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# Multi-operator and neutral host small cells

Drivers, architectures, planning and regulation

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# Small Cell Forum accelerates small cell adoption to drive the wide-scale adoption of small cells and accelerate the delivery of integrated HetNets.

We are not a standards organization but partner with organizations that inform and determine standards development. We are a carrier-led organization. This means our operator members establish requirements that drive the activities and outputs of our technical groups.

We have driven the standardization of key elements of small cell technology including Iuh, FAPI/SCAPI, SON, the small cell services API, TR 069 evolution and the enhancement of the X2 interface.

Today our members are driving solutions that include small cell/Wi-Fi integration, SON evolution, virtualization of the small cell layer; driving mass adoption via multi-operator neutral host; ensuring a common approach to service APIs to drive commercialisation and the integration of small cells into 5G standards evolution.

The Small Cell Forum Release Program has now established business cases and market drivers for all the main use cases, clarifying market needs and addressing barriers to deployment for residential, enterprise and urban small cells. Our most recent release focused on how to accelerate the commercial adoption of virtualization in small cell HetNets. It examines the business drivers and barriers to adoption, provides the nFAPI specification for a transportable MAC/PHY split for LTE small cells, addresses networking aspects such as architectures and x-haul bandwidth and latency requirement, as well as important aspects such as synchronization, orchestration and virtualized workload placement.

The Small Cell Forum Release Program website can be found here: www.scf.io

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### **Executive summary**

There are powerful market drivers for small cells to be deployed in a multi-operator or neutral host environment, especially when they are in enterprise locations. Increasingly, mobile traffic is concentrated indoors, and locations of all kinds – from office buildings to public spaces such as malls or railway stations – need to support mobile usage, regardless of which operator the employees, customers and visitors are subscribed to. This is only becoming more important as businesses go mobile-first and adopt bring your own device policies.

There are already neutral host solutions available and standardized. Distributed antenna systems (DAS) and Wi-Fi are well established in this regard, but have disadvantages for operators and site owners in many environments – the high cost of DAS, for instance, and the QoS challenges of Wi-Fi in public or unmanaged areas. Small cells address many of those disadvantages, but have not been widely deployed in a neutral host context, despite the availability of standards like 3GPP MOCN, and a clear market need.

This document seeks to address some of the most common reasons why deployment has taken off slowly, outlining existing solutions and pointing to emerging ones, as well as highlighting lessons that can be learned from DAS and Wi-Fi.

The barriers to neutral host deployment are less about technical solutions. Small Cell Forum research has identified more serious inhibitors, and this report provides a way forward in each case:

- Deployment issues, such as the sharing of cost, risk and processes between different parties (the spectrum owner, the enterprise, the site owner, the neutral host and so on). Using the example of a study conducted by Nokia, the best combination of shared and dedicated cells and the processes to roll them out, are discussed.
- Spectrum and regulatory issues are very regionally specific and can be daunting where regulators do not, for instance, permit spectrum sharing, but there are many signs of progress round the world as the need for neutral host becomes clearer.
- Management of neutral host solutions emerges as a perceived barrier, but there are many approaches which are already proven, in some cases borrowing ideas from DAS, whose approach will start to converge with small cells in the virtualized environment.

The deployment of neutral host small cell networks will become more compelling still, with the emergence of virtualized platforms which can support multi-tenancy, enabling larger number of service providers, sometimes on a dynamic basis, and a larger variety of spectrum and cell types. Small Cell Forum's work on the nFAPI interface and other aspects of virtualization are important building blocks as the first virtualized platforms start to emerge, mainly in the enterprise environment where the need for neutral host is strongest.

Those approaches are described in detail, and the report also looks ahead to some of the further changes which are over the horizon in 5G, including Project SESAME, a 5G initiative which points to many of the future developments in flexible neutral host small cell platforms.

# Solving the HetNet puzzle

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#### 1. Introduction

Work has already started capturing key requirements for the fifth generation of mobile technology (5G) that is scheduled to be deployed around the end of the decade. This new technology will not only have to operate in an environment that continues to see exponential growth in data traffic, but will also see an increasing percentage of that traffic consumed from indoor locations, continuing current trends in peak density.



Figure 1–1 Activities performed – indoor vs. outdoor

Figure 1–1 illustrates the trend exhibited by today's smartphone users, clearly demonstrating their increasing preference for engaging in online 'mobile' activities when indoors compared with outdoors [1]. 5G, then, needs to be designed to thrive in an environment where, even today, over 80% of mobile data is being consumed indoors [2]. Indeed, Cisco's VNI Analysis is predicting that by 2019, around the time the first operators will be getting ready to deploy standardized 5G networks, 96% of all data will be consumed from indoor locations [3].



Figure 1–2 Cisco VNI estimates for data consumption in 2019

This means that the success of 5G will be determined by the wide scale market adoption of indoor systems.

In most indoor environments, multiple users will be accessing services from multiple mobile network operators (MNOs). In addition, enterprises may have a contract with a particular network operator, but they will still require multi-operator networks to support their customers and, in a 'bring your own device' (BYOD) environment, their staff. Therefore, multi-operator support is important, so that all stakeholders can be served equally. While this can be achieved by RAN sharing or roaming deals between all the MNOs, these can be hard to negotiate while maintaining a balance of control and revenue which is acceptable to all.



An alternative approach is to employ a third party that acts as a 'neutral host' for all the MNOs. The term 'neutral host' describes a firm that provides services for a number of operators wishing to deploy infrastructure in a particular location. In this model, the neutral host collaborates with multiple operators to provide a solution that is commercially and technically amenable to the operators and acceptable to the venue – e.g., commercial landlord, enterprise or local municipality. A common scenario is for the neutral host to provide access to the vertical asset, permitting, installation, power and, in some cases, backhaul connection. The operator, or small cell hardware vendor, is responsible for integration into the macro network, optimization and monitoring.

Today, neutral host solutions are common in the context of Wi-Fi and distributed antenna system (DAS) deployments and occasionally employed in macrocell environments. However, the neutral host option has rarely been adopted in the deployment of small cells.

