Small cell backhaul: the big picture

An update on small cell backhaul market progress, requirements and solutions

June 2013
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Authors

Julius Robson, Wireless Technology Specialist at CBNL, Leader of the NGMN Small Cell Backhaul Group and Vice Chair of the Small Cell Forum Backhaul Group

Dr John Naylon, Chief Technology Officer, CBNL
1 Executive summary

Public access small cells are now a reality with many trials complete and the first commercial networks switching on across the globe. With a staggering 97.5% of surveyed operators stating that small cells are key for the future of mobile networks, and AT&T announcing deployment of 40,000 public access small cells by end 2015, there’s no doubt that mobile broadband networks are about to undergo a dramatic transformation in their topology. In this paper we take stock of industry progress and provide our insight into what’s really driving small cell adoption, what obstacles are still to tackle, and the best practices that are being developed as networks roll out.

Small cells are not just about capacity. Growth in demand is often cited as the key driver for small cells to provide ever more capacity, since technology is approaching efficiency limits and “we’ve run out of spectrum”. However with all the LTE spectrum being made available, some studies suggest that the capacity crunch might in some regions just be a temporary squeeze. Yet the momentum behind small cells continues to gather pace, showing that the benefits of small cells are wider than only increasing capacity. We look at the bigger picture on what other factors are driving operators to deploy small cells, and how their motivation impacts the style of deployment, and the type of backhaul needed.

Backhaul is NOT a barrier to deployment of small cells is the conclusion from the Small Cell Forum’s extensive analysis of the different solutions. Their new white paper looks inside ‘backhaul toolbox’ and considers in detail each of the different solutions and the scenarios to which they’re best suited. One aspect not covered by the Small Cell Forum document, though, is the total cost of ownership (TCO) of the different solutions. Our fundamental analysis of key cost elements finds that the relative cost of point-to-multipoint (PMP) and point-to-point (PTP) backhaul depends on network density, with the ‘crossover’ point around two small cells per backhaul sector. For higher densities around ten small cells per sector, we see TCO savings of 45% for PMP compared to PTP.

Backhaul is backhaul although operators are looking to small cells to help reduce cost per bit, it is quite clear they are not prepared to compromise on their customers’ quality of experience. This means backhaul connectivity must continue to be ‘carrier grade’, and we must look to improve efficiency in order to cut costs.

They work in trials, but will they scale? Small cell and backhaul trials are underway across the industry with many positive results reported, including some of our own. Whilst trials ‘prove the concept’ works in the real world, they don’t necessarily guarantee they’re ready for wide scale commercial deployment. CBNL’s VectaStar Metro solution brings to the small cell arena the benefits of over a decade of backhauling some of the world’s busiest data networks. We have designed the new VectaStar Metro around the proven principles of the VectaStar platform to provide a high capacity solution that’s rapid to roll out and provides TCO savings when compared to other forms of backhaul.
2 Market progress in small cells and backhaul

The cellular industry is undergoing dramatic changes in order to keep pace with the recent uptick in demand for mobile broadband. New 4G spectrum and technology are being made available, and the network is becoming a smaller place.

*A fundamental shift in cellular topology*

- Small cells now outnumber macrocells\(^1\) and although these are predominately consumer deployed femtocells, it nevertheless marks a fundamental shift in the way licensed spectrum cellular services are being delivered. Macrocells are still the most cost effective way to roll out wide area coverage for high mobility users, but small cells are now needed to focus capacity and coverage depth where nomadic consumers demand it.

*Leading operators are making moves*

- AT&T has announced support for LTE public area small cells and aims to deploy more than 40,000 to cover dense urban areas
- Telefonica O2 deployed small cell Wi-Fi network in London during the summer of 2012, backhauled by CBNL. This demonstrates ability to install and backhaul small cells on street furniture, paving the way for cellular services
- As of November 2012, there were five live commercial public access small cell networks\(^2\), including a small cell LTE network from SK Telecom.

