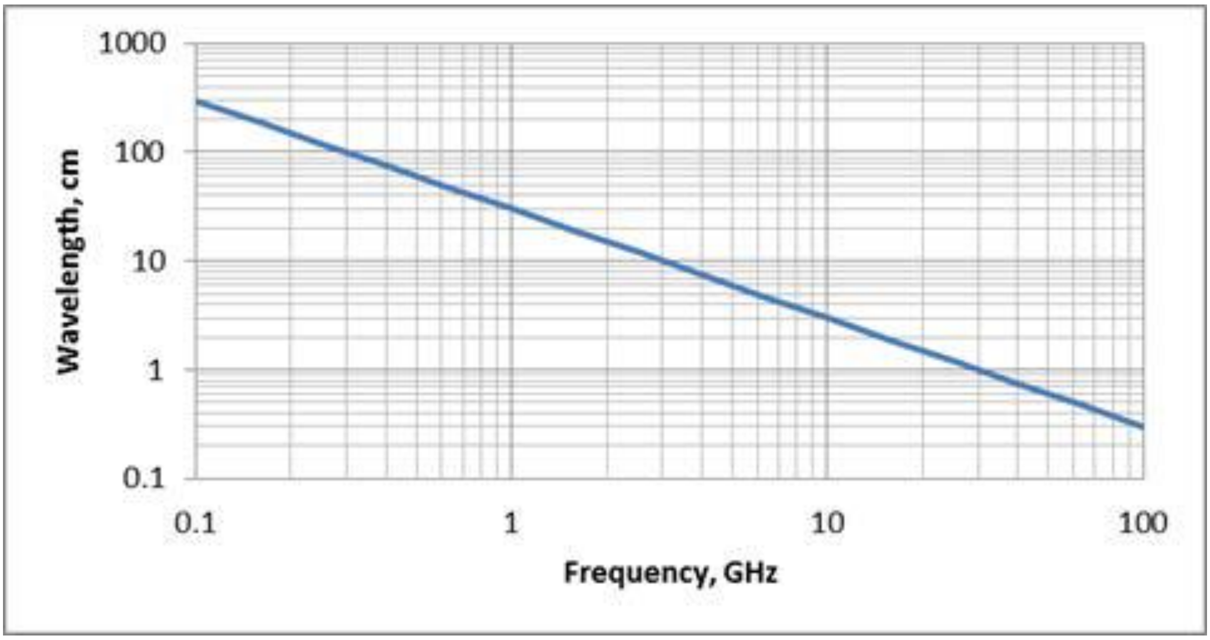


Figure xxx wavelengths at different carrier frequencies (note the Log Log scale)

4.2.2 Bandwidth

The channel sizes and operating bandwidth of RF components and systems are generally in proportion to the carrier frequency at which they operate. At higher frequencies there are more Hz of bandwidth available in proportion to the carrier. Wider bandwidths are available at higher carrier frequencies.

Three broad ranges of carrier frequencies are used to categorise solutions: sub-6 GHz, microwave (6-60 GHz) and millimetre wave (60-80 GHz), The types of licensing regime available in these different ranges will also differ.

5 Challenges and solutions

Microcells, virtualized Cloud-RANs, DAS and distributed radio solutions, and large-scale small cell networks all require large numbers of sites, often in different locations to traditional towers, masts and roofs. The key challenges in addressing all the requirements outlined above are summarized in Table 1 and detailed below:

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Table 1. Key challenges and potential solutions to dense network deployment

Challenge	Solution
TCO and cost of capacity	Advanced capacity planning, spectral efficiencies, shared or neutral host networks, automation/SON
Coverage and QoS	Flexible regulations to cover non-traditional cell sites e.g. rural, underground car parks
Backhaul and power	Standardized frameworks agreements with fiber or copper owners; mixed toolkit of backhaul and power options
Pre-deployment: site acquisition and equipment approval	Common rules on which equipment classes can be exempt or subject to fast track approval; a batch process for groups of cells
Deployment and maintenance processes for large scale	Create simplified common frameworks for access to sites; simplify installation procedures; automate maintenance

6 Capacity, coverage and cost

6.1 Cost of capacity, TCO

Challenge: addressing vast predicted rise in capacity requirements, while keeping TCO down and allowing operators to make a profit on their services.

Solutions:

- Capacity planning, management and optimization
- Spectrum efficiency
- Spectrum and network sharing
- Coordination and automation, including SON (self-optimizing network)

The biggest challenges with small cells relate to the cost and complexity of site acquisition, provision of transport connectivity to each site, and enabling the site effectively. As a larger number of sites are needed, and assuming stagnation in the number of paying subscribers, there are fewer subscribers per site to pay for the site costs. For many operators, these challenges are so significant that it might be difficult–to add small cells to augment their macrosites, even where this would have been a cost-effective way to improve network experience.

