Understanding Small Cells— Addressing Unparalleled Network Expansion and Traffic Growth

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Cellular networks have evolved and expanded dramatically over the last decade, caused by a paradigm shift from voice-centric, circuit-switched, centrally-optimized networks–designed for coverage–towards data-centric, packet-switched and organically-deployed networks–designed for capacity.

Mass market smartphone proliferation and the emergence of bandwidth-intensive applications that demand "always on", high speed, low-latency wireless connectivity, are increasingly constraining the resources of existing networks.

To deal with this traffic growth, operators can use traditional methods to expand network capacity, but these are often costly. Today, data traffic is growing at a rate faster than network expansions, leaving operators challenged with how to develop pricing models to maximize revenue per bit, while deploying networks that minimize cost per bit. Meanwhile, coverage issues and the congestion due to heavy data traffic continue unabated.

With all this, how are operators going to offload traffic from high density macro network and provide better coverage to network dead zones?

Of the techniques to increase capacity and quality, frequency reuse through addition of more cells sites seems to provide the highest capacity gains. And small cells have emerged as one of the key alternatives to address coverage and traffic. Still, like any technology, small cells come with their own set of challenges that must be overcome to fully realize their potential.

This whitepaper analyzes the major trends in the small cell industry and the different challenges that the Mobile Network Operators (MNOs) will face when deploying small cells. Understanding the benefits and challenges are critical to making the right decision around this exciting technology.

AN INTRODUCTION TO SMALL CELLS

The LTE network promises to provide subscribers with faster access to different data services, with lower latency, high throughput and guaranteed bit rate. Starting with rollout of services in particular circles, the MNOs are now planning to have pan-national services, but face dead zones in metropolitan areas and coverage problems in rural zones. Meanwhile, locations like offices, universities and coffee shops continue to be the hotspots for mobile traffic. This high-bandwidth consumption at certain locations and the coverage issues at others continue to trouble MNOs. Small cells are expected to answer these challenges.

"Small cells" is an umbrella term used to represent the low-power wireless access points that operate in the licensed and unlicensed spectrum. They have become the preferred solution for both the subscribers as well as the wireless service providers who face the challenge of the wireless broadband data explosion. Small cells not only increase capacity, but also add coverage and enhance the end user experience. They allow operators to generate additional revenue from increased usage and, potentially, new services.

Small cells can be classified based on their coverage or the location of deployment, as follows:

	Femtocell	Picocell	Microcell/ Metrocell
Indoor/Outdoor	Indoor	Indoor or Outdoor	Outdoor
Number of users	4 to 16	32 to 100	Approximately 200
Maximum output power	20 to 100 milliwatts	100 to 250 milliwatts	2 to 10 watts
Maximum cell radius	10 to 50 meters	200 meters	2 km

SMALL CELL INDUSTRY TRENDS

Small cell technology has received mixed acceptance since its launch in 2007. Compared to the evolution of the 3G macrocell technology, 3G femtocells were standardized late in the game by the 3GPP. It was meant to overcome the indoor coverage issue faced by the MNOs. But, learning from the 3G experience, the LTE femtocells were standardized only soon after the LTE standards for the macro network were defined. LTE small cells are already considered a key deployment model by MNOs who have operational LTE networks and those who plan to launch them.

Several surveys have shown the key drivers encouraging the MNOs to deploy small cells are:

- Optimization of areas with very high data usage
- Optimization of in-building and public venue coverage
- Offloading of the macro network
- Densification of the footprint of the network
- Saving CAPEX

The priority of the drivers can differ between MNOs; however, these are helping to accelerate small cell deployments.

EMERGENCE OF LTE SMALL CELLS

According to a recent report by Infonetics Research (as shown in Figure 1), the worldwide Femtocell market will be close to $900 million by the end of CY 2014[1]. LTE femtocells will account for close to half of the projected revenue. LTE femtocells were first deployed in late 2012, so this projection illustrates a significant pick up on LTE femtocells in coming years.