Although indoor small cells have 'crossed the chasm' into mainstream usage and are generally accepted as essential for the creation of hyperdense networks that will be the foundation of 5G, there continue to be challenges in scaling indoor deployments. A global survey of enterprises commissioned by Small Cell Forum highlights the importance of multi-operator support in accelerating indoor enterprise deployments; with the market size being cut in half if solutions cannot deliver multi-operator capabilities. In short, if multi-operator solutions are not available – and given that the deployment of three or four separate networks is rarely acceptable – the opportunity will be lost, to the extent revealed in Figure 1-3.



#### Figure 1–3 Enterprise small cell forecasts, with and without multi-operator support 4

Similarly, a recent report by Mobile Experts [5] analyses the challenges in deploying indoor systems, concluding that the indoor market for small cells 'has been held back by products which require cooperation of mobile operators and complex projects with multiple stakeholders'. The report concludes that only those 'products which satisfy the technical need and simplify the deployment process will find explosive growth'.

The need for many enterprises, venues and verticals to serve all visitors, irrespective of carrier affiliation, is one of the key deployment requirements that needs to be understood. In particular, even though there is full support for multi-operator capabilities across the LTE ecosystem, enabling effective sharing of indoor small cell infrastructure, the challenge is that these capabilities have not been widely deployed. The impact of this is that Wi-Fi has become the default 'small cell' technology for multi-operator support [6]. Furthermore, it is clear that, compared to the ease with which unlicensed Wi-Fi systems can be shared, the barriers to sharing solutions that rely on exclusive/individually-licensed spectrum are extremely high.



This document describes alternative approaches to delivering shared infrastructure within a small cell environment, including comparing small cell solutions with classical DAS solutions. Standardized 3GPP network sharing capabilities are reviewed and the applicability of those techniques to small cell deployments are analyzed. We also consider multi-operator deployments using licensed-exempt solutions.

In addressing the overall solution for deploying shared small cell systems, we find that current specifications are incomplete, including those associated with the management systems required to support multi-operator deployments. We also identify those areas that may require proprietary or pre-standard definitions.

Looking forward, this document also analyzes the new sharing options that can be achieved through small cell virtualization. Similarities between DAS sharing and physical network functions (PNF) sharing are discussed from both architectural and operations perspectives.



#### 2. Market drivers for neutral host small cells

As small cell deployments evolve from offering basic residential and urban coverage and capacity solutions, towards foundational infrastructure that addresses increasing data consumption within indoor environments, the desire to be able to support multioperator coverage and service becomes stronger.

In general, small enterprises can tolerate single-operator deployments, and may even use them to leverage a better subscription deal. Larger enterprises, on the other hand, cannot bind themselves to a single operator and require multi-operator solutions to deliver connectivity to a broad range of stakeholders. Retail environments, transportation hubs, healthcare environments and education establishments all want to be able to offer connectivity to all their visitors, irrespective of carrier affiliation. This means that demand for multi-operator support that leverages a common, shared small cell infrastructure is becoming increasingly pressing.

A significant opportunity for small cells is currently at risk because of limited deployment of multi-operator small cells. If commercial support for multi-operator technology were to remain at its current level until 2020, the installed base of non-residential small cells could be more than 4 million units (i.e., 32%) smaller than indicated by current forecasts (which assume multi-operator support), with corresponding reductions in network performance and service reach.

Beyond the absolute reduction in numbers, without multi-operator capability many key stakeholders are significantly underserved, since they require small cell functionality to support and enhance their business cases and accelerate their deployments. In short, multi-operator capability is critical for several reasons, including the ability to:

- drive enterprise adoption in many sectors;
- improve the economics and simplify the deployment process of dense indoor or urban networks;
- enhance the revenue opportunities for MNOs investing in small cells, or to support third-party neutral host models;
- enable services, including those used for mobile commerce and the Internet of Things, which rely heavily on the participation of all MNOs to support the widest range of customers;
- enable new monetization opportunities that rely on providing data insight and analytics derived from all visitors to a particular enterprise, venue or location.

And without small cells, the mobile broadband model is diminished overall. As mobile usage is now essentially pervasive, there is a requirement for everyone to be able to connect wirelessly wherever they are, and regardless of their choice of MNO. Without this, the rewards of strategies like mobile-first and BYOD are compromised.

It could be argued that the choice of MNO is essential to the competitive landscape – that consumers should indeed choose their service provider on the basis of the quality of service, including the pervasiveness of coverage. This has some weight, but it misses the point.

By continuing to attempt to attract consumers directly, without acknowledging their existing and independent loyalties, preferences and constraints – for instance, to a brand of hotel chain, shopping mall, enterprise campus, home, hospital – MNOs are ignoring the competitive needs of those malls or hotels etc., who become proxy service providers themselves. For instance, when a hotel guest complains about mobile service, they complain to the hotel, not to the mobile operator. And each hotel



is not large enough to have the ear of all the operators, and so the situation goes unresolved. By failing to deliver uniformly good mobile service, independently of the MNO, the industry is failing these proxy service providers, and failing the wider consumer.

Without multi-operator support, a subset of users will be forced to resort to venue Wi-Fi, a service that may be hampered either by insecure connectivity that may hinder usage, or by the poor on-boarding often associated with Passpoint<sup>™</sup> secured Wi-Fi networks.

Better availability of multi-operator solutions, then, would be a significant accelerant of small cell deployment in the enterprise and public markets, as the following findings indicate:

- Among enterprises, 12% are holding back from small cells because of lack of a multi-operator solution (up to 20% in some regions).<sup>1</sup>
- Almost 30% of mobile operators say they would accelerate their small cell roll-out plans if they had a robust multi-operator solution.<sup>2</sup>
- About 40% of cable operators and 35% of enterprise/vertical service providers are interested in harnessing small cell solutions to expand their portfolio.<sup>3</sup>
- Deployments of non-residential small cells could be 50% higher in 2016-20, if the brake of limited multi-operator support were released.

The gap in service revenues between a single operator-only market and a multioperator landscape is even greater, because the latter can enable many new value chains offered by new players, with innovative revenue models, to enter the market alongside traditional MNOs. Moreover, looking ahead to 5G, there is increasing acceptance that 5G needs to enable MNOs to serve new markets. In particular, in addition to supporting the evolution of established mobile broadband use cases, 5G needs to support a set of capabilities that enable the fifth generation of mobile technology to more effectively serve vertical markets – markets that will increasingly require multi-operator support.