6.1.1 Key cost considerations

Today, operators are planning how to deploy HetNets for sufficient capacity and quality of experience, for the lowest TCO. In Figure 5, some example deployment costs are shown. These indicate a favorable case for microcells and picocells, but even so there are cost challenges. (The 100% reference is a 3-sector macro cell deployment on an existing macro site.) These mainly relate to site acquisition and installation costs (professional services), constituting today up to 30% of typical outdoor small cell TCO when also including the related opex. Transport constitutes up to 20% of the TCO. The capex of small cell RF and baseband is typically <20-30%, and thus a relatively small part of overall TCO but is a significant contributor to driving value of an outdoor small cell site. Thus, to minimize TCO per subscriber overall, the operator is recommended to compromise less in demands for base station capacity and quality and focus attention on maximizing the number of subscribers successfully served by each small cell or cell cluster, and to lower the opex for optimization, care and maintenance.

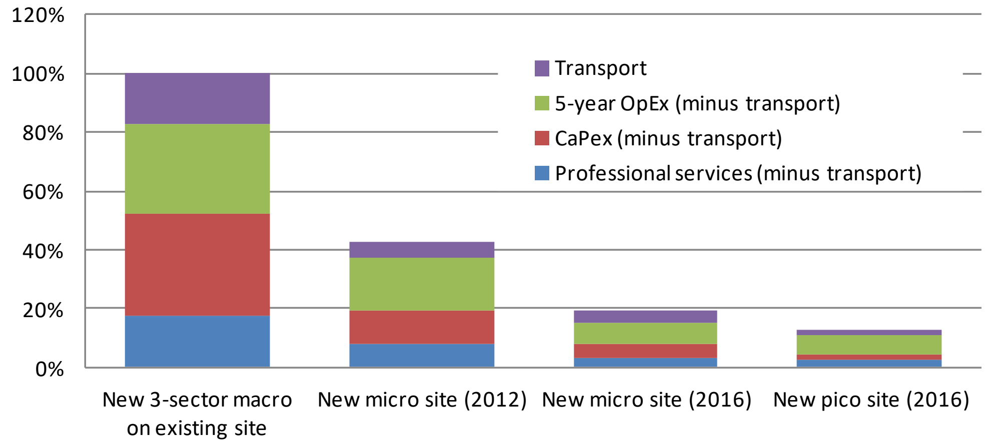


Figure 5. Example TCO values and predicted cost indicator development (LTE, European operator reference case, 2012).[3]

Figure 5 also includes a four-year cost scenario to reduce the costs of micro and pico sites further and so make them fully complementary to the macro network in terms of resource allocation and TCO. This is important to enable the operator to augment the microcell with smaller cells, where targeted capacity is required, rather than an overall upgrade across the whole cell. An overall cost reduction of 2-3 times is achievable for outdoor small cells, or for microcells. if the enablers discussed in this paper are implemented. In fact, if operators take a

[3] We show TCO/GByte assessments for various network upgrade scenarios and three different traffic growth ratios (versus 2012 reference). The Y-axis denotes the percentage of users which do not get the targeted QoS level for the given network upgrade step (lower is better). The X-axis shows the normalized TCO/GByte (lower is better). The different upgrade steps assume different QoS targets for the network as specified in the figure.

holistic approach to macro and small cell deployment, they could reduce the TCO/bit by between 25 a compared with 2012 levels, enabling a better balance between network costs and revenues.

To achieve these cost reductions, operators need to address many issues in parallel, including more efficient delivery of radio capacity

- a carefully laid-out strategy for combined macro and small cell deployment to maximize spectrum usage
- automated management and optimization
- adoption of new low energy technologies
- and repeatable, simplified processes for site acquisition and deployment (desirable)

In many of these cases, regulators and local authorities can play a significant role, and so help to drive TCO down to levels which the operators cannot achieve single-handed.

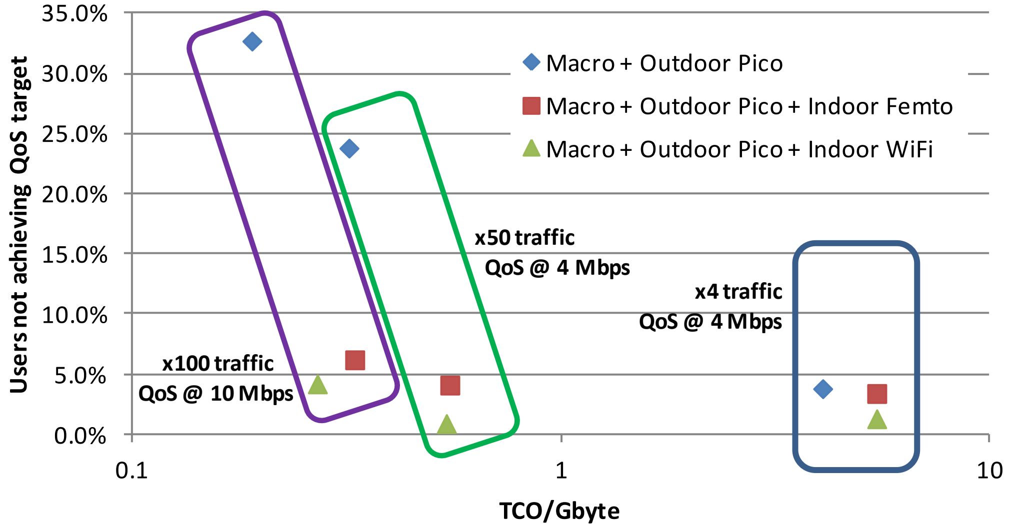


Figure 6. TCO per carried Gbyte evolution versus traffic and QoS growth rate (versus 2012 reference) for different network realizations (dense urban environment, European operator example).

