White Paper

Building Better Small Cell Solutions

DragonWave

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TABLE OF CONTENTS

Building Better Small Cell Solutions

Mobile traffic is expected to increase 18-fold by 2016.

The demand for high-speed wireless access driven by tablets, smart phones and bandwidth intensive applications is creating a need for much greater capacity on mobile networks. Adding to this pressure are the myriad of new network enabled devices hitting the market every month, most having larger, higher resolution screens built for video – which already accounts for over 50% of traffic on mobile networks[1]. While it is increasingly difficult for service providers and analysts to predict future demand, a recent forecast shows 18-fold increase in mobile traffic by 2016[2]. Meeting this capacity requirement represents an extraordinary challenge to service providers.

While 4G mobile networks have been touted as the solution to the capacity shortfall, the spectral efficiency gains achieved by these new wireless technologies simply cannot keep up with demand nor can they provide sufficient bandwidth for media rich applications in high tele-density areas. Adding additional Radio Access Network (RAN) spectrum offers a partial solution, but scarcity and high cost typically limit the extent to which spectrum can address the capacity problem. Figure 1 illustrates the capacity gap faced by operators over the coming years.

Despite the advances in mobile network technologies, there is a growing gap between end user demand and access bandwidth.

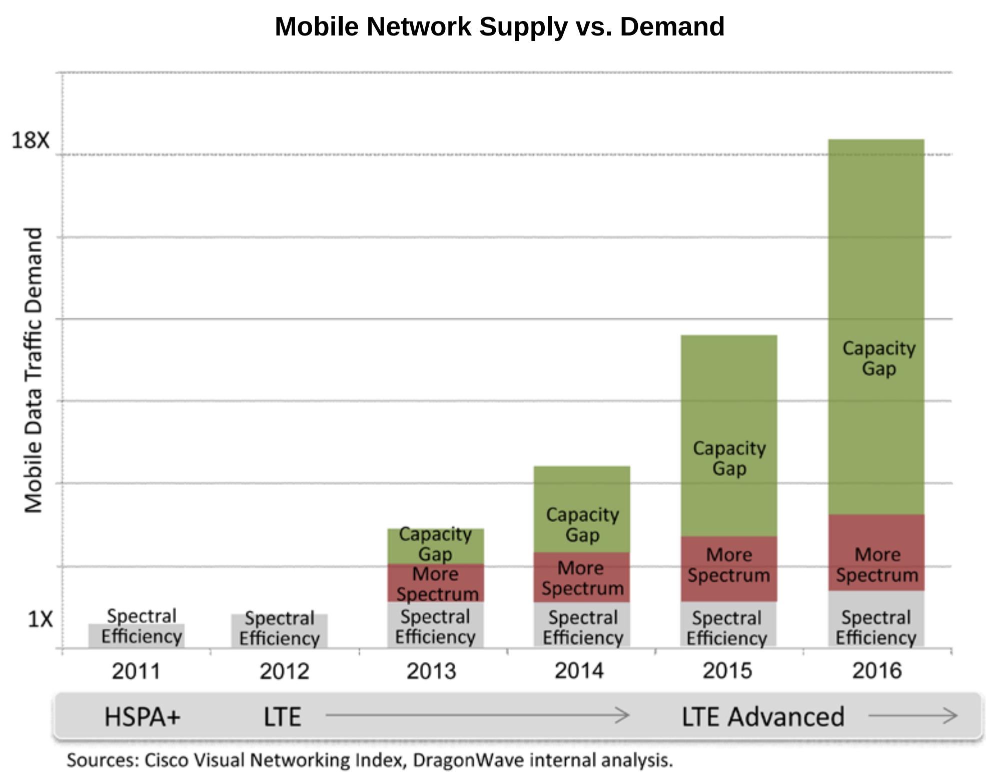


Figure 1: The Mobile Network Supply/Demand Gap

Based on forecasted demand, the current macrocellular network model will not scale sufficiently to address the growing capacity gap; therefore a new approach is needed. By looking at the evolution in wireless networks over the last 45 years,

technology advancements and increased spectrum allocations have driven less than 5% of the overall capacity gains[3]. The vast majority of the capacity improvements have been achieved through increased cell density.
Many service providers are thus addressing the mobile capacity challenge by deploying smaller cells (or small cells) as an underlay to their macrocellular networks. These small cell deployments operate below the clutter level in order to improve coverage and offload traffic from the over-burdened macrocellular network. Not only does this architecture provide the scale for future demand, it also provides important improvements in coverage and spectral efficiency.

