White Paper

Microwave Technology Innovations Enabling Efficient and Homogeneous LTE Macro & Small-Cell Backhaul

Contents

1. Executive Summary

Microwave (MW) technologies lead the backhaul evolution toward next-generation mobile networks. While primarily considered as macro-cell backhaul solution, in the upcoming 4G mobile network landscape, MW technologies also extend to the small-cell layer, hence proposing a unified backhaul approach. Two, very significant innovations are introduced:

- New, high-capacity backhaul nodes aggregate traffic in the critical points of the backhaul network with dense radio links on towers. The new nodes considerably reduce equipment footprint, both in the antenna mast and indoors. Furthermore, these nodes are capable to support every PtP and PtMP architecture, thus extending operation to the area-licensed spectrum MW bands. More importantly, such telecom-grade equipment considerably reduces operation and network management complexity and costs.
- Field-proven MW technology is re-engineered to a more compact and aesthetically-pleasant form factor, suitable for street-level deployment and small-cell backhaul applications. All the benefits of MW spectrum are preserved, while new, game-changing auto-alignment and auto-provisioning features come into play.

MW technologies, when supported by innovation and flexible architecture, can best fit the diverse mobile backhaul scenario requirements.

2. Introduction

Mobile broadband penetration is growing at a remarkable rate worldwide and as a consequence data traffic in mobile networks is booming. To cope with increased traffic demand, especially in urban areas, mobile networks architecture has been redesigned, whilst the introduction of new technologies (e.g. LTE) has been combined with the adoption of new network design paradigms.

Enhancing macro-cell capacity with more spectrum, more sectors and advanced antenna systems is not sufficient. Operators now really need to:

- integrate other data access technologies, such as WiFi in the so-called Het-Nets,
- enhance indoor capacity with femto, micro and pico cells, and finally
- add outdoor small cells,

supplementing the macro layer and offer much more capacity to indoor and outdoor hotspots.

An essential task when designing such a high-capacity mobile access networks is the selection of the best backhaul technology mix. There are a wide variety of technologies and solutions available as carriers for backhauling traffic. Operators might adopt more-than-one technologies deploying each where most appropriate. It's critical though for the backhaul network to meet specific cost, coverage and capacity objectives, without compromising service quality.

Wireless technologies, such as MW Point-to-Point (PtP), MW Point-to-MultiPoint (PtMP), and millimeter-Wave (E-Band/V-Band), provide operators the best options when it comes to implementing combined macro-cell and small-cell backhaul. With respect to wireline solutions, wireless-based backhaul can reach any area while featuring:

- High Capacity – Up to 2 Gbit/s per link
- High Reliability – Up to 99.999% link availability
- Lower CapEx
- Faster deployment
- Higher flexibility, using the right topology mix tailored to network needs.

Intelligent MW backhaul solutions in particular, providing flexible multi-point (PtP / Relay / PtMP) topologies are of utmost importance in supporting high-capacity, last-mile access and aggregation networks at the macro and small-cell layers.

The purpose of this paper is to:

- Explain how the changing Radio Access Network topology affects backhaul transmission, where a convergent solution is needed to bridge the gap between the demands of the past with the emerging LTE upcoming demands.
- Elaborate how the MW backhaul technology innovations can further speed up small-cell deployment, capitalizing on the vast knowledge and expertise gained by operators worldwide from planning, deploying and optimizing MW technologies.

3. Establishing a Solid Foundation for Unified LTE Backhaul with the MW Converged Backhaul Aggregation Node (CBAN)

MW PtP is preferred for LTE macro-cell backhaul as it offers a number of advantages already appreciated by mobile operators:

- Mature, field-proven technologies that anyone can trust.
- Cost-effective backhaul over fiber enabling rapid deployment and network rollout.
- Massive capacity up to 2 Gbit/s per link through the support of higher modulation schemes (1024-QAM /4096-QAM) and the use of advanced radio techniques (XPIC, RLA).
- Top-notch reliability over NLOS / unlicensed technologies based on spectrum licensing. Even higher service availability can be realized with 1+1 HSB protected configurations and Ethernet rings.
- Higher nodal capabilities allowing the aggregation of traffic from many surrounding mobile Base Stations.
- Advanced IP networking with standard-based Ethernet operation and management features as well as full multi-service capabilities for legacy traffic.