It can be seen in Figure 6 that the x50 and x100 traffic growth scenarios can be managed with macro and outdoor small cell upgrades alone, but have a high probability of missing QoS targets for end users. To be sure of hitting those targets, indoor solutions are needed in addition for both the x50 and x100 scenarios. Across all studied environments, and for a TCO-efficient approach, small cells will complement evolved macro sites but will not displace them.

The four essentials for effective and affordable densification are:

- Capacity planning, management and optimization
- Spectrum efficiency
- Spectrum and (optionally) network sharing
- Coordination and automation, including SON (self-optimizing network)

6.1.1.1 Improving the efficiencies of vast capacity – planning, management and optimization

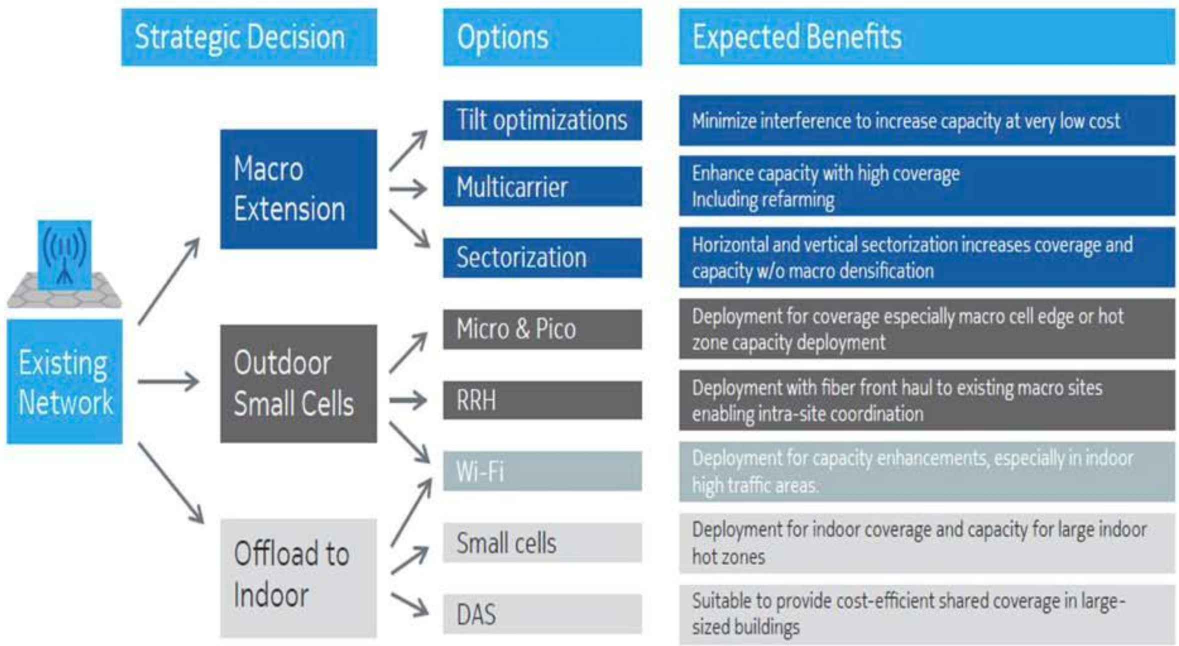
Operators have been adding density to their networks since the start of the 3G era, deploying traditional sites and using smaller cells to increase targeted capacity. However, the second half of this decade will see an acceleration of that process to address very high data demands such as those of business parks or sports venues.

The key will be intelligent densification – not just building additional layers of coverage and capacity, using small cells, WiFi and DAS (distributed antenna system), but ensuring these interwork efficiently with the macro layer, and that they deliver targeted capacity in a personalized way, to improve customer experience and ARPU, and to use the operator's network resources more efficiently and flexibly.

Overall, the operators' response to the capacity challenge will be to adopt two layers (at least) of cells, macro for coverage and true mobility, and small cell for capacity and indoor services. A third layer may evolve at the end of the decade for the internet of things (IoT).

The combination of increasingly high-bandwidth end-user applications with the desire for full access at any location is shifting the network focus from being coverage-limited to capacity-limited. This puts significant focus on proper capacity planning in order to meet rapidly evolving user expectations.

A clear strategy needs to be established to drive network expansion plans that will address end-user capacity needs, moving away from reactive to a more proactive approach of introducing capacity. The following figure illustrates some typical capacity solutions in use today:



In addition to well-established solutions such as Wi-Fi offload and sectorization in the macro cell, there are other emerging tools that can improve capacity, like carrier aggregation in LTE; new spectrum choices including higher frequency bands; improved antenna technologies such as multibeam and 4T4R MIMO.

These options, as well as small cell densification, must be considered together to form an efficient and flexible capacity strategy. A combination of all these techniques will be necessary since by 2020, MNOs will be facing ultra-dense capacity requirements plus the evolution of new IoT services.

When formulating a capacity strategy, measurable targets will have to be defined, quality of experience (QoE) being a critical one. This strategy will set the objectives and constraints of the design and form the basis of a good planning phase related to business and technology realities

During planning, and ongoing optimization, of the network, constant feedback on key performance indicators (KPIs) such as call drops and average data speeds will be needed to monitor the growth in traffic and identify issues which may impact on commercial KPIs such as QoE.