While small cell architectures hold a lot of promise, they also present a set of unique challenges for operators. This paper provides an overview of the benefits and drivers for small cell architectures, followed by an examination of integrated small cell solutions designed to address the deployment challenges of small cell networks. Lastly, the paper discusses small cell backhaul alternatives and highlights the key requirements for microwave-based small cell backhaul solutions.

SMALL CELL Networks: Overview

As a dense underlay to the macrocellular layer, small cell networks typically have cells that are a few hundred meters in size and are deployed at street level, on light poles, buildings sides or other suitable structures.

Small cell networks are a high cell-density underlay to the macro-cell layer.

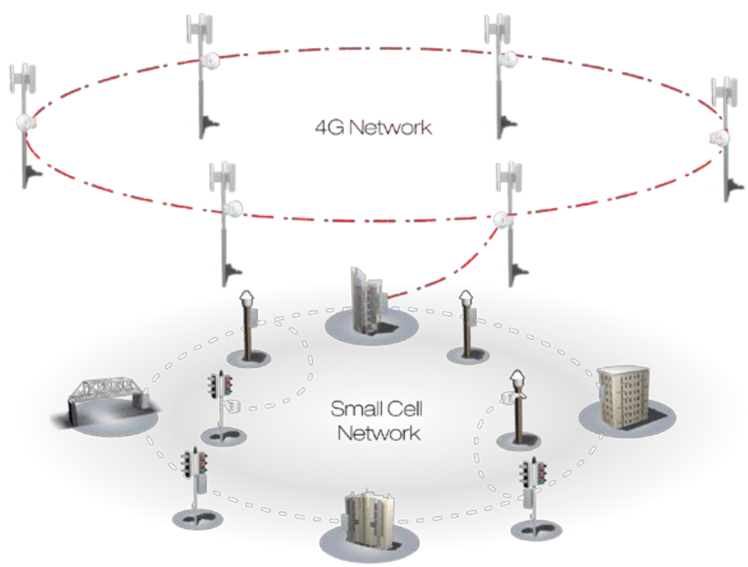


Figure 2: Small Cell Underlay Network

The future of small cell networks lies in fully integrated solutions.

Initial small cell deployments have consisted of a micro-base station with fiber centric backhaul due primarily to the lack of availability of viable wireless backhaul solutions. Looking forward, small cells are evolving towards fully integrated units containing a micro-base station, battery backup, wired or high capacity microwave backhaul and switching – all within a small pole-mounted enclosure optimized for urban environments.

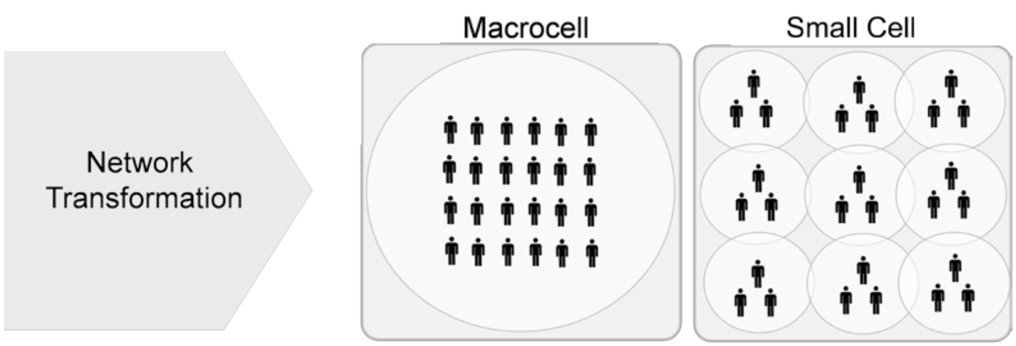
Any discussion on small cell networks is usually accompanied by a mention of Distributed Antenna Systems (DAS), which offer another approach to expanding coverage and cell density. With these systems, transmit power is split among several antenna elements, providing coverage over the same area as a single antenna system but at a reduced power level. While DAS systems improve coverage and make more efficient use of spectrum, they generally rely on centralized base station processing and thus do not deliver the same capacity gains seen in small cell networks consisting of distributed base stations. In addition, DAS generally require RF signals to be converted and distributed over fiber and are therefore most commonly installed indoors or in other locations where fiber is readily available.