The above features make licensed MW PtP the ideal solution for macro-cell LTE backhaul, best fitting high-capacity mega-cells and Advanced Antenna Systems (AAS) applications. Interestingly, *the functionality of nodal solutions can now be extended to leverage synergies among best-of-breed MW technologies*.

CBAN (Converged Backhaul Aggregation Node) from Intracom Telecom is such a solution integrating every available MW backhaul technology while meeting smart design and development objectives:

Combine MW PtP, extended PtMP and E-Band solutions in one node. The Intracom Telecom CBAN platform can simultaneously support all types of wireless technologies – PtP and PtMP, MW and millimeter-Wave – allowing seamless interworking among different technologies, and aggregating all networking functionality in Ethernet and TDM interfaces toward the operator transport network.

Utilizing split-mount and all-outdoor radios. CBAN can support split-mount PtP systems, as well as all-outdoor systems using power on Ethernet modules. In this way, CBAN can be used as an aggregator, for both Intracom Telecom and any other vendor equipment, allowing operators to use a single aggregation site for different technologies / vendors.

Unifying operator planning & design works for macro and small cells. CBAN can be collocated with a macro-cell Base Station. With its PtMP and E-Band capabilities, CBAN can serve a multitude of small cells supported by this macro-cell. Considering its high-capacity PtP links, CBAN can also backhaul all traffic generated by both the macro and the small cells.

Simplifying operation & maintenance activities. By offering operators the ability to aggregate different technologies in one unit, and by providing a single network interface toward the transport network, CBAN serves as a single reference point for bulk network connectivity.

Providing unified network & service management. All elements of the CBAN application are managed by a single unified management suite, uni|MS™, allowing operators to use a single platform to manage diverse wireless technologies.

Optimizing Total Cost of Ownership (TCO). When an operator can utilize multiple wireless technologies converged over a single platform (with one management suite, all from the same equipment vendor), the benefits of building a network solution, optimizing network design based on actual needs, and maintaining & troubleshooting the network, are maximized.

A typical CBAN application is depicted below, in Figure 1. PtP, E-Band and PtMP technologies are concurrently used to provide efficient backhaul for macro-cell and small-cell combined applications.