6.1.1.2 Spectrum efficiency issues

In general, Latin American operators have limited and expensive spectrum resources, so efficient use of those assets is essential. Small cells will also help to make more use of precious spectrum resources, particularly by making it more practical for operators to harness higher frequencies.

With LTE, new spectrum has been auctioned in 1800 MHz, 2600 MHz and AWS bands in Latin America. Since more bandwidth is demanded for LTE, there are other recent bands coming into use, often in higher frequencies, which makes them primarily useful for small cells. These include 3.5 GHz TDD. However, the challenge of new spectrum is the wait for devices and equipment (macro and smallcells) to be available at affordable prices. Another spectrum option is refarming as traffic on GSM and UMTS declines.

Whatever the choice of bands, operators need to maximize their spectrum efficiency, for instance by mitigating interference and implementing MIMO and higher modulations (256 QAM).

When deploying both macro and small cells in a HetNet, they can also use co-channel deployment, since it is inefficient to dedicate an exclusive carrier for the small cell layer, especially in countries where there is insufficient spectrum according to UIT recommendations. However, co-channel deployment requires refined coordination strategies between the macrocell and the small cells, and is especially challenging where there are different vendors in the respective layers.

Technologies like LTE-Unllicensed and LTE-LAA are emerging as a way to run LTE small cells in 5 GHz unlicensed spectrum, though regulators in Latin America have yet to define the rules for Wi-Fi coexistence and other issues.

LTE in 5 GHz spectrum which will be inherently a small cell approach in this high frequency and will provide new options for LTE operators indoors, and for alternative service providers.

Small cell HetNets will include cellular technologies and Wi-Fi, and emerging standards such as WiGig, and will also interwork with personal area network technologies like Bluetooth.

The 5G shift to high frequency spectrum bands including millimeter wave is a key focus these airwaves will only be suited to dense networks.

Using a combination of approaches to spectrum can have a profound impact on TCO, and operators and regulators must focus on:

- Deploying technologies with greater spectrum efficiency advantages.
- Enabling functionalities that can offer more bits/Hz over the air.
- Considering new spectrum possibilities, licensed or unlicensed, as well as spectrum refarming and reuse.

6.1.1.3 Spectrum and network sharing

The new architectures demand more sites in all layers, but this makes it hard to find and secure suitable sites at affordable cost. Network sharing is one solution to improving TCO for dense networks and easing pressure on sites and other resources such as backhaul.

Technologies exist today to enable multi-operator networks, notably the 3GPP's multi-operator core network (MOCN).

There are two main network sharing scenarios. One, capacity and coverage expansion of shared radio networks built with existing macro stations. In this scenario, MOCN with micro- and pico-base stations is used to share capacity between the operators.

Two, RAN sharing can be used to expand indoor LTE or 3G coverage where the property owner (shopping mall, railway station, university etc.,) does not permit each operator to deploy its own base stations. MOCN infrastructure with indoor pico- or micro-base stations is the most efficient scenario.

It is worth noting that MOCN has impact in User Equipments. Moreover it is relatively new for smallcells

One of the operators, or a neutral host, takes the responsibility of operating the network and provides the connections to each sharing operator's core network.

Higher support for shared models is essential to TCO in dense networks, and therefore to accelerated adoption and resulting economies of scale. If commercial support for multi-operator systems were to remain at its current level until 2020, the installed base of non-residential small cells could be more than four million units, or 32%, smaller than indicated in current forecasts, which assume multi-operator support, according to Small Cell Forum estimates. This would come with corresponding reductions in network performance and service reach.

New approaches will be required to shift the economics and build business model confidence. Some are already emerging into the commercial world, including neutral host and PaaS/NWaaS (platform/network-as-a-service) services. Others are on the horizon, including highly flexible virtualized architectures, which will be an important focus for several SCF working groups in 2016, and which could be the catalyst to mass deployment of multi-operator small cell networks.

6.1.1.4 Coordination and automation

Efficient coordination between small cells and the macro layer; automated optimization; and resulting interference mitigation are all essential to HetNet efficiency and to reducing TCO.

The offload value of the small cell must be maximized without penalizing the performance in the macro layer. With dedicated spectrum for the small cell layer, many coexistence issues are relieved, but densification still calls for coordination and joint optimization of small cell and macrocell layers.

Effective interference coordination methods as well as mobility robustness enhancing features are needed to reduce the higher opex spending on network optimization, troubleshooting efforts and ensure smooth end-user experience throughout the network. Above all, coordination and optimization has to be automatic and adaptive to track variations in traffic and loads which will be more dominant as there are less active users per cell site

LTE and LTE-A offer extended ways in which a macrocell can optimize the performance of the entire multilayer network including small cells. To this end, there is a trend towards a centralization of some SON and radio resource management (RRM) functions to optimize performance of HetNets. With 3GPP Release 10 and onwards, a semi-centralized approach is envisioned where some RRM control for small cells resides within the overlay macro base station.

Semi-centralized features are fully supported by the default distributed base station architecture and are enabled via X2 transport. In Release 10, one such feature is eICIC, which enables a range extension for the in-band small cells combined with selected muting of the microcell, to improve data rate coverage and capacity in the whole macrocell area.