SMALL CELL Drivers

Capacity

As new types of network enabled devices come online and service providers begin to offer users single mobile data plans for multiple connected devices (iPhone + iPad) demand will greatly outstrip capacity.

Small cell architectures offer a combination of better coverage and more base stations which results in a dramatic increase in network capacity; an area previously covered by a single macrocell can see more than an order of magnitude increase in capacity with the addition of a small cell layer.



	Macrocell	Small Cell
Target capacity per cell	100 to 300 Mbps	50 to 150 Mbps
Cell density relative to macrocell	1	5 to 25
Total capacity	100 to 300 Mbps	250 Mbps to 3.75 Gbps

Aggregate small cell capacity far exceeds small cell capacity while using existing spectrum allocations.

Figure 3: Macrocell vs. Small cell density and capacity.

As show in figure 3, the target capacity for a small cell is lower due to the use of lower complexity (and cost) single sector base stations. It is the increase in the cell density which results in higher network capacity.

In-Building Coverage

By deploying base stations at street level (below the clutter level), small cell networks offer improved in-building penetration at lower transmit powers. This is particularly relevant to operators who are using higher-frequency access spectrum, such as 2.5

GHz and above; the lower propagation characteristics of these higher frequencies mean that in-building penetration would suffer significantly in traditional macrocellular architectures.

Spectral Efficiency / Re-Use

While some spectral efficiency gains are achieved with 4G networks and the use of MIMO technology, the majority of bandwidth increases are due to the larger channel sizes defined by these new standards. For example – HSPA is limited to 5 MHz carriers whereas LTE has defined channel bandwidths of up to 20 MHz and LTE advanced defines channel bandwidths of up to 100 MHz. A recent study by Rysavy Research projects that service providers will need over 200 MHz of spectrum in order to meet the bandwidth requirements of their users in 2016[4]. With most operators holding between 50 and 100 MHz of spectrum, there will clearly be a shortfall based on current architectures.

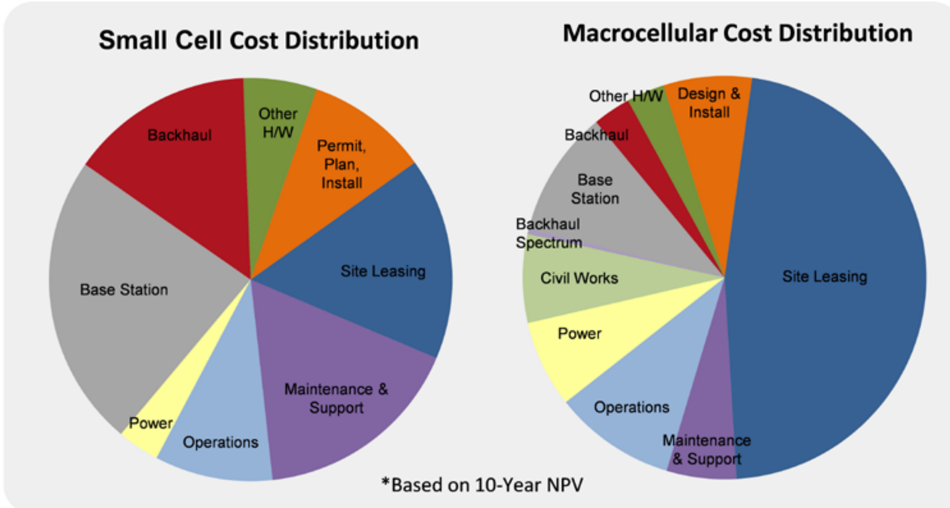
Small cell networks present a compelling solution to this spectrum shortfall. Smaller cells allow for a large reduction in transmit power, enabling operators to re-use RAN spectrum within the small cell network layer. In addition, for those deployments using microwave backhaul, operators have the ability to reuse the same backhaul spectrum for the higher elevation macrocells and the street level small cell – potentially leading to significant licensing savings.