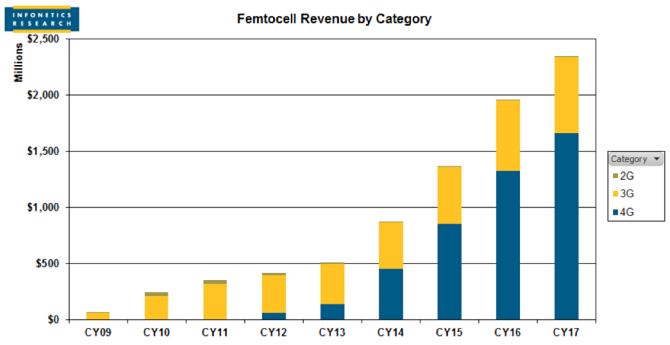

Figure 1. Femtocell Revenue by Category

The projection shows substantial revenue from the 3G small cells, which makes sense, since a majority of customers will still be 3G subscribers. As VoLTE is still an emerging technology, LTE networks today support data services only. MNOs still must rely on the 3G network to support voice. Thus, mobile operators want small cells to be dual-mode so that they can support 3G as well as 4G subscribers and provide data and voice services.

RISE OF NONRESIDENTIAL SMALL CELLS

Until now most small cell deployments have been residential femtocells; however, there is an upward trend towards enterprise and outdoor small cells. Based on figures recently published by the Small Cell Forum (shown in Figure 2), the enterprise and urban small cells are growing by 86% and 84%, respectively[2]. There's a tremendous growth in the non-residential small cells especially in urban deployments. MNOs are implementing large numbers of small cells in coffee shops and office buildings across cities. This has happened already in many Asian countries, such as Japan and South Korea, and countries like China and India will soon turn to small cells as one of the primary tools to overcome very high density. And Europe is expected to see the same trend.

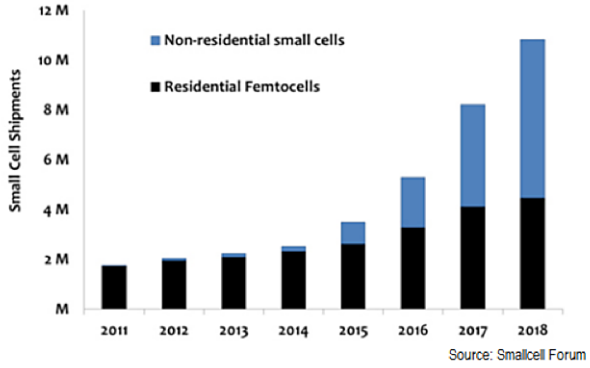

Figure 2. Shipment Projections for Residential and Nonresidential Small Cells

EMERGENCE OF HETEROGENEOUS NETWORKS AND CARRIER WI-FI

LTE is the preferred radio access technology and there will be increasingly more LTE networks and subscribers in the future. Since LTE and 3G handsets need to coexist together for quite some time, MNOs will deploy multi-technology small cell networks that can cater to both the 4G and 3G subscribers. These networks will efficiently share the backhaul power, real estate for the small cells, and deploy a common gateway to connect them to the core network. This has been the driving factor behind small cell vendors increasingly supporting 3G, LTE and also Wi-Fi in the same unit.

Wi-Fi uses the same frequency bands and protocols worldwide. Almost all the communication devices (e.g. smartphones, tablets, laptops) support Wi-Fi. It is the preferred mode of Internet access at restaurants, coffee shops, airports and hotels. The ability to exploit unlicensed spectrum in addition to licensed spectrum while providing a seamless subscriber experience has a clear appeal for the service providers and MNOs. And they are starting to view Wi-Fi as another wireless technology that can augment their macrocell and small cell networks. Wi-Fi can be used to offer a fast, reliable and cost-effective wireless broadband access while offloading the 3G/4G mobile data to relieve RAN constraints. MNOs can choose to direct best-effort traffic to the Wi-Fi network and use the LTE small cell networks for traffic like streaming video or VoIP, which require more stringent QoS.

A recent survey of key MNOs by Infonetics Research suggests that there is an upward trend towards multimode devices with 3G, LTE and Wi-Fi capability embedded in the same box.[3]