![Image](Image)

*Pictured: Telefonica O2 deployed small cell Wi-Fi network in London during the summer of 2012, backhauled by CBNL.*

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\(^1\) “Small Cells Outnumber Traditional Mobile Base Stations” Informa telecoms and media, Oct 2012, [http://goo.gl/mnrC5](http://goo.gl/mnrC5)

Neutral hosts join the ‘lamp grab’

- Virgin Media has won a contract to deploy metrocells in several UK cities which will initially support Wi-Fi but could be upgraded to cellular in the future.
- Virgin Media UK has announced plans to offer a Small Cell as a Service and has completed extensive trials in the UK. Colt Telecom, Cloudberry Mobile and Clearsky have similar offerings.

Municipalities and real estate owners value their assets

- London boroughs of Westminster, Kensington and Chelsea auctioned rights to street furniture to Telefonica O2 with the requirement to deploy open access Wi-Fi in time for the 2012 Olympics.
- Transport for London are working with independent experts Real Wireless to consider the value of making their assets available for small cell deployment.

Regulators rulemaking to facilitate small cell rollout

- “FCC rules aim to simplify small cell roll-outs”, new proposals to streamline planning processes for mobile broadband infrastructure.
- “FCC details proposals for small cell band in 3.5GHz”.
- “Small Cells Outnumber Traditional Mobile Base Stations”.

Backhaul is front and centre in the SCF’s metro release:

- Small Cell Forum announced at Mobile World Congress 2013, their new release programme which structures their work around the different applications – residential, enterprise, rural and of course metro. One of the key early works within their metro package is the extensive paper on backhaul. More on this later.

In this paper we consider the implications of small cells for backhaul networks. We start by outlining the requirements for backhaul systems intended to provide high capacity connectivity to street level small cells. We then consider the pros and cons of different technology solutions, such as fibre, PMP microwave, PTP microwave, NLOS, millimetre wave, etc.

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3 “Has O2 built the biggest smallest network in the world?”, Alcatel Lucent, Jun 2012, http://goo.gl/jiiLg
3 What’s driving small cell deployment?

Capacity, capacity, capacity… or is it?

The generally understood driver for small cells is that the rapid increase in demand for mobile broadband cannot be met through increases in spectrum and spectral efficiency alone, and that a significant increase in the number of sites is needed to increase capacity through reuse. This is certainly an underlying trend, and over the past 50 years, cell densification has contributed over an order of magnitude more to wireless capacity than increases in spectrum and spectral efficiency combined.

However two recent spectrum studies for Ofcom suggest that in the UK at least, the new ‘digital dividend’ spectrum is taking the pressure off in the short term. Figure 1 suggests no significant up-tick in small cells until around 2020 in a suburban environment. Figure 2 considers the demand for spectrum taking into account increases in spectral efficiency. It shows the peak of spectrum demand in 2011-12 is alleviated by the new allocations.

Figure 1. Spectrum and Capacity Analyses for Ofcom, Sources: Real Wireless

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7 “From Angst to Ambivalence to Acceptance: The Story of how Cellular has Evolved to Embrace Wi-Fi”, M Rumney, M. Lawton, Agilent Technologies Jan 2013, [http://goo.gl/4djAs](http://goo.gl/4djAs)

If overall capacity is not the immediate issue in some markets, then what else is driving operators to make commitments to rolling out small cells in the short term?

**Tackling today’s congested 3G macrocells**

Whilst there may be the potential for high network capacity with LTE, it does not mean that everyone has access to it – consumers will take time to switch tariffs and acquire devices. In the meantime certain 3G macrocells will continue to be congested, and small cells can act as immediate pain relief here.

**Improving consumer quality of experience**

In the context of mobile broadband, the user quality of experience refers primarily to the range of data rates that they might experience in different places and at different times of day. The experienced data rate is partly impacted by the signal quality, but more so by the number of other people sharing the same cell. Small cells improve both of these aspects – they generally improve signal quality across the network by reducing the length and loss of the terminal-base station signal path. They can also reduce the amount of sharing needed. Since small cells have a smaller catchment area, they are much less likely to be widely shared than a macrocell.

**Improving coverage depth**

It’s claimed that 70% mobile traffic is generated indoors, yet most cellular networks are focused on outdoor coverage. Although much of this can be offloaded with Wi-Fi, indoor coverage is still needed for cellular only services such as voice. Small cells down near street level can see better into buildings than their rooftop macro counterparts, and thus provide greater depth of coverage. Taking these difficult to reach users off of the macro layer can also have benefits for network efficiency as discussed below.