Economic Leverage

Delivering higher capacity is only practical if operators achieve a dramatic reduction in cost per bit. Due to their flexible all-outdoor deployments, integrated small cell systems offer several important operational and capital cost advantages over macrocell networks, as show below in figure 4.

Small cell networks deliver up to a 10X savings in TCO relative to macrocellular networks.

Unlike macrocell networks, the cost distribution of small *cell is more heavily weighted to CAPEX rather than OPEX.*



Fully integrated small cell platforms provide flexible deployment options and rapid installation.

Small Cell Cost (As a % of Macrocell)			
CAPEX		OPEX	
Base Station	20 – 30%	Site Leasing	1 – 3%
Civil Works	—	Maintenance & Support	20 – 30%
Installation	10 – 15%	Operations	10 – 15%
Backhaul	40 – 60%	Power	5 – 10%

Sources: Heavy Reading, Yankee Group, American Tower, Senza Fili Consulting, DragonWave analysis.

Figure 4: CAPEX/OPEX comparison between small cell and macrocellular networks.

A single integrated platform has several advantages over multi-box small cell solutions.

Depending on the region and deployment location, site leasing, civil works and power costs can all be greatly reduced for an integrated small cell unit when compared to traditional cellular networks which involve multiple boxes at the tower site. The access to suitable mounting locations is a critical factor in any network evaluation and can make or break a business case. By shifting cost from large ongoing operational expenses (OPEX) to one-time capital items (CAPEX), the operator can achieve a total cost of ownership savings of up to 10-times when comparing the 10-year NPV of a small cell to that of a macrocell.

Small cell solutions must be designed to meet city zoning requirements.

The small cell advantage is even more pronounced if we include the cost of new RAN spectrum that would be required to increase the capacity of a macrocell network to the levels achieved in a small cell.

FULLY INTEGRATED SMALL CELL SOLUTIONS

With small cell networks operating at street level, existing towers cannot be utilized and operators must establish new installation locations on non-traditional structures – including street light poles, traffic light poles, bridges and the exterior walls of buildings. In order for the small cell units to operate in these locations, they must be fully integrated environmentally hardened outdoor units containing the base station, backhaul radio(s) with independently aligned antenna arrays, battery backup, environmental alarms, and in many cases local switching capabilities.

Running fiber to street lights and other small cell sites could cost up to 50X more than a high-

capacity wireless backhaul solution.

Having a single unit to deploy means less cabling, simple alignment, and a rapid, single-visit installation. This offers a significant operational and cost advantage over multiple-box small cell solutions which require multiple site visits from different installation crews, complex cabling and power.

The placement and high visibility of the small cell units mean that operators must comply with a range of city zoning requirements. These generally dictate that street light pole-mounted equipment must be within a single enclosure with strict space and weight requirements. In addition, aesthetics are an important element – the units must blend into the urban environment.

Backhaul is perhaps the greatest challenge in any small cell network. The unique locations where small cell units are installed mean that operators need to have a flexible backhaul strategy. The primary small cell backhaul options include fiber, in-band wireless and microwave.

Given that most small cells are deployed in high tele-density urban areas, fiber would seem to be an obvious, future-proof choice. In reality, while fiber is typically abundant in urban regions, it is rarely present where small cell units are deployed; street light posts and the exterior walls of buildings rarely have fiber in place and running fiber to these locations presents significant challenges in terms of cost, time-to-deploy and city permits. If an operator was inclined to trench new fiber to each small cell location at a cost of more than $100 per foot, a single run would cost up to 50-times more than an alternative high capacity wireless solution like microwave.