Neutral host providers (which may, in fact, be MNOs which host other providers), have an opportunity to serve a wide range of venue types – including universities, enterprise buildings, hospitals, shopping malls and convention centers – where property owners are restrictive and typically prefer one infrastructure for all mobile operators. Venue owners can have an excellent wireless infrastructure which can be used to their benefit. For example, an excellent in-building wireless service for all operators may be one of the key decision criteria for a company to locate to an enterprise building.

Benefits for operators include predictable costs and the offloading of the complexities of deployment and management, as well as the ability to scale capacity up and down in alignment with demand and the business case.

<sup>&</sup>lt;sup>1</sup> Rethink operator survey 2016

<sup>&</sup>lt;sup>2</sup> Rethink operator survey 2016

<sup>&</sup>lt;sup>3</sup> Rethink operator survey 2016



#### 3. Barriers to conventional sharing approaches

So why have multi-operator small cells not been deployed at greater scale, given the clear market demand, and the fact that a shared deployment can actually mitigate some of the traditional challenges of small cell roll-out, such as access to sites and backhaul?

According to stakeholders on all sides, there are five main factors that have held back multi-operator small cell deployment:

- technology;
- regulatory barriers to spectrum or active network sharing;
- ownership and responsibility;
- uncertainty about the revenue model/ROI;
- alignment of business objectives between different stakeholders.

The key technology and regulatory challenges and solutions are covered below. However, just as serious as technology to the adoption of multi-operator small cells are issues of ownership, cost responsibility and revenue models.

Enterprises suggest that one of the main barriers to small cell adoption is the expectation that they will shoulder most of the deployment costs (the same applies to DAS). In fact, a fifth of enterprises in the Nemertes study for Small Cell Forum noted `unfair division of responsibility' as their primary objection to small cells. Of course, this is not specific to multi-operator networks. Nevertheless, it undoubtedly limits the potential spread of such networks by discouraging enterprises from even considering the small cell option. Public venues are particularly unwilling to pay to improve mobile quality of service, believing that the MNO should shoulder responsibility for providing this to the public.

However, a recent report by Mobile Experts [7] analyses the economic value derived from enterprise wireless systems, from both the operator and enterprise's perspective. The report clearly demonstrates that the enterprise has significantly more to gain from good indoor wireless coverage than the operator. It argues that this mismatch in derived value can only be addressed by the enterprise funding the deployment of the indoor systems.

The 'who pays?' problem is further exacerbated in the context of multi-operator small cell deployments, where there is even less incentive for the MNO to fund the deployment of a network which will, in the view of many, just 'enable their competitors'. While most MNOs have embraced the mobile virtual network operator (MVNO) model to increase and diversify their revenue streams, beyond national roaming deals few go as far as to share their networks or spectrum with direct MNO rivals, unless mandated to do so by regulators.

As Nick Johnson, CTO of ip.access put it, multi-operator core network (MOCN) technology 'essentially opens the door to a free-for-all in terms of resources. There's no commercial benefit to the first mover. All the first mover does is open the door to their competitors. So there are no first movers.' [8]

A recent survey by analysts Rethink found that the need to carry the upfront capex burden, and uncertainty about the ROI, are the most important barriers deterring MNOs from building multi-operator networks (see Figure 4–1). Other factors which were commonly cited included fear of enabling rivals (a top three concern for over half



of respondents); concerns about differentiation from those rivals (38%); and issues of network congestion (32%).





#### Source: Rethink survey

Carriers also have qualms about being tenants on a network hosted by another service provider. Here, the concerns are also centred on uncertain monetization models (placed in the top three by 51% of MNOs), as well as the risk of having limited control over quality of experience (QoE) (45%), or over differentiation (38%). These barriers emerged from the entire survey base, but the order of importance varies between MNO tenants and other service providers. For the latter group, the biggest issues relate to the price of access fees (36% placed in their top three concerns), as well as lack of control over QoE (32%).





## Figure 3–2 Chief barriers for service providers to be tenants on neutral host small cell networks

Source: Rethink operator survey



#### 4. Technical solutions for neutral host small cells

The most established cellular neutral host solution is the distributed antenna system (DAS), but this has severe limitations for any but the largest enterprises and public spaces. Figure 4-1, from a study by Infonetics for Viavi Solutions [8], summarises the main reasons. The greatest of these is deployment cost, which was seen as a barrier by 75% of the survey respondents. Others relate to deployment issues such as fiber cabling requirements, the second most cited barrier.



#### Figure 4–1 Barriers to DAS deployment (Vivavi/Infonetics)

There is clearly an opportunity for small cells to address the key barriers to DAS adoption and provide a more workable solution for most enterprises. After all, small cell technology has been specifically designed to support scalability – from small to large – at affordable cost of equipment and operation, and with simplified deployment and management processes. Given that there are clearly technology solutions and standards available, the critical barriers clearly relate to product availability and market barriers, as well as to the need for simpler processes of roll-out, cost sharing, spectrum access and so on.

There are three main approaches to network sharing, which are not exclusive to small cells.

- Multiple operator RAN (MORAN) has a higher level of independence than MOCN – the baseband and RF are shared, but there is a dedicated carrier and independent RRM and service deployment.
- Multiple operator core network (MOCN), all the elements are shared, including spectrum, except the core networks.



 Gateway core network (GWCN) in which interworking takes place at the core network level.

These are now described in greater detail below.

3GPP has defined the MOCN feature to enables the radio access network to be shared, as shown in the Figure 4-2 below [1]. The shared radio access network operator is labelled as 'X' and the core network operators as 'A', and 'B'. Typically, one of the core network operators will also be the radio access network operator, although to generalise the approach, an independent entity to operate the shared RAN network is shown.

Note: In this figure, horizontal colored banding of components is used to illustrate a component that is shared between multiple operators, with single color components representing elements dedicated to one particular operator.

In addition to the MOCN configuration, in which only RAN elements are shared, 3GPP has also defined an alternative approach to shared networks, whereby both RAN and core network functions are shared [1]. This configuration is referred to as gateway core network (GWCN).