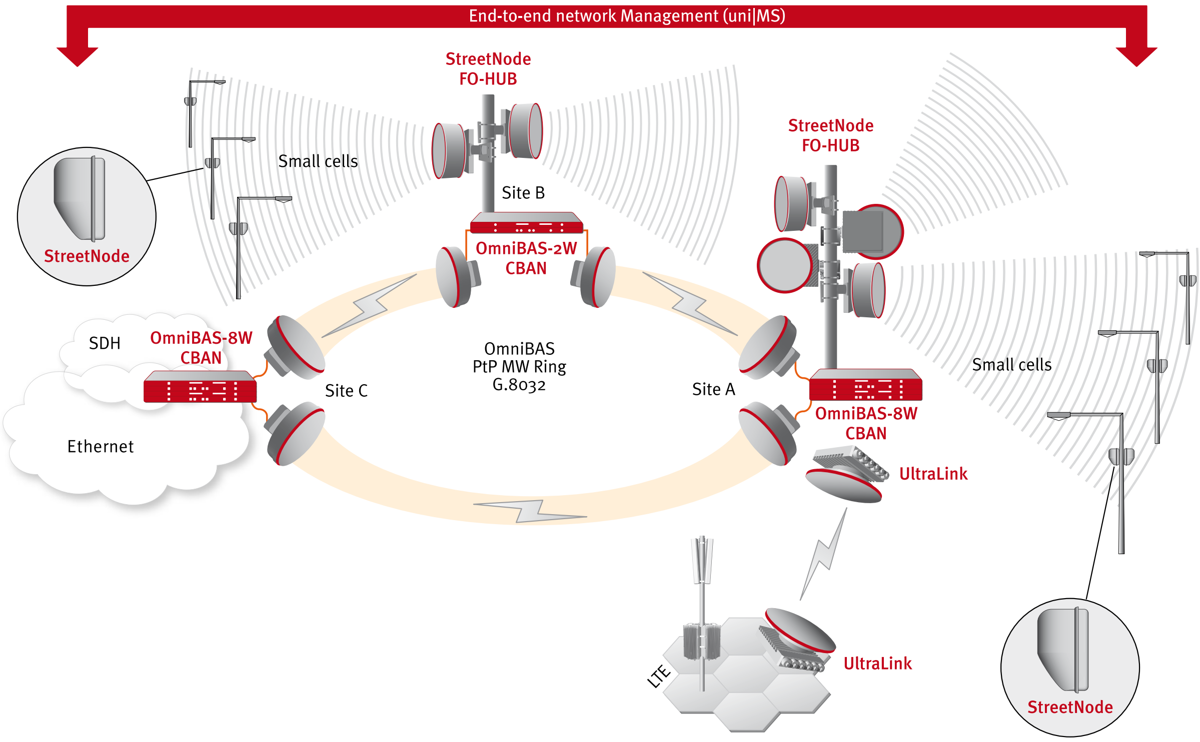

Figure 1: Converged Backhaul & Aggregation Node

4. Accelerating Small-Cell Deployment with MW Backhaul Technology Innovations

4.1 Introducing the Small-Cell Layer

The main mobile network evolution trend is the deployment of compact-form, purpose-located (for local service) Base Stations, the so called “small-cells”. Complementary to the LTE-enhanced macro-cell layer, small-cells will be deployed at street level to enhance the 4G network capacity at “hotspots”. These service hotspots, based on UMTS/LTE/WLAN technology, are expected to be deployed at a ratio of 2 to 5 per macro-cell. Compared to the macro-cell mobile network, which has gradually been built over the years, small-cells are to be deployed within a relatively-shorter time frame.

The existing mobile network, consisting of the macro Base Stations and the associated radio backhaul network, is traditionally deployed on building rooftops. The macro-cell backhaul layer typically extends 20 m to 30 m above the ground level in urban areas.

On the contrary, small-cells will be deployed at street level, on lamp posts or building walls, at approximately 6 m to 9 m above the ground. This is a greenfield 4G service layer, and therefore a new street-level backhaul service layer is required (Figure 2).

