Wireless Backhaul Solutions for Small Cells

High Capacity Comes In Small Packages

Abstract

Small cell sites, known as microcells, picocells, and femtocells, are set for widespread deployment in order to improve mobile data coverage. Small cells present backhauling challenges that differ from those of traditional macrocells. This application note reviews these challenges, and presents Ceragon's family of small cell wireless backhaul systems.

Introduction

As the popularity of data-oriented cellular devices and applications continues its rapid rise, mobile network operators are experiencing difficulty meeting traffic capacity demands. Despite the introduction of advanced 4G/LTE mobile technologies into their networks, operators' forecasts show that additional steps are required to enhance capacity and maintain current quality of experience levels.

As a result, operators have begun to introduce small cells into their networks in order to keep up with demand. Small cells, available in micro, pico, and femto varieties, operate at higher frequencies, and offer greater bandwidth then their "macro" counterparts. Costs are reduced as small cells circumvent the need to deploy cumbersome and expensive new base stations.

Offering full compatibility with macrocells, small cells can be used to provide a second layer of coverage in 3G and LTE networks, resulting in higher throughput and data rates for the end-user, while improving performance at the cell's edge. Small-cell stations use less energy than macrocells and have a far smaller physical footprint, allowing them to be easily hidden from view.

Small cells enable further improvements in network coverage, allowing additional access points to be placed in public access areas such as shopping malls, inner-city business districts, and airports.

In addition, small cell access points are an ideal solution for last-mile backhaul. Small cells can connect buildings and many outdoor locations, providing the 'last-mile extensions' that are often needed for near-line-of-sight (NLoS) solutions.

Comparison of Small Cell Architectures and Requirements

In this section, we look at the different cell sizes and the requirements unique to each of them. The diagram in Figure 1 below illustrates the following points:

1. **RF Powering**. As cell size increases, so does the RF power needed to provide the required coverage. As a result, the base station becomes larger and heavier, and more expensive as well.

2. **RAN Architecture**. Traffic emanating from larger cells is routed over the Radio Access Network (RAN) to the core network through the RNC (via the Iu-b interface). Traffic from smaller cells, most specifically femtocells, may be more efficiently routed over a separate gateway (via the Iu-h interface) using an additional device, such as a Home NodeB Gateway.

3. **Deployment and Management**. While larger cells are deployed and managed by the mobile operator, responsibility for femtocells usually lies with the subscriber, with potential OPEX implications for the operator.

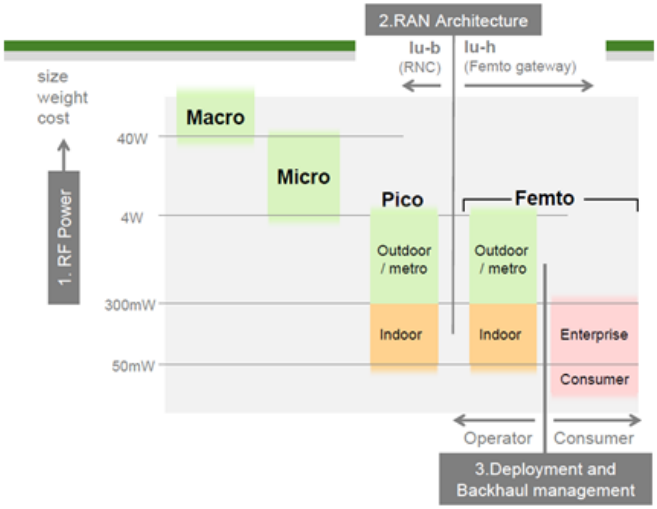

Figure 1: Small Cell Types and Characteristics (Source: NGMN)

The following table summarizes the differences in capabilities and requirements between large and small cells.

Characteristic	Macro / Micro cells	Pico / Femto cells
Coverage	Wide area	Hot spot
Type of coverage	Outdoor coverage	Indoor coverage
Density	Small number of high capacity sites	Large number of lower capacity sites
QoS requirement	High availability	Best effort
Mobility	Seamless mobility	Nomadic mobility (location-based sessions)
Bandwidth flexibility	Multi-band sectors	Sectors support single band only
Orientation	Designed for voice	Designed for data

Table 1: Cell Types and Characteristics (Source: NGMN)

Small-Cell Backhaul Challenges

Implementing smaller cell configurations raises new challenges for the mobile operator's backhaul planning and operations teams. Whereas fixed-line backhaul solutions provide optimal capacity, operators are generally limited by the lack of copper and fiber availability, as well as by the need to deploy base stations on telephone poles, lampposts, and other structures that limit wireline access. In cases like these, operators in need of quick deployments will generally choose wireless solutions in order to backhaul small-cell traffic.