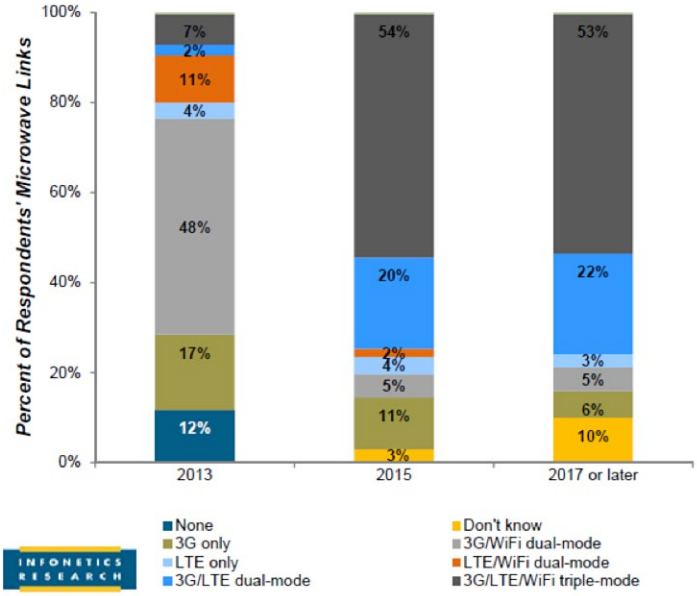

Figure 3. Choice of Small Cell Type by MNOs

[1] "2G, 3G, LTE Mobile Infrastructure and Subscribers – Market Share, Size, and Forecasts", Edition: 4Q13, Published: March 4, 2014
Analysts: Stéphane Téral, +1 408-583-3371, stephane@infonetics.com – Richard Webb, +1 408-583-3369, richard@infonetics.com

[2] Small cell Forum Release Three. Document 030.03.03, "Small cells – big ideas. How small cells left home – and where they're going next", February 2014

[3] Small Cell Coverage Strategies: Global Service Provider Survey, October 1, 2013

SMALL CELL CHALLENGES

It appears that a single small cell solution may not be able to solve all current and future traffic and coverage issues, so many solutions will need to work together. The decision around solution needs to be based on balancing the pros and cons so that the cumulative benefit maximizes performance. The task is to understand and evaluate the different challenges that each alternative introduces.

The most likely challenges are:

RF Interference

Operators are opting to have a mixed network of macrocells and multi-RAN small cells—dubbed heterogeneous networks (or HetNet)—to boost capacity and system throughput many times more than a conventional network. However, in such a network where there is frequency reuse and the number of small cells is more; there will be interference caused due to the overlap of cells.

The interference can be managed effectively by different mechanisms available today. Effective power and frequency management can be implemented. Using the Inter Cell Interference Cancellation (ICIC) technique, the HeNBs can communicate via the X2 interface to mitigate the inter-cell interference for UEs at the cell edge. Another way to ensure that a UE is using both the best DL and the best UL carrier is to employ the Coordinated Multi Point (CoMP). By using the Self Optimizing Network (SON) methods, the power control and frequency parameters can be changed in the real time depending on the different information received from the UEs, the mobility in the network and the amount of traffic through it.

The MNOs need to use the interference avoidance mechanisms to ensure that they are able to utilize the benefits of the heterogeneous networks.

Backhaul for Deploying Small Cells

Backhaul is required to connect the small cells to the core network. Backhaul selection must be based on the type of the small cell to ensure that it is cost effective and that performance is uncompromised. The availability of the wired backhaul is limited and the traditional microwave and millimeter-wave line-of-site (LoS) wireless backhaul cannot guarantee availability to street-level small-cell installations in dense urban environment.

Non line-of-sight (NLoS) and near line-of-site (NrLoS) wireless backhaul using sub-6 GHz bands are promising candidates for ubiquitous small-cell backhaul; however, when using licensed spectrum, narrow bandwidth channels put strict limits on backhaul capacity, and most sub-6 GHz spectrum bands are expensive and frequently not available for licensing. In locations where multiple options are applicable, total cost of ownership will decide the preferred choice for the backhaul. Most networks are expected to evolve towards using a mix of both wired and wireless backhaul. MNOs will therefore need to plan their infrastructure carefully to ensure the network does not face bottlenecks due to insufficient backhaul upstream.

Handovers

With macrocells the cell size is, obviously, big and the chances of handover are fairly low. But with small cells there could be more than one cell at a particular location. That means when users move, there will be frequent handover between neighboring small cells or to the macrocell. This frequent handover can strain the network due to the volume of handover-related procedures.

Femtocell Gateways can be deployed in the network, incorporating paging and handover-optimization techniques, so that the core network is not impacted by this.

In addition, due to the large amount of small cells deployed in the network, every small cell needs to handle increased traffic related to the neighbour management. The neighbour lists and other data must be negotiated and managed across clusters of small cells and the macrocells.

The integration of carrier Wi-Fi to the cellular network also adds to the complexity. Entities like the Access Network Discovery and Selection Function (ANDSF) need to be added to the core network so that they can assist customer handsets to discover non-3GPP access networks and provide them with the policies that help connection to the networks.