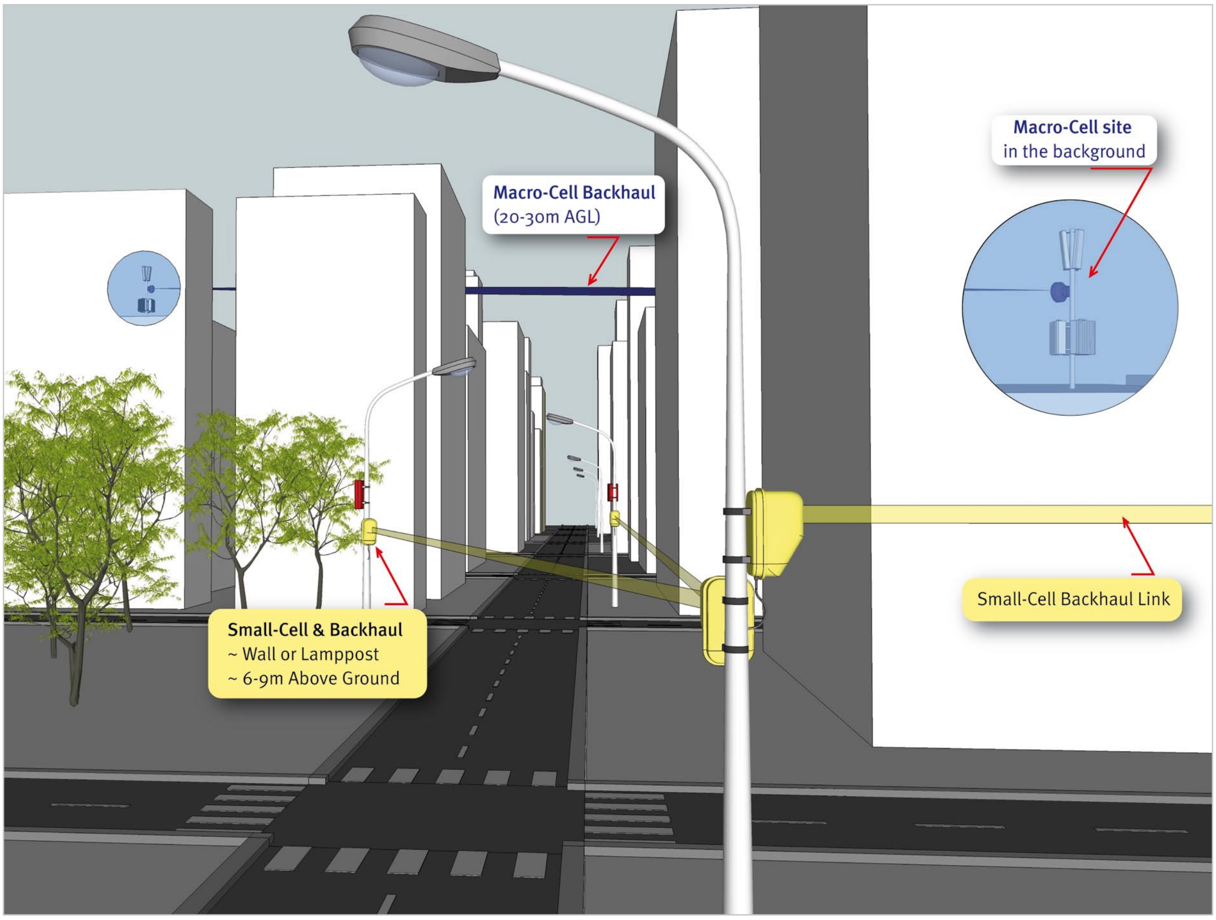

Figure 2: Street-Level, small-cell Backhaul network view

A small-cell backhaul solution will be based on a fiber and radio technology solutions mix. Fiber cannot be available at every small-cell location, and extending it to all small-cell points-of-presence will be quite expensive and time-consuming. Radio technologies on the other hand can quickly and efficiently establish the required backhaul infrastructure. In particular, MW technologies, in area-licensed spectrum, constitute an ideal solution for small-cell backhaul.

4.2 MW Technology Innovations

MW radio technologies are field-proven and constitute the primary solution for mobile backhaul. The existing research and development ecosystem, as well as the associated hardware and software innovations, can also be used for small-cell backhaul. This approach ensures synergies across the entire mobile backhaul domain. The technology innovations include:

Compact Size: MW radio units can be re-engineered to become highly-compact while having appropriate shape for lamp post or wall mounting. Instead of parabolic antennas, which could raise public concerns, innovative antenna systems are enclosed in an all-in-one box (of less than 4 liters in volume) without any performance tradeoff.

Customized Design: Street-level MW units are optimized by balancing a high system gain and a low power consumption. In reality, the radio link length is constrained by the clutter to hundred of meters, and hence smart system design not only satisfies complex connectivity scenarios, but also reduces interference contamination, as well as power bill.

Superior Performance: The adverse street-level propagation conditions are addressed with innovative mechanisms capable of mitigating the street-level multipath caused by the moving vehicles. MW backhaul can establish carrier-grade links operating at very high modulation schemes (i.e. 1024-QAM). In reality, 540 Mbit/s full-duplex links are a common practice.

Re-invent Deployment: An innovative internal antenna system performs link auto-alignment, while zero-touch unit provisioning allows retrieving the latest firmware and configuration profile from the NMS server. These features significantly reduce the installation time, as well as human-made errors. A self-test process runs in the background detecting and resolving any issues before the engineers leave the site. Given the difficulty of accessing the lamp posts, typically during low-traffic hours and with the use of special cranes, minimizing the installation time and avoiding site re-visits greatly reduces costs.

Flexible Network Architecture: Software-defined MW radio technologies allow a common, state-of-art system to operate in both PtP and PtMP architecture. The different network profiles (i.e. hub, terminal or radio edge) are realized with distinct firmware and configuration files, using a single unit. Radio planners can leverage this capability to optimize small-cell backhaul networks, realizing any network architecture.

The StreetNode™ unit from Intracom Telecom (see Figure 3) is a distinct paradigm, which employs the already-described MW technology innovations.

Figure 3: The StreetNode™ small-cell backhaul unit

4.3 Exploiting the Value of Area-Licensed MW Spectrum

While the MW spectrum is perceived to be over-utilized for mobile backhaul in the macro-cell layer, there is approximately 6.5 GHz or 3.25 GHz paired (FDD) spectrum available in the 26, 28, 32 and 42 GHz bands. This so called "area-licensed" spectrum, apart from being regulated and unused, it has some distinct advantages for the small-cell backhaul application compared to other options, such as the sub-6 GHz and 60 GHz spectrum. These advantages include:

Regulated Spectrum: The probability of in-band interference from unauthorized parties is eliminated, and it is regulator responsibility to preserve the law. The license-free solutions (i.e. those using the 60 GHz spectrum) may suffer from third-party interference.