In addition to the 3GPP MOCN and GWCN configurations, there is also a non-3GPP sharing configuration which is widely used in the macro environment. This configuration is referred to as multi-operator radio access network (MORAN) and is also shown in Figure 4–2. As illustrated, the MORAN model shares backhaul interfaces and base station hardware – including feeder cables, antenna, power supply, etc – but excludes the TRX/RF aspects from sharing. This means that licensed radio resources, their schedulers and configuration are not shared, resulting in each operator being responsible for configuring their own cell to broadcast their respective public land mobile network (PLMN) identities.

In the MOCN and GWCN configurations, each cell in the shared RAN additionally broadcasts system information about the available core network operators, e.g., in LTE where SIB1 includes the list of up to six PLMN identities of the supported networks. UEs can decode this information and use such in network and cell selection and re-selection procedures.





Figure 4–2 The three approaches to network sharing

Importantly, in order to accelerate adoption of shared small cell networks, it should not be assumed that the corresponding macro networks are also shared. Hence, it is important to consider the integration of a shared small cell architecture into a nonshared macro environment.

#### 4.1 Radio considerations

An important consideration from a technology perspective is whether or not neutral host-capable infrastructure places any additional requirements on the small cell radios. And the answer depends somewhat on the choice of MORAN vs MOCN, and the spectrum holdings of the sharing partners.

In a MORAN deployment, the installation consists of multiple radio heads at each node, where each radio is transmitting in the spectrum of its sharing host. In such deployments today, the radio heads are actually defined in advance as being the approved devices for the sharing host's network. The MORAN deployer is simply deploying kit in a particular configuration that is already known to function within the operator's spectrum holding. As the industry develops, the MORAN deployer may take more responsibility for specifying and approving the kit.

For example, the Joint Operator Technical Specification (JOTS)<sup>4</sup> model currently in use in the UK for DAS deployments may be applicable. If the radio heads achieve a smallcell JOTS accreditation (however that may be defined in future), then the MORAN deployer may be able to choose the supplier more freely. That freedom will place more

<sup>&</sup>lt;sup>4</sup> http://www.cellularasset.com/insights-and-expertise/insights/joint-operator-specification/



requirements on the radio head itself, since it must, at least in principle, be capable of operating in all the spectrum of all the sharing operators, not just one. And while such radio heads already exist today, the basic component cost of the small cell radios increases according to the number of bands that need to be supported. The implications of this tradeoff have yet to be fully explored.

In MOCN or GWCN deployments, where all the traffic is carried on a single RF carrier, the choice of spectrum donor determines the radio requirements. The MOCN radio needs only follow the spectrum holding of one operator, not all.

There is a general requirement for multi-band radios in certain territories where spectrum is not licensed nationally. In the US, for example, spectrum is licensed according to major trading areas (MTA). Each MTA may only be a few square kilometres in extent, and the same spectrum licensed by one operator in one MTA may be licensed by another in the adjacent MTA. To avoid logistical nightmares in particular for small cells where volumes and high, radios agile enough to be deployed freely across all the whole spectrum holding of an operator are nearly a necessity. The implication of this is that, in such territories, multi-operator capability in itself makes no additional requirements of the radio.



#### 5. Deployment considerations for neutral host solutions

In terms of small cell deployment, a neutral host solution addresses one of the biggest challenges which has sometimes held back roll-out and densification, indoors and in urban areas. This is the impracticality of securing sites and backhaul, and controlling interference, when several operators build out separate networks.

However, there are many deployment considerations when planning a neutral host small cell network.

From the operator's point of view, one is that most of the activities from design/plan build and operate are undertaken by the neutral host and so there is less control over the final result, but also less upfront investment. Figure 5–1 illustrates how responsibilities are shared between neutral hosts and MNOs according to different business models.



Figure 5–1 Commercial models mapped to deployment considerations

The most fundamental difference between neutral host and single-operator network deployments is, of course, the number of cells. However, MNOs must be sure that these cells are deployed in the best positions and with optimal tuning so that they deliver high levels of QoE even with the additional burden of traffic from several operators.

In 2015, Nokia carried out a study of small cell neutral hosting from a radio propagation perspective [9] using detailed public information and 3D maps for a European city centre of approx 1.5Km<sup>2</sup>. It was based on 3G technology, where the improvement goal was to reach a QoE of 1.8Mbits/sec across the whole area.

The main objectives of the study were to:



- To establish the improvement in QoE for each operator with the deployment of a individual and dedicated small cells layer
- To establish the QoE for each operator using a neutral host technique to best fit all operators at once
- To establish if any operator dedicated small cells would be necessary to add to objective 2 to bring the QoE up to, or better than objective 1

The study used a variety of inputs (see Figure 5–2) to measure coverage, interference and site requirements.



Figure 5–2 Process used in the Nokia neutral host study

The transmit power of the small cells was 3+3W and the target QoE was 1.8Mbits/sec or (CQI = 17). The tooling was configured so that this could be achieved from a mixture of the macro or small cell layers.

The results, as summarised in Figure 5–3, showed that a neutral host small cell network considerably increased the number of users which three MNOs could serve at1.8bps QoE.

Neutral Host	Neutral Host Operation		or 1 Operator 2		Operator 3	
	BEFORE Activation	AFTER Activation [VAM]	BEFORE Activation	AFTER Activation [VAM]	BEFORE Activatio n	AFTER Activation [VAM]
Average HSDPA served users @ 1.8bps QOE	483	614	366	478	329	482
Improvement		23%		25%		35%

#### Figure 5–3 Capacity uplift in number of served users at 1.8bps

Adding 3G small cells to mature 3G networks provides a significant boost to total QoE. Adding dedicated small cells to each of the 3G networks (objective 1) would require the deployment of 57 small cells split across the operators. By comparison, the total number of sites required in a neutral host, or site sharing mechanism (objective 2) would be just 19 sites, one third of the total (19/57 = 33%).

If the target is to make the QoE graphs equal or better (objective 3) for each operator is applied, rather than with the deployment of an individual and dedicated small cells layer, then some additional small cells, dedicated to one specific operator, would need



to be added to the shared neutral host deployment. Therefore, and because of, the different existing macro 3G network grids, a total of 6 extra sites would be required and hence total site count would be 25/57 = 44%:

- operator 1: no change in sites
- operator 2: +4 sites
- operator 3: +2 sites

This still represents a major reduction compared with an individual operator standalone deployment of small cells.