Combining benefits from a common SON and integrated RRM framework with eICIC can drive up to 100% more value out of each small cell site; meaning the total network capacity as well as the subscribers served by the small cell itself. Such features favorably contribute to lowering TCO per subscriber across the entire HetNet. Some example performance results with just eICIC coordination shows significant benefit of tight coordination between the macro and the small cell layers.
Full integration of outdoor small cells is possible by sharing (or pooling) baseband functions with macrocells and deploying the outdoor small cell RF as a low-power remote radio head (RRH) with a dedicated fronthaul transport solution. This corresponds to a centralized baseband approach seen from the small cell layer's perspective and may be combined with a complete centralized RAN approach. In this case, the RRM functionality is shared between macro and small cells.

Many advantages exist, including inter-site carrier aggregation for higher peak rate and capacity performance, common scheduling gains, and improvements to handover robustness and efficiency. Up to 90% performance gains per small cell can be delivered, compared to a non-eICIC, non-centralized approach. Furthermore, some vendors have demonstrated a Dense RAN approach based on RRHs boosting end user performance during mass events, which is suitable for very dense deployments with extreme peak traffic load in both uplink and downlink, as in stadiums. However, for most operators and for general outdoor small cell deployments, these functionality and performance advantages cannot justify the added cost required to provision dedicated high data-rate and low-jitter fronthaul transport.

6.1.1.5 Interference

Management of spectrum reuse is the key to capacity, and interference is part and parcel of reuse. Small cells enable dense frequency reuse to significantly increase network capacity and coverage. If they are deployed on a dedicated carrier or configured as 'open access', they can provide these benefits with little or no negative impact to the existing macrocell service.

However, in dense environments a dedicated carrier may not be available or the cell may be configured in closed access mode. In this case, a number of corner case interference scenarios may occur at the extremities of the coverage.

Automated techniques have been developed and proven in large scale commercial deployments which mitigate interference to ensure the benefits of small cells can be realised without any compromise to user experience. Simulation of a typical co-channel, closed access deployment scenario shows adding small cells to an existing macrocell network brings 100x improvement in network capacity and mean user throughput.

6.2 Coverage and QoS enhancement

Challenge: achieving ubiquitous coverage cost-effectively, to address the digital divide and support new IoT services

Solutions: Simpler and more flexible site planning regulations for new types of sites e.g. rural rooftops, underground car parks

Densification is not just about capacity. Many of the services which will drive operator growth are reliant on excellent coverage too, especially indoors. Small cells enable operators to adopt a service-based approach to coverage planning, installing cells where there are gaps which affect service quality. This is important, in particular, for:

- Enterprise quality voice including VoLTE and rich communications services (RCS)
- Advanced messaging services, which can differentiate the operator from over-the-top offerings like WhatsApp. These may feature video messaging and unified mailboxes.
- Mobile enterprise video applications such as videoconferencing
- Enterprise contracts with data services SLAs
- Many IoT and M2M services which need to reach end points – fixed or mobile – in the most difficult locations, such as under the street (for smart parking).

Early cellular networks were designed to deliver voice services, and the primary factor driving the planning of networks was to achieve consistent, unbroken coverage. Large macrocells supported wide area mobility and omni antenna patterns were common.

As the number of subscribers increased, and data started to be supported, networks evolved with sectorized cells and reduced coverage areas. The term ‘capacity network’ was born.

In later phases, new services were developed alongside voice, increasingly involving high bandwidth data and Internet access. While this has shifted attention to capacity, it does not mean that coverage is no longer an issue. Recent research shows that the second most important cause of churn is unreliable connectivity. Users move to another operator because they do not get consistent performance, not because they want higher peak speeds. Along with capacity, then, small cells have an important role to extend coverage and good quality network availability to every corner, even hard-to-reach areas like urban canyons or basements, affordably. This will be even more important for some IoT applications, such as wireless smart metering, which require 100% coverage.

7 Planning and regulation issues

7.1 Backhaul and power

Challenge: Affordable access to backhaul and power

Solution: Flexible toolkit of different backhaul options including copper, wireless, fiber; standardized framework agreements with fiber or copper owners and powerline owners.

Another key challenge with outdoor cells is the need to provide scalable low-cost backhaul transport, both in terms of evolving traffic demands per site but also in adding further small cell locations. Being at or below roof-top level and with high focus on low cost per site, there is no single solution that fits all operators (even all sites for the same operator). Thus selecting the right option is a key aspect. Costs associated with scaling and maintaining transport is a significant risk factor in deploying Hetnets where costs need to be controlled tightly.

Many of the challenges associated with small cell backhaul have been addressed by the Small Cell Forum's work program and by individual vendors and operators in recent years, and a wide range of technologies exists for different scenarios. However, as networks densify, and start to be adapted for new use cases such as M2M, new challenges are arising. In most cases these relate less to technology than to deployment processes where large numbers of cells and backhaul connections are involved.