In-band wireless, where a portion of the access spectrum is used for backhaul traffic, offers another backhaul option. The advantage here is the ability to leverage existing spectrum asset; the disadvantage is that such spectrum is extremely valuable and typically best reserved for delivering revenue generating services. In addition, combining access and backhaul functions within a Time Division Duplex (TDD) construct results in lower backhaul throughput and introduces delay, making it unsuitable for many real-time applications.

With the many constraints of alternative backhaul options, out-of-band wireless solutions often offer the most compelling option when it comes to small cell backhaul.

The advantages and disadvantages of alternative backhaul frequencies.

Microwave Backhaul for SMALL CELL

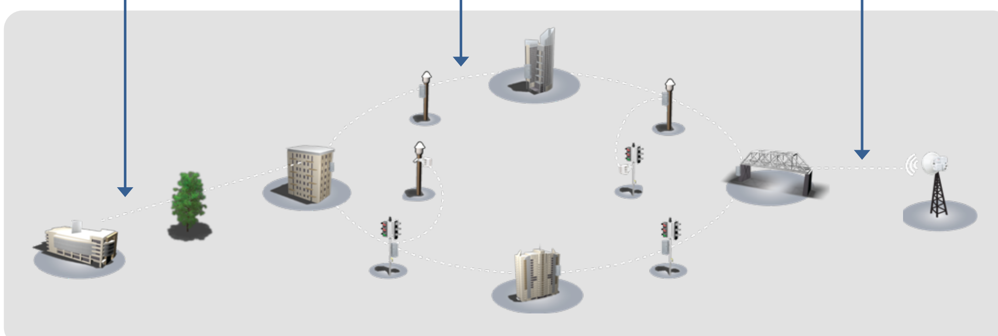
Microwave backhaul offers several benefits in small cell architectures. By using dedicated frequencies, operators can maximize the use of their high-value access spectrum to deploy new services and increase revenue. In areas where fiber is not present, microwave backhaul links can be established quickly and cost effectively, with complete integration of all radio, modem and antenna elements within the small cell unit.

Flexible Frequency Support

The importance of small small cell package sizes that are optimized for street light pole-mounting and comply with city zoning restrictions, demand small (typically sub-1 foot), high-gain antennas. This, coupled with the need for minimal interference, generally leads to licensed higher frequency use, as outlined in the table below.

Small cell solutions or platforms should support a range of backhaul frequencies to ensure optimal performance in difference deployment scenarios.

Sub-6 GHz	24 – 42 GHz	60/80 GHz
• Non-line-of-sight applications • Lower capacity links • Potential for self-interference • Low cost	• High capacity links • Stringent SLA requirements • Good line-of-sight (weave back and forth down streets) • Can handle longer spans • Require area licensing for small antennas	• Areas where frequency congestion is an issue and/or self-interference must be minimized • Suitable for shorter spans • Minimum size restrictions on 80 GHz antennas in some regions



Simple installation, management and scalability

As show above, sub-6 GHz frequencies are not optimal for high-capacity small cell backhaul but can provide an option for low capacity links where a direct line-of-sight is not possible. Unlicensed frequencies such as 5.8 GHz are subject to a large amount of street level interference, rendering this band unreliable for mobile backhaul applications. Other sub-6 GHz licensed frequencies use valuable access spectrum which is better used to deliver services. In addition, these solutions generally employ point-to-multipoint architectures with fewer redundancy options, resulting in lower availability than a ring or mesh solution. Lastly, these systems are subject to higher levels of self-interference, greatly impacting performance.

Packet-based performance

24–42 GHz microwave backhaul delivers a strong combination of capacity (with some systems supporting multi-gigabit throughput), reach and highly reliable licensed operation. 60/80 GHz systems are ideal for locations where frequency congestion is an issue and only short spans are required. This is particularly true when these systems are coupled with very small antennas (under 5”), which offer an attractive form factor but are only able to provide reliable connectivity over very short hops.