Reducing the aggregate number of small cell sites by 56% (QoE equal or better for each operator compared with the deployment of individual and dedicated small cells) or even 66% (applying neutral-host model to all sites shared by all operators) will lead to a significant reduction in costs. For a scenario in which two mobile operators decide to jointly apply a neutral-host model (e.g. operator 1 and operator 2 in our case study) the aggregate number of small cell sites would be reduced by 40% (QoE equal or better for each operator, compared with the deployment of a individual and dedicated small cells). Or even 50% (applying neutral-host model to all sites shared by both operators); resulting again in a significant reduction in costs also for dual operator neutral-host model.

#### 5.1 Spectrum and regulatory issues

A major issue associated with MOCN or GWCN based neutral host solutions is that of spectrum sharing. MOCN only accelerates sharing where the operators can agree about how this can be managed, usually because they have complementary assets that may already have resulted in a macro MOCN arrangement. MORAN, like DAS, can avoid the spectrum sharing dilemmas, but has been less well supported by the small cell ecosystem and requires more deployment effort, with – in many scenarios – less clear short term impact on total cost of ownership. Future flexible approaches to spectrum sharing – such as licensed shared access (LSA), Citizens Broadband Radio Service (CBRS) in the US, and LTE in unlicensed spectrum – will offer new ways to address these issues.

For now, though, there are more immediate spectrum and regulatory issues to consider.

Operators spend a lot of money on spectrum, and are often unwilling at first exposure to let their competitors have access to it. But this reluctance fades for two reasons – the reduced cost of the infrastructure, where up to six networks can be served for the price of one, and where the spectrum is underused anyway, and the owner can earn revenue they would otherwise miss, by carrying traffic on behalf of a competitor, by measuring it and charging for it.

Infrastructure sharing in general, and spectrum sharing in particular, invite the participation of third parties to manage the shared resources on behalf of the MNOs. Over the last twenty years, such a model has become well-established in terms of passive infrastructure – towers, antennas, cables, splitters, power, backhaul – and many of the tower companies involved in this are extending their vision to include the sharing of the active infrastructure – the basestations and active RF components, and the spectrum. The same arguments that were deployed against tower-sharing twenty years ago are being deployed against spectrum sharing today. We expect the argument to follow the same lines with the same result, where the cost of maintaining



a real or imagined competitive advantage in spectrum terms is more than outweighed by the cost savings of the fully shared infrastructure.

When considering the scope for multi-operator small cells in a regulatory context, a key question is whether or not the use of shared spectrum is permitted. This would allow for dynamic spectrum resource partitioning between operators, as opposed to the more straightforward distributed antenna system (DAS) or multi-operator radio access network (MORAN) approach where some active elements of RAN infrastructure may be shared, but each operator is constrained to transmit only within its own individually licensed spectrum assignment.

Historically, spectrum sharing has not always found favor with regulators, since it has often been viewed as a potential threat to healthy competition between national operators. However, the research undertaken during the production of this report indicates that several countries around the world have already authorized the use of active network infrastructure sharing including RAN/spectrum sharing in certain circumstances. This has been allowed, or even encouraged, in some countries where regulators have had strong policy objectives to extend mobile broadband coverage to areas of low population not likely to be served by multiple competing networks. The regulatory mechanisms by which this has been achieved are not always clear and vary from one country to another although some broad themes emerge.

One relatively straightforward route adopted in several countries has been for participating operators to form a joint venture (JV) at the time of a national spectrum award. The JV has then applied for a licence to operate a network across a range of frequencies, thereby permitting spectrum pooling and variable distribution between the individual participating operators.

Alternatively, in countries where a fully liberalized regime is in place, spectrum trades have occurred subsequent to the original award process, to enable transfers of spectrum rights from existing licence holders to a new JV. Both these approaches do, however, pose the risk that regulators and competition authorities may bar such applications or trades if distortion of competition is judged to be a significant risk. Nevertheless, there are several examples whereby such deals have been accepted and this is especially likely to be the case in developing countries or regions where policy objectives to extend broadband coverage may outweigh competition concerns.

Newly emerging regulatory frameworks may bring additional opportunities for multioperator small cell operation in spectrum currently occupied by military and other incumbent applications. The licensed shared access (LSA) concept developed within the European regulatory framework is one approach which may enable shared spectrum authorizations to be applied for. A similar approach called authorized spectrum access (ASA) has been adopted in the United States which is primarily targeted at small cells. This is exemplified by the new CBRS service in 3.5 GHz (see below).

In particular, compared with the high barriers to MOCN adoption when using individually licensed spectrum, it is anticipated that operation in new shared spectrum will accelerate adoption of sharing techniques.

In future, new approaches to shared and flexible spectrum may enable neutral host models which have limited reliance on the MNO's spectrum at all. A significant step to enrich small cells as a service (SCaaS) offerings and simplify the spectrum situation would come with provision of spectrum specifically reserved for neutral host small cells. This has been discussed by various regulators, notably the FCC, and would make



it far easier for cloud platform as a service (PaaS) providers to deal directly with non-MNOs. An early example was seen in The Netherlands, where Mixe Communication Systems has deployed a neutral host GSM enterprise small cell network in the 1800 MHz DECT guard band, after that was opened up for this specific purpose.

The next step from dedicated shared spectrum would be dynamic and on-demand aspect to spectrum. Such ideas became commonly discussed after Google's influential submission to the FCC during the 700MHz auction – with the idea of a hosted 700MHz network in which capacity could be used by many small service providers and offered on-demand.

Advances in dynamic spectrum access and cognitive radio, geolocation databases and other technologies are making it more practical for spectrum to be shared without significant risk of interference. Options for multi-operator small cells in future may include 5 GHz (e.g., using MuLTEfire); or 3.5 GHz, particularly in the US CBRS band, which has three tiers of access with different levels of openness. While the top level is for incumbent federal users with full protection, both the bottom level (for general access) and the middle layer (for priority access) could support innovative approaches to small cell deployment.