**Offloading – or is it ‘onloading’ macrocells?**

One operator told of placing small cells at the edges of their macrocell coverage with the intention of offloading the users with poor user signal quality. To their surprise the

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amount of macro traffic then increased rather than reducing. In this example, the small cells are offloading the low quality users which were slowing things down for everyone. This improved the net spectral efficiency of the macro, and increased the amount of traffic it could support.

**Capacity stimulates demand**

Looking at demand forecasts such as Cisco’s well known Visual Networking Index\(^\text{12}\) would suggest that there is a fixed demand for mobile broadband, and we just need to build enough capacity to satisfy it. However like many things in life, the more you get, the more you want. New wider roads encourage more people to drive, and higher quality mobile broadband encourages increased data consumption. Operators anecdotally report increased traffic levels where they are trialling service enhancing technologies such as LTE and small cells.

**Getting ahead of the curve – the lamp grab**

Even if in some markets the true capacity crunch is a few years away, new technologies and best practices don’t work themselves out overnight. We currently see an industry manoeuvring into position of being ready to scale deployments to keep up with consumers’ ever increasing expectations for quality of experience. Another reason to get ahead of the competition is that many of the suitable street furniture sites are being made available en-masse to only one party. The lamp grab is underway, and both operators and real estate owners need to understand the true value of these assets to make sure the price is right.

**In summary, many motivations**

In summary we see a mix of motivations driving operators to roll out small cells. In the following section we consider how these impact the style of deployment, which in turn has implications for the best practice backhaul solutions.

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http://goo.gl/xxLT
4 Styles of small cell deployment

As we have seen, operators will have a range of motivations to deploy small cells to address different aspects of their service offering, and as a result we will see different styles emerging. Figure 3 summarises these in the form of a decision tree. Consumer and enterprise deployed femtocells are increasingly being used by operators to let the customer upgrade the network where they need it most at the home and the office. Since these will predominantly use leased line backhaul we will not discuss them further in this paper, but focus instead on the operator deployed metrocells, microcells, ‘meadow’ cells and picocells.

We divide the primary motivation into either capacity or coverage enhancement. However, de facto adding a small cell to the network provides a degree of both, so what’s the difference?

Our definition, adopted by the NGMN, considers whether the small cell is deployed in addition to existing macro coverage, or whether it brings a new service to an area where is was previously unavailable. In the days of voice, the service is either there or not. However in the age of mobile data the ‘service’ can range from GSM EDGE with a few kilobits per second, to multi-megabit HSPA or LTE. A general definition is that coverage enhancement brings a new service (or level of service) to an area where it could not previously be experienced, even during quiet times with only one user accessing the network. Capacity enhancement can be considered as a way of increasing the number of people that can have a given level of broadband experience in an area during the busy times. Although a small cell will likely improve both coverage and capacity, the definitions consider the operators primary motivation for deployment.

Within the categories of capacity and coverage, we see the following styles

- Persistent demand hot-spots can be targeted providing a site within range can be acquired and suitable backhaul connectivity provided. This approach is demanding from both backhaul coverage and capacity perspectives. Non-line of sight (NLOS) solutions may be needed in the places where high capacity fibre and line of sight (LOS) wireless cannot reach
- Consumer quality of experience can also be enhanced by ‘peppering’ small cells in general areas of high demand, making the most of available sites that can be easily backhauled with high capacity LOS wireless or fibre
- Operators will also use small cells to address not-spots in both outdoor and indoor locations. Where coverage is the primary motivation, lower capacity backhaul solutions can be considered. Uncovered outdoor areas are likely to be in remote locations, requiring long rage solutions such as satellite or point-to-point microwave. Indoor small cells might connect into the building’s LAN or use a distributed antenna system.

For more detail on deployment styles, please download a copy of our white paper:

"Five ways to deploy small cells and the implications for backhaul", CBNL, Aug 2012,
http://goo.gl/xLtcR

Figure 3. Decision tree showing styles of deployment for small cells
5 Small cell backhaul requirements from the NGMN

Whilst many different solutions have been proposed for small cell backhaul, it’s not until recently that a common agreement has emerged around what they’re actually required to do and the level of performance required.