This section discusses the series of challenges faced by operators choosing to deploy small cells.

Bandwidth Provisioning

From the backhaul perspective, small-cell backhaul traffic is generally lighter than that of macrocells, but traffic levels are expected to increase. Due to the concentration of users close to the site, the backhaul connection may quickly become the bottleneck. Current rule-of-thumb assumptions for picocell sites range from 50 Mbps to 100 Mbps. In addition, small cells will have to deal with a higher degree of burstiness than macrocells.

Availability and redundancy

Small cells can provide capacity enhancement to an existing macrocell. In case of a malfunction in the small cell, the macrocell would still be able to maintain basic services.

When small cells are deployed to enhance capacity within existing coverage, backhaul availability may be more relaxed than for macrocells.

Aggregation layer – increased capacity and availability

While enabling increased network capacity, small cell architectures increase capacity requirements from the backhaul network and may also require additional aggregation sites. Network operators should consider planning aggregation links of at least 1 Gbps, with scalability to 2 Gbps.

Small Footprint and Weight

Smart integration of small cell sites into existing backhaul access points can help lower operator footprint. 'Zero footprint' designs are highly desirable for network operators, as they reduce both installation and site rental costs.

Typical small cell sites should be suited for deployment atop street poles and traffic lights, or mountable on rooftops and walls, necessitating a small form factor for the whole cell site solution, including both the access and backhaul solutions. Weather-proofing is also required.

Line-of-Sight is not Always Available

When deploying backhaul links for small cells, line-of-sight (LoS) may not always be feasible. In urban environments, it may well be impossible. Alternatives to point-to-point wireless backhauling must be considered.

Backhaul Access Points

The location of small cells vis-à-vis their backhaul connection points is an important consideration for operators. Locating the small cells nearer to subscribers makes access to backhaul hubs more difficult. While a high proportion of outdoor cells can be reached with LoS microwave links, many indoor links will require NLoS connections.

The following table describes the most common locations for placement of small cell stations:

Cell Type	Backhaul Access Points
Macro	Tower top (or bottom), rooftop
Micro – metro	Mostly outdoor, utility pole, wall, roof
Pico / Femto – outdoor	Street fixtures, rooftops, walls, overhead cables, utility poles
Pico / Femto – indoor	Backhaul to the building, then use internal wiring or backhaul direct to the small cells
Femto – enterprise	Office, factory, shop, café
Femto – consumer	Home

Table 2: Location to backhaul for the different type of cells (source - NGMN)

Dense Areas and Spectrum Availability

While small-cell use improves capacity and availability, the increased cell density adds complexity to existing backhaul networks, as the proximity of cell sites creates possible interference issues. In addition, spectrum reuse requires special attention as the deployment of small cells increases, as additional frequency pairs are added to the backhaul system.

Cost-effective Solution

Significant cost reduction is required for the small cell backhaul network. Since many small cells are required to provide the coverage of a single macrocell, many new backhaul links must be deployed to carry their traffic. In order to maintain a targeted cost-per-bit, dramatic per-link savings must be accomplished.

Operators can benefit here from the lower availability requirements of small cells, thanks to the higher reliability of existing macrocells. Small cell failure will reduce capacity, but will not result in service outages.

Other Requirements

- "Green" solutions – offering reduced power consumption.
- Flexible network architecture – backhauling infrastructure should be easily adaptable to chain, ring, and point-to-multipoint topologies.