#### Figure 5–4 The 3.5 GHz ASA sharing scheme (CBRS) in the United States

#### 5.2 SCaaS deployment models

The proliferation of service providers with an interest in harnessing small cells will drive multi-operator support, since these various stakeholders will want a choice of MNOs with which to partner for mobile access. That, in turn, will stimulate a broad neutral host model in which a network is deployed on a wholesale basis, to support a wide variety of MNOs and MVNOs, increasingly on a dynamic and flexible basis. That model is several steps away from current commonly supported neutral host services, but it will be enabled and further evolved with the emergence of virtualized platforms (see below).

Neutral host models can significantly lower barriers for some operators. They will often be combined with SCaaS managed services such as cloud-based capacity management or billing for the tenants. (However, SCaaS is not confined to neutral host services –



some companies offer back office management services for a single operator's deployed small cells.)

Benefits for operators include predictable costs and the offloading of the complexities of deployment and management, as well as the ability to scale capacity up and down in alignment with demand and the business case.

Backhaul	<ul> <li>Provide fibre and wireless</li> <li>End-to-end managed service</li> <li>Aggregation economies</li> </ul>
Deployment issues	<ul> <li>Single point of contact for site provider</li> <li>Wide choice of locations</li> <li>Assured timescales</li> <li>Pre-approved planning</li> </ul>
Site provider needs	<ul> <li>Rapid enhancement of service to citizens</li> <li>Assured revenues</li> <li>Deal with changing mobile market conditions</li> </ul>

Figure 5–5 Deployment efficiencies of neutral host or SCaaS Source: Luminet



#### 6. Management of neutral host solutions

To allow the neutral host and multi-operator models to expand to their full potential as new use cases emerge will require changes to architecture as well as changes to the business processes.

As seen above, where the MNO is the host, it is important to improve the balance between the cost/management responsibility it takes on, and the potential returns on that investment. The ability to support a wide range of tenants, many of them noncompetitive with the MNO's model, is significant in that, as is the ability to control quality of experience, and allocate network resources, according to business priorities.

Architectures are starting to emerge to enable this. It is important that the resource management model of the eNodeB is made fully MOCN-aware, to enable greater operator control over its resources. As in DAS, the host operator needs to be able to allocate resources and power budget between tenants from a console. In future, this approach can evolve, in a virtualized environment, towards full network slicing, in which large numbers of service providers can access their own resources (see chapter 7).

The 3GPP has recently published Technical Report 22.852 which adds new use cases for enhanced RAN sharing and create normative requirements (and specifications) for OAM access for participating operators, support for load balancing, the generation and retrieval of usage and accounting information, on-demand capacity negotiation, handover functionality, interoperable SON and for PWS support over the shared RAN.

#### 6.1 Multiple PLMN-ID based shared small cells

For full MOCN enabled cells, each small cell is required to broadcast system information describing the available core networks. In particular, in UMTS the master information block (MIB) includes the information element termed 'multiple PLMN list' and in E-UTRA, the SystemInformationBlock1 includes the information element termed 'PLMN-IdentityList'. These information elements identify up to five (UMTS) or six (E-UTRA) multiple public land mobile networks of a cell in a shared network. Importantly, the current 3G small cell management system definition in TR 196v2 [10] does not currently support the definition of such management information elements for 3G small cells.

Contrast this with LTE where for E-UTRA, TR-196v2 defines the FAPService.{i}.CellConfig.LTE.EPC.PLMNList.{i} object that includes the list of PLMNIdentities broadcast in System Information Block1. No equivalent object is defined for UMTS to enable the multiple PLMN list to be configured by the 3G small cell management system.

#### 6.2 Common PLMN-ID based shared small cells

Pre-Release 6 UEs may be supported in a shared network by using 'equivalent PLMN' or ePLMN capability. A list of ePLMNs can be sent to the UE by the core network at each location and/or routing area update and indicates a list of PLMN identities that the UE should treat as being equivalent to the registered PLMN.

In particular, consider the case of two core networks, MNC#1 and MNC#2 that agree to share a network. In order to support pre-R6 UEs, these two core network operators can define a new PLMN-ID, e.g., corresponding to MNC#3. Each of the core networks



will then signal that the PLMN-ID associated with MNC#3 as being equivalent to the HPLMN.

The shared 3G small cell can then be configured to broadcast the PLMN-ID associated with MNC#3 which will ensure that UEs from both MNC#1 and MNC#2 will consider the shared 3G small cell as being equivalent to their home PLMN. In contrast to MOCN, E-PLMN configuration for 3G is supported by TR-196v2 defining the FAPService.{i}.CellConfig.UMTS.CN object that includes the EquivPLMNID list to enable the 3G small cell management system to configure equivalent PLMN functionality.

#### 6.3 Qualification of network listen derived neighbor cell

In typical 3G/LTE small cell deployments, the neighbor cell list will be automatically configured by using network listen capability in the small cell. The small cell will typically be configured to only include neighboring cells associated with its broadcast PLMN-ID in its neighbor cell list. In both multiple PLMN-ID and common PLMN-ID operation, the small cell needs to be signalled the PLMN identities of the core networks sharing the small cell from the small cell management system. The small cell can then ensure that neighboring cells from overlapping macro networks belonging to both core networks are included in the neighbor cell list.

For LTE based small cells, the TR-196v2 PLMN List object can be used by the small cell to qualify network listen derived neighbor cell information. For 3G based small cells, the lack of PLMN List object means that the small cell should be configured to use the equivalent PLMN list to qualify network listen derived neighbor cell information.

The 3G/LTE small cell is able to report the PLMN-ID of its neighboring cells using the TR-196v2 management object to the small cell management system.

#### 6.4 Identifying neighbor cells in shared networks

In UMTS, as well as of system information block (SIB) 11/11b is being used to signal inter-frequency, intra-frequency and inter-RAT neighboring cells, SIB Type 18 can additionally provide the UE with knowledge of the PLMN identity of the neighboring cells to be considered for cell reselection. This then enables a shared 3G small cell to be operated in an environment of two non-shared macro networks.

Note: Pre-Release 6 UEs will not have the capability to decode SIB type 18 information.

In E-UTRA, the measurement reports enable the UE to indicate to the shared small cell, the decoded PLMN identity/ies associated with the neighbor cell measurement.

There may be instances where the small cell management system is used to manually configure neighboring cells. Consequently, the small cell management system may be configured to provide the small cell a table of neighboring cells, for example that can be used to augment the list of neighboring cells identified by network listen procedures.

