# White Paper

# The Road to 4G is Easier with Microcellular Solutions



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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<sup>1</sup>. While it is increasingly difficult for service providers and analysts to predict future demand, a recent forecast shows 26-fold increase in mobile traffic by 2015<sup>2</sup>. 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.



#### Mobile Network Supply vs. Demand

Sources: Cisco Visual Networking Index, DragonWave internal analysis.

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<sup>3</sup>. The vast majority of the capacity improvements have been achieved through increased cell density.

Mobile traffic is expected to increase 26-fold by 2015.

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



Many service providers are thus addressing the mobile capacity challenge by deploying smaller cells (or microcells) as an underlay to their macrocellular networks. These microcell 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 microcellular 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 microcellular architectures, followed by an examination of integrated microcellular solutions designed to address the deployment challenges of small cell networks. Lastly, the paper discusses microcell backhaul alternatives and highlights the key requirements for microwave-based microcell backhaul solutions.

#### MICROCELLULAR NETWORKS: OVERVIEW

As a dense underlay to the macrocellular layer, microcellular 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.



Figure 2: Microcell Underlay Network

Initial microcell 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, microcells 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

Microcell networks are a high celldensity underlay to the macro-cell layer.

The future of microcell networks lies in fully integrated solutions.



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 microcellular 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.

### MICROCELLULAR 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.

Microcellular 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 microcellular layer.



Figure 3: Macrocell vs. Microcell density and capacity.

As show in figure 3, the target capacity for a microcell 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), microcellular 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.

Aggregate microcell capacity far exceeds macrocell capacity while using existing spectrum allocations.



#### **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<sup>4</sup>. With most operators holding between 50 and 100 MHz of spectrum, there will clearly be a shortfall based on current architectures.

Microcelluar networks present a compelling solution to this spectrum shortfall. Smaller cells allow for a large reduction in transmit power, enabling operators to reuse RAN spectrum within the microcellular 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 microcells – 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 microcellular systems offer several important operational and capital cost advantages over macrocell networks, as show below in figure 4.



| Microcell 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 microcellular and macrocellular networks.

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

OPEX.

Unlike macrocell networks, the cost distribution of microcellular is more heavily weighted to CAPEX rather than



Depending on the region and deployment location, site leasing, civil works and power costs all generally greatly reduced for an integrated microcell unit when compared to traditional cellular networks which involve multiple boxes at the tower site. 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 microcell to that of a macrocell.

The microcell 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 microcell.

#### FULLY INTEGRATED MICROCELLULAR SOLUTIONS

With microcellular 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 microcell 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.

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 microcell solutions which require multiple site visits from different installation crews, complex cabling and power.

The placement and high visibility of the microcell 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 microcell network. The unique locations where microcell units are installed mean that operators need to have a flexible backhaul strategy. The primary microcell backhaul options include fiber, inband wireless and microwave.

Given that most microcells 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 microcell 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 microcell location at a cost of \$150 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

Fully integrated microcell platforms provide flexible deployment options and rapid installation.

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

Microcell solutions must be designed to meet city zoning requirements.

Running fiber to street lights and other microcell sites could cost up to 50X more than a highcapacity wireless backhaul solution.



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 microcellular backhaul.

#### MICROWAVE BACKHAUL FOR MICROCELLULAR

Microwave backhaul offers several benefits in microcellular 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 microcellular unit.

#### Flexible Frequency Support

The importance of small microcell 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.

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

As show above, sub-6 GHz frequencies are not optimal for high-capacity microcellular 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

The advantages and disadvantages of alternative backhaul frequencies.



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

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.

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

#### Simple Installation

Microwave backhaul solutions for microcellular networks must be hardened, alloutdoor units with radio, modem and power supply fully integrated into an urbanlandscape-friendly microcell 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.

With the majority of microcell 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 microcellular 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 4.

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

Simple installation, management and scalability

Packet-based performance

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



network topologies such as carrier-grade ring and mesh configurations.

Microcellular 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 4: Network topologies. The rectangles represent the high-point in the backhaul node that is an exit point for the microcellular 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. Microcellular 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 microcellular platforms offer a flexible, simple and cost effective solution for microcellular 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.

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

<sup>&</sup>lt;sup>1</sup> Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update (2010-2015), 2011

<sup>&</sup>lt;sup>2</sup> Cisco VNI, 2011

<sup>&</sup>lt;sup>3</sup> Where will an increase in cellular capacity come from?, Senza Fili Consulting & Arraycomm, 2011

<sup>&</sup>lt;sup>4</sup> Mobile Broadband Capacity Constraints, Rysavy Research, 2010