Reduced Multipath: Compared to sub-6 GHz applications, the MW radio signals are highly absorbed by the clutter (terrain, buildings), hence multipath effects are greatly reduced. Street-level MW links can sustain carrier-grade, higher-order modulation.

Higher Frequency Re-Use: Since MW signals are highly absorbed by the clutter, the transmitter-inflicted interference to other links in adjacent streets is minimal. A MW small-cell backhaul solution can be implemented utilizing two frequency channels (i.e. 2x56 MHz FDD), as well as the simple radio planning procedure used for macro-cell backhaul. With two channels only, street-by-street frequency re-use is possible.

Reduced Attenuation: Compared to 60 GHz applications, MW frequencies experience reduced propagation attenuation due to rain and oxygen phenomena, achieving higher ranges for the same system gain.

Favorite Licensing Scheme: The area-licensing scheme allows deploying an unlimited amount of backhaul links within a particular area. The spectrum usage fee is fixed, favoring the deployment of dense backhaul networks and typically keeping the per-link cost low.

Macro- / Small-Cell Backhaul Spectrum Sharing: The area-licensed spectrum is already popular among mobile operators who already use it to enhance macro-cell backhaul. The same spectrum (and the same frequency channels) can be re-used for the small-cell backhaul, with minor coordinated radio planning. As depicted in Figure 2, the macro-cell backhaul equipment (shown in the background, behind the front buildings) and the street-level backhaul equipment don't have a direct line-of-sight (LOS). This applies for the vast majority of practical cases and denotes that co-channel interference will be blocked in the direct path or will be absorbed in the multipath.

4.4 Intelligent Small-Cell Connectivity

Deploying a street-level backhaul network on lamp posts and building walls may be a challenging task. The solution must not only reach the small-cells in “difficult” locations within the clutter, flexibly and in a scalable manner, but must also achieve carrier-grade performance with minimum costs.

MW technologies favor a *LOS - multihop - multipoint* approach. By establishing street-level backhaul links, the radio planner is deemed to follow the clutter layout, hence, from a practical perspective, the majority of backhaul links will extend along the streets with a direct LOS available (Figure 4). Deploying MW LOS links can be considered a best practice, as per-hop range, reliability and capacity are maximized, while latency is minimized.