We at CBNL have been driving the development of industry consensus around small cell backhaul requirements through our leadership of groups within the NGMN Alliance and the Small Cell Forum. Both organisations have now published detailed recommendations for different aspects of the backhaul, and the eager reader is encouraged to download free copies for their backhaul bookshelf.


The NGMN Alliance complement the work of standards organisations by providing a coherent view of what the operator community requires for rapid and cost effective deployment of mobile broadband technology. Their work is driven by the operator community, but supported by vendors and research bodies. Their recent paper on small cell backhaul adds to a growing body of work by their backhaul working groups, and builds on their other publications in Next generation backhaul requirements[^14], Backhaul architectures[^15], LTE backhaul capacity provisioning[^16], Security[^17] and Integrated Quality of Service Management[^18].

In their paper the NGMN identify, analyse and make recommendations for backhaul performance and feature support across the following categories:

- **Backhaul architecture**: Support of 3GPP interfaces similar to macrocells. Aggregator nodes may be used.
- **Coverage and connectivity**: Last mile coverage to small cells 3-6 metres above street level as opposed to rooftops and towers.
- **Quality of service**: User experience should be same on small cells as on macrocells.
- **Capacity provisioning**: Small cells operate at a higher spectral efficiency than macrocells, but with fewer users per cell, and fewer cells per site. This results in a lower mean throughput during busy time than a macrocell but similar peak (i.e. small cell backhaul traffic is burstier than macrocell traffic).
- **Availability and resiliency**: When used to enhance capacity of a macro layer (i.e. overlapping coverage) lower availability of small cell backhaul is acceptable.
- **Synchronisation**: Relaxed frequency synchronisation requirements for the lower power base station classes. Stringent phase sync requirements for some deployments (e.g. LTE TDD). Similar backhaul synchronisation support requirements as for macro.
- **Security**: IPsec mandatory when the backhaul is not trusted due to vulnerability of small cells to tampering.

• **Operations Administration and Maintenance (OAM):** Large numbers of small cell connections mean consolidated mass-management is all the more important.

• **Physical design:** Small cell and backhaul units must be small and light to enable easy installation in street level locations, be touch safe and tamperproof.

### 5.1 Capacity requirements

The backdrop to the small cell phenomenon is the mass adoption of mobile data services, which not only increase the volume of capacity required, but completely change its characteristics too. A detailed analysis by the NGMN\(^{19}\) shows that very high peaks in backhaul traffic from an LTE base station occur when the cell is lightly loaded. This is the opposite to legacy voice-only networks where peaks occur simultaneously on all base stations during ‘busy hours’. Building on NGMN’s earlier guidelines for LTE macrocell provisioning, their small cells paper provides a set of backhaul provisioning recommendations for both LTE and HSPA small cells, shown in Figure 4.

![Figure 4. Backhaul provisioning recommendations for small cells, source: NGMN\(^{20}\)](image)

Small cells exacerbate the burstiness of backhaul traffic, as they typically cover fewer users than a macrocell and support only one omnidirectional cell and one carrier per site. Averaging traffic over fewer users and cells means lower traffic on average, but the peaks stay the same as they are limited only by the maximum speed of the deployed technology.

Backhauling many small cells each with bursty traffic is best done by pooling resources between them with a point-to-multipoint (PMP) solution. A case study of measured traffic on a data rich HSPA+ network shows that a PMP topology achieved 50% improvement in spectral efficiency compared to a point-to-point\(^{21}\). The vast majority of solutions proposed for small cell backhaul are PMP.

Operators “don’t want to micromanage last mile capacity”. Traffic demand will increase rapidly and continuously. However, the exact locations of the demand will not be known in advance. Small cells will need to be installed in the capacity hotspots as they appear. Operators want to be able connect up the new site to the backhaul without having to re-plan the whole network. This plays to another strength of PMP solutions, where capacity is shared dynamically amongst many small cells and thus can be managed at a much higher level.