Based on input from the operator community, Small Cell Forum's backhaul working group, defines its chief issues as:

- Deployment scalability for dense deployments
- E2E SON, including backhaul
- Planning regulation
- Backhaul, fronthaul and everything in between
- Self-backhaul
- 5G backhaul
- Backhaul spectrum

However, industry input is not sufficient on its own. There also needs to be support on the regulatory side. Where small cells are backhauled by fiber-to-the-site, a transparent regime for wholesale access and pricing will help make deployment predictable and repeatable. Where wireless backhaul is used for small cells, it will be important for operators to be able to mix and match different types of spectrum – as in the access network – for the optimal cost:efficiency:performance ratio.

Regulations for backhaul spectrum licensing vary between different countries in the Latin American region, but generally there are four types of licensing, with different pros and cons:

License exempt
Anyone may transmit within the band provided equipment complies with certain standards. These usually include, as a minimum, in-band power limits and out-of-band emissions. No fee is payable, making for very low-cost operation. However, this can lead to heavy usage in areas of high traffic demand, and uncontrollable interference from other users may impact quality of service.

Link licensed
Traditional microwave point-to-point links are typically licensed per link. The operator provides the locations of the link end points to the regulator, and receives a spectrum allocation for that link. The regulator takes the responsibility of ensuring that there is no interference with other links. While this provides a high level of link reliability, the interaction with the regulator takes time, depending on the degree of automation of the regulator's coordination process. Such an approach may not scale well for backhaul to a constantly evolving small cell network.

Light licensed
This is a lightweight version of the link licensing scheme. Users enter link data into an online database; this helps prevent interference. Costs are lower than with a link licensed scheme.

Area licensed
The licensee may transmit in a given channel assignment anywhere within a region, which is typically country or county-sized. The user is responsible for managing interference. Complex adaptive co-ordination schemes have evolved to maximise utilisation and efficiency.

There is also a growing trend towards dynamic licensing of what is known as white space. In this case, devices wishing to transmit must first make a request to an online database, to identify available channels (or 'white spaces') in the vicinity of the transmitter. The database can be used to protect primary users such as digital TV broadcasts, which occupy different channels in different regions. White spaces not used by the primary users may then be available on 'free-for-all' basis or on a light licensed basis.

7.1.1 Power issues

Various innovations can lower the TCO of the mobile site if the operator is willing to share the radio application with other use cases such as smart lighting. For instance, street poles can be 'bank switched', with the power to the lights switched ON at night, and turned OFF in the day, but with always-on power for the small cell – resulting in 30 to 60% savings in power. These 'smart LED street lights' for example draw ~30 to 45 watts each versus sodium vapor lights which may draw ~65 to 100 watts. Additionally, LED technology has a lifespan of as much as 7-10 years whereas sodium vapor bulbs need replacement every 2 or 3 years.

So the conversion of bank switch lights to always on power could represent a win:win for the cellular operator (which gains access to always-on power) and the municipality, which enjoys a power savings and longer lifespan for street lights.

The efficiency of the power supply has an impact in reducing electricity costs since it is indicative of the amount of energy lost in the conversion process from AC to DC. Generally the standard efficiency is about 96% or more. Depending on energy prices, use high efficiency technology means reducing opex.

The duration of battery backup time is directly related to the size of them. This is clearly a limitation for a system to be mounted on a pole. Production systems currently have a range of 30 minutes. There is the possibility of installing such solutions without battery for size reduction

7.2 Pre-deployment – equipment approval and site acquisition

Challenge: identifying, acquiring and gaining approval for large numbers of small cell sites, quickly and at low cost

Solutions: Simplified and standardized rules for approving small cell equipment and site usage; batch site processes; simplified installation

Identifying the appropriate sites for macro and small cells deployments in urban areas, either in large venues or outdoor areas, is critical for optimal network performance. There are many variables involved with selecting the appropriate site locations including time to market, capital cost, operational cost and vertical asset availability.

For densification, large numbers of sites need to be identified and approved, planning permissions secured and other requirements, such as aesthetics and power limits, satisfied. These may vary considerably in different regions.

The smoother and more streamlined these processes can be, the easier it becomes to deploy small cells to the scale at which they will deliver the maximum benefits, and within optimal time and cost limits.

Site acquisition is not easily obtained, and often comes at high cost, with landlords getting increasingly aware of going rates but having limited or nor understanding how to assess values of cell sites to operators. While for many landlords, the rental price is the key aspect, the operators may be more interested in cell site suitability with regards to construction and maintenance, zoning approval and permits, as well as how further capacity upgrades can be done without renegotiating the lease agreement. To this extent, being able to identify attractive site locations and to identify hot zones are key challenges and must be coupled closely to the site acquisition process. As networks further densify, additional regulation to avoid unsightly radio solutions may happen.

The high volume of cells will require operators to seek the leverage of street assets, specifially street poles and bus stops. Street poles become attractive, not just for power (see above) but for their volume and proximity to subscribers. In addition, the street poles are typically owned by government municipalities enabling negotiation of assets on a regional basis, not per site. This is also true of other third parties which control large portfolios of sites such as owners of billboards, bus stops or public buildings.

Light poles have attracted particular attention because there are benefits for both sides - the mobile operator can install small cells powered by the street light, and the municipality can achieve smart lightning as part of a smart city initiative.
This type of arrangement also has the attraction that contracts can be established with a single partner which controls multiple sites, while sites such as poles or billboards also minimize visual contamination.

However there are still challenges in the product design related to weight, size, wind loading and static. Products highly optimized for street deployments will lead to greater municipal acceptance and site acquisition.