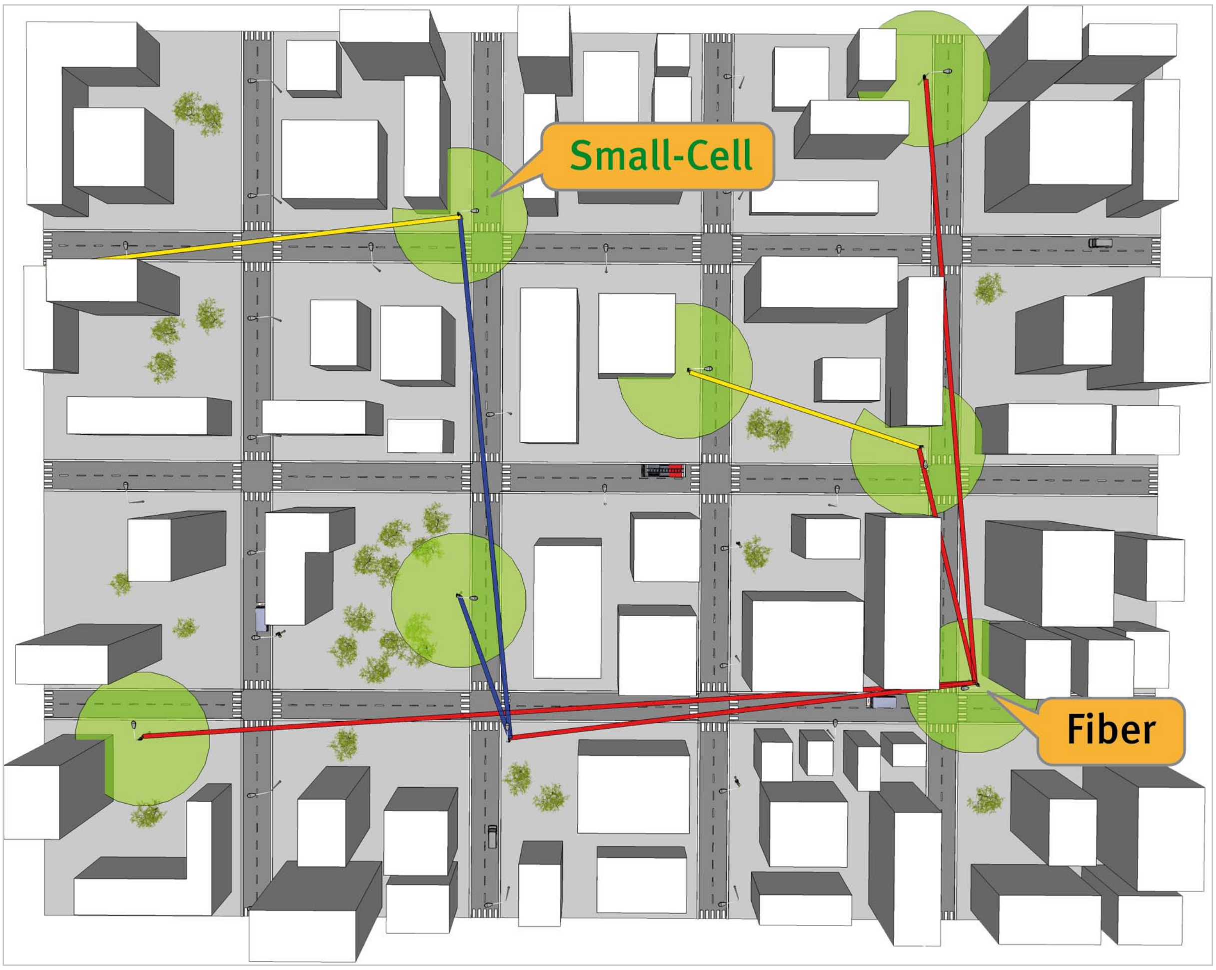

Figure 4: Realistic MW multihop - multipoint small-cell backhaul solution, efficiently extending from the fiber core interface to reach all small-cell locations

In typical urban environments, it is unlikely to have core network fiber interfaces at every small-cell location. From each available fiber network point-of-presence, the MW small-cell backhaul will extend several hops to reach all the regional small-cell locations. A realistic multi-hop network will greatly resemble the one depicted in Figure 4. As previously explained, a single piece of MW equipment will realize flexible PtP or PtMP connections. Figure 5 depicts a different view of the network, from a street-level perspective.