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The NGMN paper provides an overview of the range of backhaul solutions available, but a more in depth analysis can now be found in a related paper by Small Cell Forum:


The Small Cell Forum’s objective is to stimulate the adoption of small cell technologies. In its former guise as the FemtoForum, it developed the ecosystem for consumer deployed residential and enterprise femtocells and paved the way for the large scale commercial deployments we see today. In February 2012 it broadened its scope to address ‘public access’ or operator deployed small cells, and changed its name to Small Cell Forum.

To clarify the different applications, the Forum has now created a Release programme which packages its work along the lines of the main use cases: Home, Enterprise, Metro and Rural. Operator deployed backhaul fits into the latter two of these, and CBNL joined the forum to help further industry consensus around requirements and solutions.

Small Cell Forum is driven equally by both operators and technology vendors, and has attracted many proponents of the different solutions in the small cell backhaul toolbox. The Small Cell Forum backhaul paper complements the earlier work by the NGMN by adding a vendor view of the characteristics of the different solutions available.

**Wired solutions**
- Direct fibre
- Digital subscriber line (xDSL)
- FTTx
- Hybrid fibre-coax (HFC) and DOCSIS® 3.0.

**Wireless solutions**

<table>
<thead>
<tr>
<th>Category name</th>
<th>Carrier Frequency</th>
<th>LOS or Non LOS</th>
<th>Spectrum Licensing</th>
<th>Connectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millimetre 70-80 GHz</td>
<td>70-80 GHz</td>
<td>LOS</td>
<td>Light licensed</td>
<td>PTP</td>
</tr>
<tr>
<td>Millimetre 60 GHz</td>
<td>56-64 GHz</td>
<td>LOS</td>
<td>Unlicensed</td>
<td>PTP</td>
</tr>
<tr>
<td>Microwave PTP</td>
<td>6-56 GHz</td>
<td>LOS</td>
<td>Link licensed</td>
<td>PTP</td>
</tr>
<tr>
<td>Microwave PMP</td>
<td>6-56 GHz</td>
<td>LOS</td>
<td>Area licensed</td>
<td>PMP</td>
</tr>
<tr>
<td>Satellite</td>
<td>4-6, 10-12, 20-30 GHz</td>
<td>LOS</td>
<td>Licensed</td>
<td>PMP</td>
</tr>
<tr>
<td>Sub 6 GHz unlicensed</td>
<td>2.4 GHz, 3.5, 5 GHz</td>
<td>Non LOS</td>
<td>Unlicensed</td>
<td>PMP</td>
</tr>
<tr>
<td>Sub 6 GHz licensed</td>
<td>800MHz-6 GHz</td>
<td>Non LOS</td>
<td>Area licensed</td>
<td>PMP</td>
</tr>
<tr>
<td>TVWS</td>
<td>600-800MHz</td>
<td>Non LOS</td>
<td>Dynamic</td>
<td>PMP</td>
</tr>
</tbody>
</table>

Table 1. Definition of the different small cell solution categories

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22 Small Cell Forum Releases www.scf-releases.com
Small cells are just emerging now and the industry has not yet discovered which solutions best fit the bill. It is most likely that operators will tackle the problem with a toolbox of solutions and develop an understanding of which tools suit which scenarios.

**Fibre: Great where already available, otherwise slow and costly to install**

Fibre provides a very high capacity and low latency connection, however it is neither fast to install nor cheap to do so. Fibre will be needed to provide connectivity at the point-of-presence, and will be present at an increasing number of indoor locations. However, given the need to keep up with evolving traffic demand, fibre is not likely to be a cost effective way of connecting up a continuously evolving set of outdoor small cells mounted on street furniture.

**DSL: Like fibre, but without the performance**

DSL is today more widely deployed than fibre, and where already installed can provide a basic level of connectivity. DSL data rates should satisfy the provisioning requirements for the 'loaded' HSPA and potentially 10 MHz LTE, but it will not provide the peaks needed for a good end user quality of experience. Where not already installed, it would make more sense to install fibre.