There is still considerable work to be done to achieve this scalable, repeatable, streamlined approach to planning and approval. Figure 7 shows a simplified deployment process for a public urban cell, from project initiation to network build-out and optimization. Each phase has a red, amber or green rating based on operator feedback, relating to how far they believe there are strong tools and processes in place to facilitate that particular activity. This shows clearly that there are issues with initial permissions to deploy and with installation procedures, while the operators feel reasonably optimistic about their ability to design, plan and optimize the networks. The area where they perceive the greatest bottlenecks are in site issues.

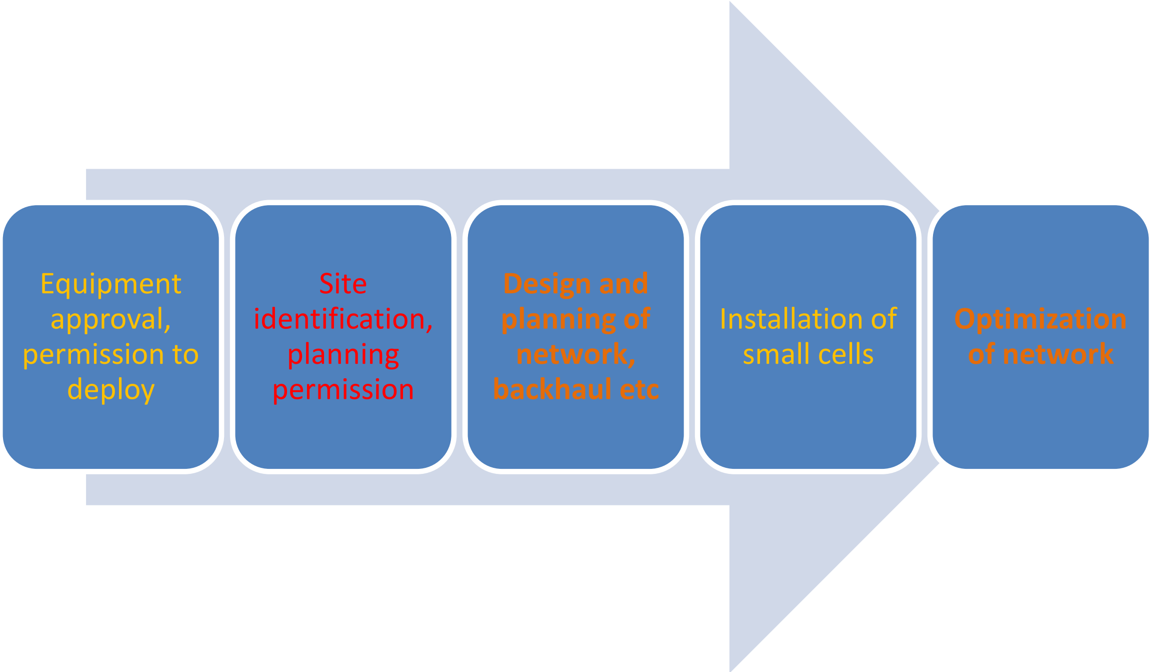


Figure 7. Simplified view of the phases of deployment

The key areas where operators report problems which either make deployment difficult, or uneconomic, are:

- Gaining permissions to deploy including equipment approval
- Identifying and acquiring sites with backhaul and power
- Rolling out the cells in a repeatable, affordable way
- Supporting neutral host or multi-operator platforms

Yet there are solutions emerging, and many regulators around the world, in light of the rising need for dense HetNets to achieve their own broadband goals, are devising creative approaches which can provide templates for others. Based on emerging best practice around the world, this checklist indicates the main areas where regulators and municipal authorities can work with operators to create a strong environment to deploy urban HetNets at scale.

- Simplified procedures to optimize administrative flows of documentation processing
- Generic declaration of equipment at national / regional / local level
- Exemptions based installation based on generic criteria: antenna height, power levels, combination of power and height, on a regional-based level
- Generic certification of equipment: internationally standardised accepted classes of equipment with installation rules/manuals => avoid additional documentation
- Generic permits for installation and operation
- Generic installation permissions (vs. site-by-site) and franchises for installation
- Environmental considerations: restriction of installation of equipment in sensitive areas
- Building permits & access to public domain rights of ways: generic authorizations to access administration facilities, single applicable documentation form at national/state level

- Taxation and fees regime- what about it
- Incentives for deployment of greener and environmental friendly equipment
- Lower/exempt taxation and local fees to encourage deployments -> alignment of rental fees with those of other ‘essential’ infrastructure (water, electricity, gas)
- New roles at the local level: new entities to handle the entire process, authorizations, certifications (operators’ third parties, administrative staff)

While these proposals would require significant changes, in some cases, to the established processes of regulators and planning authorities, the onus is not all on those agencies to change their ways. There is also the need for the small cell industry to work on areas like standard documentation and equipment definitions, and certification, and to share that work internationally, and with standards bodies and regulators.

7.3 Deployment and maintenance issues at large scale

Challenge: Installing large numbers of cells of many different types, rapidly and affordably in order to meet densification targets

Solution: Create simplified common frameworks to open up street furniture, instal equipment, reduce maintenance overheads; self-organization

Moving on from deploying a few targeted small cells within a macrocell, to rolling out large numbers of microcells, picocells, DAS nodes or C-RAN radios in one neighborhood, introduces many new challenges, especially in congested urban areas.