In such circumstances, the TR-196v2 management object allows the small cell management system to identify the PLMN-ID associated with a GSM/UMTS/E-UTRA neighboring cell.



#### 6.5 What we can learn from DAS?

There may also be lessons to learn from the DAS community.

The conventional DAS approach highlights how management capabilities need to be enhanced to accommodate sharing scenarios. In particular, OAM functions of the DAS are hosted in the management console at the head end and are both locally accessible through a user interface card and remotely via web-GUI and SNMP protocol. This allows managing the whole system from a single location. In particular, the management interface typically includes the following functions:

- System operation alarms configuration and monitoring, signals detection, delay-power-spectrum measurements
- Signal distribution signal sets creation and allocation
- **System configuration** hardware detection, operating region and bands configuration, Tx power allocation, IP connectivity settings

DAS systems have also addressed the OAM issue associated with sharing a single infrastructure across multiple tenants. In particular, some OAM configurations may not be independent from the each other, so a given OAM setting may have an impact on another one. Furthermore, a setting on a managed object of one operator may require a change the setting on another one of a different operator.

For instance, Tx power/carrier at the DAS remote unit is one of the settings that is highly dependent on the integrated configuration, because the power amplifier is typically shared across multiple carriers in a given band. DAS can cope with this issue through an anchor tenant on the system (it could be the lead carrier or the neutral host provider), which defines and enforces a fair power allocation across the operators. Also the DAS network management system (NMS) may support multiple IP addresses to provide connectivity to multiple tenants OSS.

Depending on the access rights defined for a given tenant of on the system, the NMS may expose only the specific parameters relevant for that tenant and enable changes to only those which are independent from the others tenants. An example could be the configuration of the input power alarm threshold at the DAS point of interface (PoI), or the cell delay settings associated to the signal source of given operator.

Moreover, DAS OAM systems typically support the definition of user access rights, alarm transparency which allows a non-anchor tenant to have visibility into the alarms status and alarm clearance based upon user rights. Also the OAM system typically allows the customization of measurement thresholds and alarm triggering, such as ALC power thresholds and low Tx power/carrier at the remote unit. All these features are extremely valuable for the configuration management on a shared infrastructure.



#### 7. Virtualization and neutral host

The most important future route to reducing cost and complexity barriers, and enabling new revenue streams for hosts, will be virtualization. However, multioperator support also infers that each operator has a choice in terms of suppliers, meaning that multi-vendor is a critical aspect to consider when virtualizing a RAN that is required to be shared. Importantly, the Small Cell Forum is working to define nFAPI, a multi-vendor standardized interface between the physical and virtual elements of a small cell network. This would enable multi-operator management functions like resource allocation to be handled from a centralized controller, which could belong to a neutral host or a cloud-based service provider. That would greatly simplify the deployment and control of a cluster of small cells, or indeed a DAS. A first step is likely to be a multi-instance virtualized small cell with a shared physical network function (PNF) which could replicate the DAS model.

It would make it easier to handle large numbers of tenants with different requirements of geography, availability and QoS, and to dial resources up or down according to demand. All that would enable the host operator to make more efficient use of its resources, improving its ROI, and to support a wider range of customers.

Such technologies will help to enable emerging network-as-a-service models, in which an MNO or neutral host cloud provider can support flexible allocation of network and storage resources to hundreds of service providers. On-demand capacity brokering will be a key element of this, and will be particularly important in the Internet of Things, for example to support peaks in demand or to use excess capacity for background M2M transactions.

Bandwidth on demand is significantly enhanced by virtualization techniques. There are several benefits:

- Virtualization enables far larger numbers of providers to be supported, with virtual networks created and terminated for each one, when required.
- Providers of all kinds can pay for what they use, and so cope better with peaks and troughs. The customers would pay for what they used, rather than signing rigid virtual operator or wholesale deals as they do now – thus removing a key barrier for smaller service providers or those which only need to be active at certain times of day or year.
- Capacity can be dynamically allocated to the changing needs of different users and applications, as defined by QoS, SLA etc.

#### 7.1 Increasing blurring between DAS and virtualized small cells

The virtualized small cell can be shared in a similar manner to the classical RAN architecture. Figure 7–1 below shows the conventional sharing approaches on the left side of the figure, illustrating classical DAS and MOCN sharing options. The two options on the right show sharing applied to a virtualized small cell architecture. It is evident that, while conventional MOCN based solutions can be re-created using a virtualized architecture, the new option available with virtualization is a shared physical network function (PNF) that is then parented to different virtual network functions (VNFs) operated by separate MNOs. This figure can be used to highlight the similarities between the new PNF sharing approach and classical DAS approaches to multi-operator support.







7.2 PNF sharing with individually licensed spectrum

The work SCF has done in partitioning functionality between a physical network function (PNF) and a virtual network function (VNF) enables a PNF to contain a number of PNF service instances with associated carriers/RF chains within the PNF device. This core capability can be leveraged for supporting multi-operator capabilities. Figure 7–2 shows a single PNF device that includes two PNF services, where a PNF service may be an LTE cell and where each cell can accommodate one or more carriers. In the example shown, one PNF service is shown configured to operate with two carriers, being parented to one VNF that will enable an MNO to offer carrier aggregation capabilities, and the remaining PNF service parented to a second VNF instance, operated by a second MNO that is able to offer a service using a single carrier.



#### Figure 7–2 Multi-VNF instance realization of a shared physical network function

In particular, the nFAPI management model has been designed to enable initial configuration of the shared PNF through a common P9 OAM interface, which will then be used to configure the separate transport layer connections between the PNF and VNF. Further detailed configuration of the PHY will be performed by the VNF over the P5 interface.



Hence, the entity responsible for delivering the P9 OAM service is able to partition resources of the PNF devices across multiple PNF services associated with multiple PNFs. The P9 OAM system has the ability to partition resources of the PNF service across LTE carriers if an operator wishes to do so; otherwise, allocation of resources to carriers is performed by the VNF through nFAPI P5 interface.

The overall nFAPI based sharing architecture then is shown in Figure 7–3, which clearly illustrates the similarities in management concepts between the conventional DAS management and signal source control elements and the P9 based OAM management system that is able to support control of PNF-to-VNF mapping, as well as partitioning PNF resources between the various supported operators.