**Non-line of sight (NLoS) wireless: Good for coverage, but capacity limited by available spectrum**

NLOS wireless backhaul would be the perfect solution were it not for the all the small cells and Wi-Fi hotspots using all the available low frequency spectrum already. NLoS propagation requires low carrier frequencies of less than a few GHz which are highly prized for mobile access itself, as shown in Figure 5. As a general rule, the bandwidth available for backhaul needs to be at least as much as that for access. Some claim that the spectral efficiency of the backhaul will be higher to compensate, but this seems unlikely given that access and backhaul are operating in very similar (NLoS) propagation conditions and with interference from nearby co-channel transmitters. Unpaired ‘TDD’ spectrum could be potentially be used for NLoS backhaul, but the quantity of this is small compared to the LTE and HSPA bands it will have to backhaul. The 3.5 GHz band is large and underused, however 3GPP are currently incorporating this into both UMTS (HSPA) and LTE specifications. One operator has already announced a deployment here.

**‘Free’ unlicensed spectrum – worth every penny**

The ISM bands at 2.4 and 5.8GHz provide a large amount of freely available bandwidth. However in the hotspots where capacity is needed most, the spectrum is highly likely to be heavily used already by Wi-Fi, bluetooth and other equipment. All these other transmissions represent unwanted interference which will reduce signal quality, throughput and general quality of solutions using these bands. Niche opportunities exist

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where interference can be reduced in isolated locations or with smart antenna technologies.

Figure 5. Usage of spectrum suitable for Non-line of sight backhaul (UK example shown)

**NLoS backhaul is built into the LTE standards**

Rather like NLoS backhaul, this is a feature in the LTE advanced standard called ‘in-band relay’\(^{25}\), where a base station can use half of the access spectrum to backhaul signals to a connected ‘donor’ cell site. Whilst this is good for extending coverage for early deployments, spectral efficiency for end user traffic is effectively halved, so it is not a capacity enhancing solution needed to meet increasing demand.

**Microwave – plenty of spectrum, a mature technology for fixed links**

Large amounts of bandwidth are available at ‘microwave’\(^{26}\) frequencies from 10-55GHz, which in turn means lots of capacity. These frequencies are already widely used for high capacity fixed communication links with point-to-point (PTP) and point-to-multipoint (PMP) topologies.

The small wavelength at these frequencies brings a mix of benefits and challenges. On the plus side, high gain, compact antennas are easy to build which improves link budgets. However such antennas need to be carefully aligned to the other end of the link. The short wavelength also means that effectively line-of-sight is the only option as diffraction and penetration around or through buildings and trees incurs high losses. This can be turned to advantage as the high attenuation helps reduce interference from nearby links wishing to re-use the same frequencies. Given the maturity of technologies and availability of spectrum for high capacity backhaul, microwave looks to be the mainstay of small cell backhaul solutions.

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\(^{25}\) “Further advancements for E-UTRA physical layer aspects”, 3GPP TR 36.814 V9.0.0 (2010-03), §9, p17

\(^{26}\) Microwave is general term where the wavelength is small compared to the circuit or environment under consideration. Here we consider frequencies from around 5GHz and up
Pictured: CBNL’s VectaStar point-to-multipoint microwave small cell backhaul product

V-band and E-band (millimetre wave)

Around 18GHz of spectrum is available between 57-66 GHz and 71-76 and 81-86 GHz, the latter representing a ‘window’ between peaks of high atmospheric absorption. Regulators have made this available under light licensing conditions to encourage innovation. Although background attenuation is several times higher here than in microwave bands, short high capacity links of over 1km are possible\(^\text{27}\).

New technologies are emerging to exploit the wide bandwidths available to produce high capacity point-to-point links. High gain and highly directional compact antennas are easily made given the very short wavelengths, and are needed to make the link budget work. Light or unlicensed spectrum is not anticipated to have the same overcrowding issues as 2.4 and 5GHz bands, due to the high attenuation and narrow beam antennas.

8 Fundamental analysis of backhaul total cost of ownership

Whilst it is clear that a number of solutions are technically capable of addressing the requirements, ultimately it will be the total cost of ownership (TCO) that will decide in which scenarios small cells are commercially viable.