- Installation and commissioning – new station deployment should be quick and cost effective.
- Operation, administration and maintenance – similar to that of macrocells
- Scalability – traffic demand will double every year, but the exact locations of the increases may not be known in advance. Backhaul solutions need to be scalable and flexible, in order to keep up with rapid traffic growth rates.
- Packet based – for 4G and LTE-ready support

Summary of Small Cell Backhaul Requirements

The following table provides a brief summary of small cell backhauling requirements:

Backhaul Requirement	Compared to Macrocells	Notes
Cost	Cheaper	Cost per link should be lower. Cost per bit may be similar.
Capacity	Traffic load is lighter but burstier	Small cells generate less backhaul traffic than multi-cell/mode/band macrocells, but the traffic is much burstier.
Scalability	More scalable	Faster growth requires rapid deployment despite shorter lead times.
Latency	More delay tolerant	Delay sensitivity depends on service level expectations. Femtocells are designed to cope with lower quality connections. Femtocell handover is less important.
Availability	“Five Nines” not needed	Small cells will form an offload underlay to a higher-availability macrocell.
Size & Weight	Smaller and lighter stations	Small cells require deployment in locations with limited space availability. Compact backhauling solution is essential.
Access to Backhaul	More difficult	Small cells are close to users – on the street and indoors, relatively far from backhaul sites. These sites are harder to reach than tower-based macrocells.
Installation & Commissioning	Faster, simpler, cheaper	Consumer femtocells are plug-and-play. Femtocell backhauling should also work this way.

Table 3: Summary of Small Cell Requirements (Source NGMN)

In short, successful small-cell deployments require integrated solutions that offer small footprints, easy installation, and a cost-effective price structure.

Ceragon's Small Cell Backhaul Solutions

In this section, we introduce Ceragon's small cell backhauling solutions, and show how they meet the challenges described above.

Overview of Solutions for Small Cell Backhaul

The following backhaul solutions for small-cell deployments are currently available on the market:

- Traditional microwave (6-42 GHz)
- Sub 6 GHz microwave – either point-to-point or point-to-multipoint
- "Light" licensed millimeter wave (E-band) microwave (70-80 GHz)
- Unlicensed millimeter wave (60 GHz)
- Copper wire xDSL
- Fiber optics
- Free space optics
- Cable / DOCSIS

We assume that every technology is best suited for specific scenarios, and that multiple solutions will be used on any given operator network.

This application note focuses on Ceragon's wireless backhaul offerings, which correspond to the first three points on the above list, and include both point-to-point and point-to multipoint solutions.

Point-to-point backhaul solutions

In addition to traditional licensed microwave technologies (6-42 GHz), Ceragon offers two main alternatives for point-to-point backhauling:

- Millimeter wave (E-Band) solutions
- Sub 6 GHz solutions

E-Band point-to-point solution characteristics

Ceragon's E-Band offering, the FibeAir-70, is a line-of-sight solution that can be deployed in dense urban environments.

- Supports wireless backhaul chains between street poles
- Very high capacity – up to 1.2 Gbps
- Backhaul ring topologies are supported
- "Green" design and small form factor
- Attractive licensing scheme ("light licensing")
- Abundance of spectrum
- Narrow beam-width, higher reuse factor
- Line of sight solution
- Two- or three-way wireless backhaul systems with integrated LTE Picocells

Figure 2: Ceragon's E-Band Solution

Sub 6 GHz point-to-point solution characteristics

Ceragon's sub-6 GHz solutions, the FibeAir-2000, offer medium-capacity point-to-point links that do not require line-of-sight connectivity.

- Wireless backhaul chains between street poles
- Unlicensed or licensed (such as 3.5GHz) solutions are available
- Reuse/ usage of access frequencies is possible – for example, unused WiMAX frequencies
- NLoS solution
- Capacity of up to 200 Mbps

Figure 3: Sub 6 GHz Links on an Urban Street

Figure 4: Sub 6 GHz Deployment on a Lamppost

Sub 6 GHz point-to-multipoint solution characteristics

Ceragon's sub-6 GHz point-to-multipoint backhaul platform, the FibeAir-2500, uses a wireless hub-and-spoke (tree) architecture to connect a centralized site (for example, a macrocell site) and low-cost CPE-based access points (for example, picocells)

- 200 Mbps capacity
- Point-to-multipoint link ensures that the sum of access link capacities will never overload the system uplink.
- Point-to-point solutions can be integrated in this solution – both for aggregation backhaul of both the small cell sites and the macro sites, or as a point-to-point access chain.
- Unlicensed or licensed (such as 3.5 GHz) solutions are available.
- Single-hop transmission ensures low delay and delay variation.
- Reuse of access frequencies is possible – for example, unused WiMAX frequencies.
- NLoS solution.