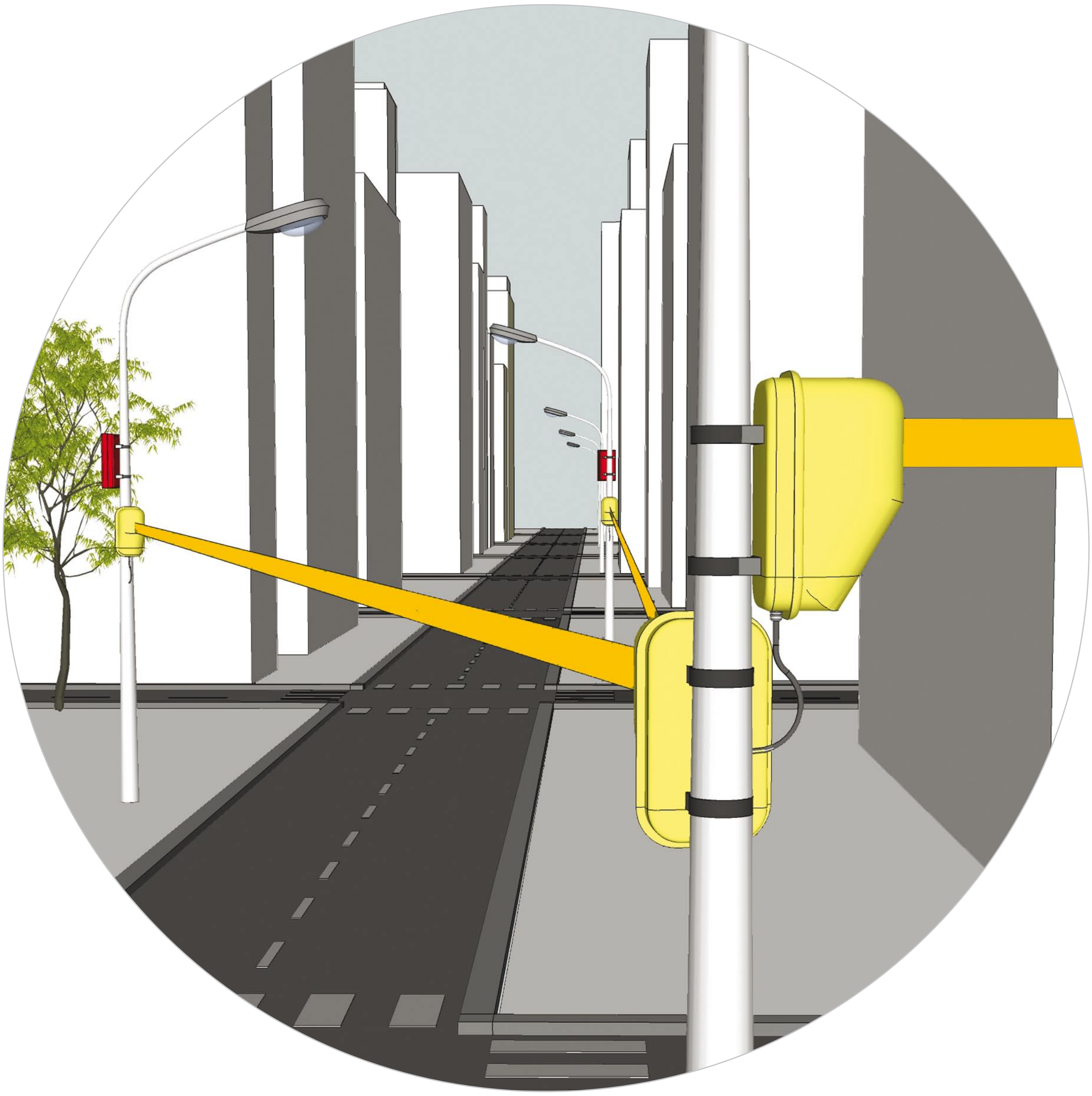

Figure 5: PtP to PtMP relay extension efficiently reaching the two small cells located at the corners

Combining two pieces of equipment, a radio planner can implement relays for use in a multi-hop architecture. In Figure 5, the relay hop is realized with PtMP configuration and by establishing two links with only three units. By adopting PtMP in specific segments of the network, operator can achieve a lower equipment count while reducing CapEx & OpEx.

5. Conclusions

The purpose of this white paper, which dealt with MW technology innovations, was to elaborate the benefits for mobile operators when opting for MW spectrum assets re-use, toward the deployment of an efficient and harmonized backhaul network that spans the LTE macro and small-cell layers.

Almost every mobile operator worldwide is already having assets that can be re-used. The benefits of asset re-use can be gained by:

- Paving the way with a solid unified LTE backhaul foundation by means of MW Converged Backhaul Aggregation Node (CBAN) solutions.
- Integrating wireless backhaul technologies into CBAN solutions; this will offer unique benefits to operators, as well as a powerful toolkit for flexible end-to-end solutions tailored to modular and scalable, high-capacity MW backhaul.
- Accelerating small-cell deployment using smart MW solutions that will facilitate flexible multipoint topologies at street level.

MW technologies can literally accelerate small-cell deployment. This is made possible by introducing innovative, customized small-cell products, and by exploiting the value of area-licensed MW spectrum. StreetNode™, as a distinct representative of best-of-breed MW technologies, not only demonstrates carrier-grade performance, but also offers features that significantly reduce the backhaul network complexity, as well as design, deployment and optimization time.

6. Glossary

AAS	Advanced Antenna System
CapEx	Capital Expenditure
CBAN	Converged Backhaul Aggregation Node
FDD	Frequency Division Duplex
HSB	Hot Standby
IP	Internet Protocol
LOS	Line Of Sight
LTE	Long Term Evolution
MW	Microwave
NLOS	Non Line Of Sight
NMS	Network Management System
OpEx	Operational Expenditure
PtMP	Point-to-MultiPoint
PtP	Point-to-Point
QAM	Quadrature Amplitude Modulation
RLA	Radio Link Aggregation
TDM	Time Division Multiplexing
UMTS	Universal Mobile Telecommunications System
WLAN	Wireless Local Area Network
XPIC	Cross Polarization Interference Cancellation

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