Table 4 summarizes some of the main aspects of urban deployment which need to be considered, and some of the challenges.

Table 4. Considerations for urban HetNet deployment

Section Title	Summary
Urban commercial models	Urban commercial models can take several forms, from operator installed, owned, and maintained to neutral host leased capacity including variants where a third party provides certain activities.
Capability design	There are many SCF documents that help to illustrate how an operator can utilize the new technology inside their existing estate, a list of appropriate documents is given.
Physical design	Physical design should be driven by small cell installation locations and aesthetics, local rules, and environmental requirements. The objective is to reduce equipment, installation, and operation cost without compromising coverage and capacity requirements.
Geographical design	Complex urban environments require proper site surveys to be conducted prior to the design and deployment phase. Additionally, RF simulations should take into account the surrounding macro environment such that coverage and capacity KPIs can be appropriately met.
Regulatory	Similar licensing and spectrum regulatory considerations are applicable when deploying Urban, residential, or enterprise small cells, although urban deployments must adhere to additional local rules.
Installation, commission and acceptance	Installation and commissioning should comply with a well-documented design while the list of acceptance tests should provide flexibility to network operators' requirements.
Central operations	Small cells must be visible to the network operations center (NOC) and serviceable.
Field force	The process steps remain essentially the same but with the ability to have other organisations enacting roles in the process can significantly reduce operational costs.
Performance assurance	KPIs are similar to those in the macro network but the thresholds for action need to be weighted and relevant to the business proposition. It is imperative to make sure the Organisation size is assessed accordingly.

Adding capacity incrementally by deploying cells one by one is not cost efficient, so processes must be created which will enable large numbers to be deployed in a standardized, repeatable way, tapping into economies of scale and the services of integrators.

Installation costs in developed markets are often the largest element of the capex budget, so process complexity and labor must be minimized. In order to lower the cost of installation, it is desirable that only physical equipment installation and making the power connection (and potentially fixed transport connection) is part of the work actually conducted on the site. In particular the skill level for installation should be extremely low (i.e., no specific HW devices and SW is required), given the scenarios explained above, how small cells deployed (and who deploys them).

7.3.1 The importance of automation

In terms of opex, a modest deployment will not favor economical installation and maintenance contracts, for instance with a municipality or tower operator. Automation is critical, since manual configuration of parameters, and manual optimization, negatively affect OPEX. And operators will triple or quadruple the managed number of nodes when adding small cells, compared to macro-only. Operation and mantainance systems will need to be adapted to this new reality. Economies of scale require tools for auto-provisioning, management and optimization to simplify the deployment.

In an automated environment, the new network element is able to authenticate itself to the network, automatically connect to its OAM system, and is integrated in the secure environment and downloads the correct software and configuration to start operation. There are further requirements to be considered as the network becomes more dense:

- **An even higher degree of automation than in a macro-only network**: to achieve a fully automatic plug-and-play procedure it is required that the base station can acquire its site identification automatically. If a GPS module is installed (which may be required anyway in a time-sychronized network deployment), it is feasible for an outdoor base station to measure its location such that the mapping of the new HW to a specific planned site can be done automatically in the OAM system [HW-to-site]. Another option is that the base station reads the Site ID from an RFID tag with which the site has been prepared (otherwise the site ID still has to be entered into the system by a human).

- **Increased multivendor capability/standardization of the auto-connectivity**: while the security-related part of the auto-connectivity has been standardized already, the basic procedure is proprietary and differs slightly for different vendors. As often the small cell and the macro layer will come from different vendors, a full standardization of the basic auto-connectivity [MV-PnP] is proposed in 3GPP SA5. The subsequent auto-commissioning then, however, is largely vendor-specific by nature.

Future improvements in the radio interface will also impact OPEX, because they will allow more users to be connected per small cell, so it is important that the cells should be 'future proof', and easily upgraded with a simple swap-out, or an over-the-air software update, to support the latest technologies at an early stage.

To summarize, one of the chief operator requirements (desirable) for large scale densification is a common blueprint – a set of processes to make the planning and deployment of HetNets endlessly repeatable.

8 Final conclusion

Dense networks are one of the current **technological tendencies** together with virtualization, Internet of Things and evolution towards 5G. One of their main characteristics is **ubiquity**, needed to offer an **excellent quality of experience.** Their **market drivers** are video services, enterprise services and the need of connecting "things". These networks have **beneficial consequences** not only in social , allowing to reduce the **digital divide**, but also in economy, favoring the increment of GDP.

This document describes **the challenges** and also, **ways of solving** them. They are:

- **Capacity and coverage cost,** which are solved by adequate planning to get an excellent **QoE.** This requires good and enough spectrum to provide services, state-of-the-art technology and automation tools.
- **Site acquisition and equipment approval,** which are solved achieving a **general and repeatable processes** for equipment certification, installation and operation permissions by areas, declaration of equipment at national/regional/local level, etc.

To sum up, this **team work sponsored by GSMA and SCF**, is a **valuable tool** which intend to help a successful densification in LatinoAmérica. **This will contribute with social and economic development of the whole region.**