Figure 7–3 Multi-operator shared nFAPI architecture

#### 7.3 Coupling new shared spectrum with virtualization

Previous sections have highlighted the anticipated acceleration of multi-operator based sharing approaches with the move to shared spectrum deployments. When shared spectrum systems are deployed using virtualization, the barriers to MOCN adoption in terms of the level of coordination between operators can be dramatically simplified. In particular, if a common PNF is parented back to individual operator's VNFs, then:

- each individual operator is free to independently ensure feature consistency between small cell VNF and the remainder of their RAN system;
- each individual operator's VNF will be integrated into its respective network management system;
- each individual operator can integrate the VNF into its own automational tools, including SON integration.

Furthermore, because the cloud PNF operator avoids handling data-plane traffic, then a scalable cloud model can be used to relase the shared PNF operator.



This approach looks to leverage the key learnings from cloud Wi-Fi systems that have focused on the cloud based management of Wi-Fi access points, whereby all user traffic is handled directly between the new access point and the carrier's VNF infrastructure



Figure 7–4 Leveraging shared spectrum and virtualization to enable new cloud managed sharing solutions



#### 8. Emerging options and Project SESAME

As the market looks ahead to 5G, there will be further architectural and deployment choices, which aim to make it far easier for a HetNet to support many service providers. There is work ongoing on increasingly complex and dynamic neutral host small cell architectures, as these are likely to be a key element of 5G networks. As such, there are some interesting ideas emerging from 5G projects, such as the EC-backed Project SESAME (part of EC 5G-PPP), some of which may be applicable to current networks too.

Project SESAME is focused on applying cloud-RAN and mobile edge computing technologies to small cells (see Chapter 8) and also with neutral host and SCaaS architectures which could enable flexible, on-demand access to wireless capacity for large numbers of service providers and enterprises, via network slicing.

In addition to neutral host platforms, it envisages CESCs (small cells with microservers integrated to support storage and processing at the network edge) [11].



Figure 8–1 CESC decomposition in Project SESAME

Several tasks within the project stand out in terms of future multi-operator platforms. Task 2.3 was to specify the CESC functions and some crucial decisions were made in terms of architecture – to support MOCN not GWCN for multi-operator, and to use the S1 functional split in the proof of concept.

Meanwhile, Task 3.1 was to define virtual small cell and Task 3.2 (in progress) is to address 'self-x' (self-organizing, self-optimizing, self-healing etc) for each tenant in a virtualized neutral host environment.

The former extended MOCN to accommodate multi-tenancy in shared RAN, while leveraging SESAME virtualization concepts. For instance, it examined modifications to existing standard interfaces and developed new ones to enable configuration of the small cells by the CESC radio access manager while addressing fault management (FM), performance management (PM) and configuration management (CM) northbound interfaces to configure small cell attributes on the real hardware and to gather cell-specific information.

The latter task came up with several conclusions:



- Resources should be able to be reconfigured on-demand, according to the SLA between the tenants and network conditions, using autonomic self-x features.
- Some of the self-x features will be managed on a per-tenant basis whilst others should be common to all the tenants.
- The framework of a distributed network management system will be developed.
- Resources can be shared across different (virtual) operators or within one operators' network. Sharing is done in terms of spectrum, adaptation of radio parameters (power control, rate adaptation etc.), edge-caching and load balancing (depending on incoming traffic per-tenant and aggregate interference).
- Study of aggregate interference models in clusters of small cell networks and the development of advanced interference prevention/avoidance techniques will be also carried out.
- On-demand resources provisioning such as number of small cells serving one operator and capacity provision will be studied including the SLA between tenants. Finally, mechanisms to audit SLA conformance will also be developed.



#### 9. Conclusion

In conclusion, we can see that there are clear market drivers to deploy neutral host and multi-operator small cells. There are also robust technical solutions available. These include:

- 3GPP standards, particularly MOCN;
- techniques borrowed from DAS and Wi-Fi, both of which are well-established as neutral host platforms (but both of which have drawbacks for the commercial operator and site);
- emerging solutions based around small cell virtualization.

We have found that the slow progress of deployment relates more to uncertainty over business models, and over the processes of rolling out and managing a neutral host platform, including issues such as spectrum sharing, cost sharing and regulation.

This document has outlined some of the solutions which already exist to simplify deployment and management, and some of the emerging options, especially related to virtualization. As the market becomes more aware and educated about these choices, confidence will rise, even as the demands of indoor data usage and mobile-first enterprises start to break down old barriers against network sharing.

As neutral host small cells are rolled out, it will be an important stepping stone towards the more virtualized, and highly multi-operator environment of 5G, as prefigured by initiatives like Project SESAME.



## References

- 1 'The Indoor Influence', Ericsson Consumerlab Insight Report, April 2015, <u>https://www.ericsson.com/res/docs/2015/consumerlab/ericsson-consumerlab-</u> the-indoor-influence-europe.pdf
- 2 '2015 State of the RAN', Amdocs, http://solutions.amdocs.com/rs/amdocs1/images/Amdocs 2015 State of RAN.p df
- 3 Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2015–2020', <u>http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html</u>
- 4 'Multi-Operator Market Drivers', Small Cell Forum, http://scf.io/en/documents/017 - R6 - Multi-Operator Market Drivers.php
- 5 'Enterprise Mobile Infrastructure', April 2016, Mobile Experts
- 6 <u>http://www.smallcellforum.org/site/wp-content/uploads/2015/11/Rome-</u> <u>Champions-Day-report.pdf</u>
- 7 'Enterprise Mobile Infrastructure', April 2016, Mobile Experts
- 8 'DAS Deployment Overview Streamlined approaches for DAS deployments', <u>http://www.viavisolutions.com/sites/default/files/technical-library-items/das-</u><u>deployment-overview-an-nsd-nse-ae.pdf</u>
- 9 Nokia, Small Cell Neutral Hosts Study for Small Cells Forum, 2015
- 10 TR196v2, https://www.broadband-forum.org/cwmp/tr-196-2-0-0.html
- 11 'System architecture and deployment scenarios for SESAME: Small cEllS coordinAtion for Multi-tenancy and Edge services', <u>https://addi.ehu.es/bitstream/10810/18270/4/NetSoft2016-Soft5G\_sesame.pdf</u>