Figure 5: Sub 6 GHz Point-to-Multipoint Backhaul Links

Licensed 6-42 GHz Point-to-Point Aggregation Links

Ceragon provides traditional licensed 6-42 GHz wireless links for backhaul aggregation, offering an ideal solution for the aggregation layer, where distances and availability are crucial. Linking centralized sites, such as macrocell sites, this solution enables 1 Gbps capacity, supporting increased service availability. In addition, it can be used to backup wireline backhaul links when required.

Ceragon's high capacity backhaul solution is optimized for a number of different small-cell aggregation scenarios:

- Compact all-outdoor point-to-point licensed radio with advanced features and high system gain (FibeAir IP-10C).
- Compact 4-radio solution, supporting 4+0 configurations, with up to 1 Gbps of capacity per radio channel (FibeAir IP-10Q).

Ceragon backhaul aggregation solutions help network operators to meet the growing demand for capacity and availability of mobile internet services in urban areas.

Ceragon Backhaul Offering Decision Matrix

Table 4 (below) highlights the capabilities of each of the small-cell backhauling solutions:

	mm Wave 60 GHz	E-Band 70-80 GHz	Point-to-Point Sub-6 GHz	Point-to-MultiPoint Sub-6 GHz
Main pros	Unlicensed, higher capacity, high frequency re-use factor	Inexpensive license, higher capacity	Both LoS and NLoS solutions	Enables high peaks to individual cells without needing to overprovision Easier Installations – CPE only
Main cons	Requires LoS, very short links	Requires LoS	**Licensed sub 6 GHz:** Expensive, medium capacity **Unlicensed sub 6 GHz:** Medium capacity	Hub and spoke configuration only Backhaul topology is more limited
Capacity	Multi Gbps	1.2 Gbps	200 Mbps Aggregated	200 Mbps Aggregated
Backhaul licensing	Unlicensed	Light License	Licensed (3.5 GHz) / Unlicensed	Licensed (3.5 GHz) / Unlicensed
Line of Sight	LoS only	LoS only	LoS / NLoS	LoS / NLoS
Backhaul network topology	Chain, Ring (PtP)	Chain, Ring (PtP)	Chain, ring (PtP)	Hub and spoke (PtMP)
Installation Type	Street poles / rooftop / wall / traffic light…			
L2 switching capability	N/A	Yes		
Terminal power consumption	N/A	20W	15W	20W

Table 4: Wireless Backhaul Alternatives for Small Cells

All of the above alternatives are effectively aggregated by Ceragon's licensed 6-42 GHz point-to-point solutions, which provide capacities of over 1 Gbps, and unparalleled reliability.

Summary

Ceragon foresees significant growth in the use of small cells, and is intent on providing market-leading backhaul solutions for operators wishing to improve service to mobile data subscribers. Ceragon's small cell backhaul portfolio includes a variety of cost-effective solutions that provide operators with optimal flexibility in meeting their unique physical, networking, and regulatory challenges.

Microwave Technology	Ceragon's Backhaul Platform
Traditional microwave (6-42 GHz) for the access and aggregation layers	FibeAir-IP 10 / Evolution IP Long Haul
Millimeter wave (E-band) microwave (70-80 GHz) links offering simplified licensing	FibeAir-70
Sub 6 GHz microwave links – point-to-point or point-to-multipoint	FibeAir-2000/ FibeAir-2500 correspondingly

Table 5: Ceragon Small Cell Product Family

About Ceragon

As the world's #1 wireless backhaul specialist, Ceragon Networks (NASDAQ: CRNT) ensures that mobile and fixed-line carriers as well as private network operators, have the transmission capacity to deliver the voice and premium data services that we all rely on. Ceragon's commitment to research and development allows us to develop generation after generation of innovative solutions for our customers. With unmatched technology that increases capacity while lowering cost, Ceragon's advanced microwave systems allow wireless service providers to evolve their networks effectively from circuit-switched and hybrid concepts to all-IP networks. Ceragon's solutions are designed to support all wireless access technologies, delivering more capacity over longer distances under any given deployment scenario. Ceragon's solutions are deployed by more than 430 wireless service providers of all sizes, and hundreds of private networks in more than 130 countries. Visit Ceragon at www.ceragon.com.