It is vital to have seamless handover from the macrocell to the small cell and between the Wi-Fi and cellular networks, so that the complexity is hidden from the customers. Any decrease in the quality of the call or call drop may lead to unhappy subscribers and customer churn.

Security

The access points connect to the core network through wireless and IP backhaul, and both of these are prone to attacks. It is important for service providers to safeguard the customer data—which is often transmitted during data calls—and information about their network. Similarly, the core network, which is prone to the denial of service attacks by illegitimate users, also needs to be defended. The femtocell technology defines the use of security mechanisms like IP security (IPSec) and EAP to overcome these threats. Operators need to carefully decide the deployment architecture based on whether they deploy single-mode or multi-mode small cells. MNOs can opt to have a single security gateway or separate security gateways for different access technologies. Figures 4 and 5 illustrate some possible configurations. An already deployed 3G small cell network can be upgraded to support 4G small cells. In that case it will be an integrated infrastructure, which is the best option to ensure low total cost of ownership (TCO).

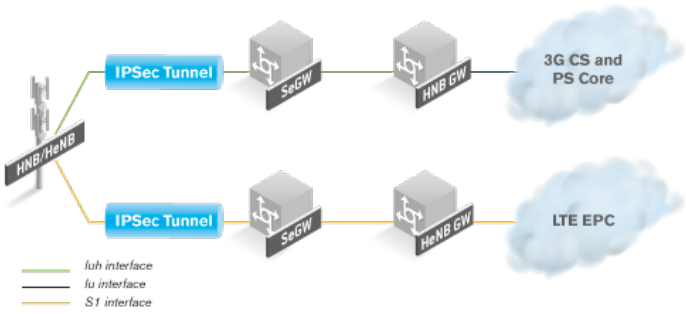

Figure 4. Separate Security Gateway and Femtocell Gateway

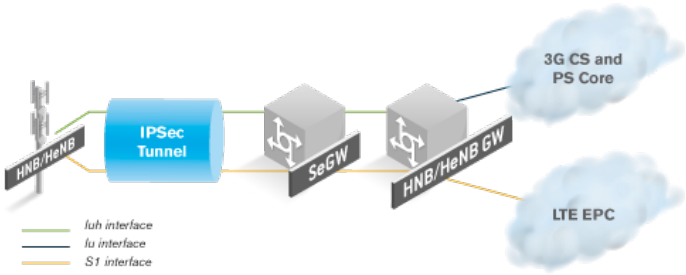

Figure 5. Integrated Security Gateway and Femtocell Gateway

And those are just a few of the major challenges that MNOs face when deploying small cells. Fortunately, solutions exist to overcome them. Careful planning is therefore a necessity when incorporating small cells into the network to maximize their potential.

MAKING IT BIG WITH SMALL CELLS

Small cell technology is certainly a promising solution to the massive increase in data traffic being experienced around the globe. It also complements the macrocell network, providing added coverage while offloading traffic from it. Available in different technologies and different capacities, they can be used for different types of subscribers and meeting different customer expectations. Small cells can certainly help MNOs reduce the total cost of ownership and increase revenue potential by accelerating deployment and improving quality of service.

But it's critical for the MNOs to integrate them efficiently into their macrocell network in order to benefit most from their advantages–and ultimately build a bigger network with better quality of experience for their subscribers.

Because of this it is crucial that, before the networks are rolled out, lab validation is performed. Validations in the lab helps ensure the equipment being deployed is capable of efficiently handling the expected traffic volumes today and into the future. Measuring the true capability of the network equipment can help the network planning department to make correct decisions around how and where to deploy what in the network–as well as prevent network over-provisioning. In-depth lab validation also prevents failures in the operational network, which is often very tedious and expensive to resolve.

With the right testing, validation and planning, MNOs are ready to make a big splash using small cells.

ABOUT EXFO

EXFO is a leading provider of next-generation test and service assurance solutions for wireline and wireless network operators and equipment manufacturers in the global telecommunications industry. It offers solutions for the development, installation, management and maintenance of converged, IP fixed and mobile networks. Key technologies supported include 3G, 4G/LTE, IMS, Ethernet, OTN, FTTx, xDSL and holds more than 35% of the portable fiber-optic test market. With 1600 employees in 25 countries, it supports over 2000 customers worldwide, and is listed on the NASDAQ and TSX stock exchanges.

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  Printed in Canada 14/06