Multi-beam backhaul support is a critical requirement in small cell solutions.

When it comes to small cell backhaul, there is no singular solution for all circumstances. What is most important for operators is to adopt a small cell platform that can accommodate a range of backhaul frequencies from NLOS up to millimeter wave, to ensure optimal performance across all small cell deployment locations.

Simple Installation

Microwave backhaul solutions for small cell networks must be hardened, all-outdoor units with radio, modem and power supply fully integrated into an urban-landscape-friendly small cell package. An independently aligned backhaul antenna array with simple Receive Signal Level (RSL) readings ensures rapid installation and configuration.

These microwave systems should also offer simple remote scalability to several hundred Mbps capacities – particularly for aggregation links. Advanced radio features such as adaptive modulation and high modulations in all channel sizes are essential in meeting the requirements of next generation access networks.

Site availability, city layout and capacity requirements will all influence the small cell backhaul architecture.

With the majority of small cell deployments expected to leverage 4G mobile technology, IP-based backhaul systems will offer the most attractive performance and economics for these networks.

Multi-Beam Backhaul for Flexible Network Architectures

The nature of small cell deployments, and the line-of-sight requirements of microwave, will demand flexibility in the backhaul network architecture. Links will either zigzag along streets, from street corner to street corner or they will connect back to a high point (such as the top of a building) in the network. Depending on pole availability, line of sight options and availability requirements, a combination of topologies will likely be utilized. These include hub and spoke, daisy chain, ring and mesh as shown in figure 5.

Support for various network topologies is enabled by multi-beam backhaul systems, which offer independently aligned antenna arrays for complete nodal capability and deployment flexibility. Single radio backhaul solutions do not support advanced network topologies such as carrier-grade ring and mesh configurations.

Small cell platforms supporting up to 400 Mbps per backhaul beam-path (1.2 Gbps aggregate capacity) deliver the level of scalability required for future capacity needs.

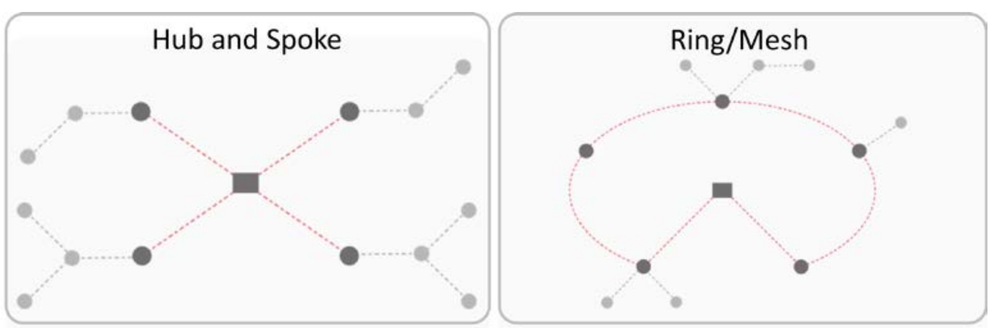


Figure 5: Network topologies. The rectangles represent the high-point in the backhaul node that is an exit point for the small cell layer.

Conclusion

Just as we have seen a trend towards distributed architectures in computing and content delivery, a similar shift is taking place in wireless networks. Small cell networks will allow operators to provide better in-building coverage, maximize the use of their precious spectrum and scale their capacity to levels previously seen only on wired networks.

Integrated small cell platforms offer a flexible, simple and cost effective solution for small cell networks. By combining all of the access, backhaul with multi-beam antenna arrays, switching and power requirements of an operator site into a single zoning-friendly all-outdoor unit, service providers can rapidly increase the density of their mobile coverage and deliver high-value services, while dramatically reducing their cost per bit.

[1] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update (2011-2016), 2012
[2] Cisco VNI, 2012
[3] Where will an increase in cellular capacity come from?, Senza Fili Consulting & Arraycomm, 2011
[4] Mobile Broadband Capacity Constraints, Rysavy Research, 2010