Here we take a high level look at the fundamental elements of TCO for different wireless backhaul solutions, and develop a framework which can be further tailored to suit individual scenarios. One operator has stated that their target for a small cell site is a TCO that is 10% of a macrocell site’s TCO.

8.1 Method and assumptions

We consider here the fundamental cost elements of these approaches as illustrated below. The initial capital expenditure outlay will include both equipment and installation costs. We include only the backhaul equipment, but it can be assumed the installation would cover both backhaul and small cell components. On-going operational expenditures such as site rental and maintenance are incurred annually. In practice there may be many other elements to the TCO, but here we focus on the main 'big ticket' items. For our analysis we consider the net present TCO over a five year period.

Figure 6. Main elements of total cost of ownership

In the example analysis shown in Figure 7 we consider the ‘units’ of cost needed to install and operate backhaul for five small cells. In the case of backhaul equipment, a ‘unit’ represents a transceiver at one end of the link. We make the assumption that equipment costs are broadly the same for both PTP and PMP terminals since any difference is just in the digital electronics comprising the medium access control and that silicon fulfilling this function is not a significant percentage of the overall bill of materials. We assume a PMP hub site to be two cost units. Figure 7a shows how equipment costs stack up for both types of solution. PTP solutions cost more in this case as each small cell site needs additional equipment at both ends of the link. Similar analyses and assumptions for installation and site rental are shown in Figure 7B and 7C.
Simple formulae can be described to calculate the units of cost needed per small cell site for equipment, installation and rental, for example:

\[
\text{Equipment cost PMP = Nsites + 2 and Equipment cost PTP = Nsites * 2}
\]

When calculating TCO, the different cost elements are weighted in the following ratios, based on figures from Mobile Experts²⁸:

- Capex equipment: 100%
- Capex installation: 33%
- Opex rental: 27%
- Opex maintenance = 5% capex

TCO is then calculated from the net present value of the capex, plus 5 years of opex. A discount rate typical of a Tier 1 European mobile operator is assumed.

### 8.2 Total cost of ownership results

Figure 8 shows the TCO to backhaul between one and ten small cells to a point-of-presence (PoP). This reveals why analyses that only consider the first link tend to overestimate the cost of PMP solutions. For two or more small cells per PoP (or macro), the benefit of amortising hub site costs is realised, resulting in a lower TCO than for PTP solutions.

Our current macro networks have on average four sites per PMP sector. So in denser small cell network we might envisage six to eight small cells per PMP sector. This would give between 38% and 42% saving. Denser networks of ten small cells per PMP sector would give 45% savings. These figures align well with a previous and more detailed analysis by Senza Fili²⁹.

We also show TCO for a V or E band based PTP backhaul (operating at 60 or 70-80GHz). This is based on the current equipment prices at these frequencies which are 2x that of microwave equipment³⁰.

Spectrum costs vary significantly from region to region and have not been included in the TCO graph. However if we compare TCO at five small cells per hub, we see PMP is fundamentally around $30k lower TCO than PTP mm wave per link. This would more than compensate for spectrum costs, which in one UK focussed study was shown to be around €1k annually for a typical microwave link³¹.

### 8.3 Total cost of ownership conclusions

For backhaul networks aggregating more than one small cell per PoP, PMP gives a lower TCO than PTP, even when all equipment costs are the same. Current prices of E-band and V-Band PTP equipment are 2x that of microwave. This further increases the TCO benefit of microwave PMP backhaul, and would more than compensate for differences in the cost of spectrum. For a TCO analysis tailored to your network deployment scenario, please contact sales@cbnl.com.

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²⁸ “Backhaul for Small Cells”, Dr. J. Wells, Mobile Experts, Nov 2012
³⁰ “Wireless Backhaul from an Intermodal Perspective”, Maravedis, April 2013
³¹ Assumes 28MHz channel at 23GHz “Take Microwave Spectral Efficiency to a New Level”, Dragonwave 2010, [http://goo.gl/EkQhh](http://goo.gl/EkQhh)
Figure 7. Comparison of units of cost needed to backhaul five small cell sites to a PoP

Figure 8. Total cost of ownership of the two backhaul approaches as a function of network density
9 Our vision for small cell backhaul

Our belief at CBNL is that ‘Backhaul is backhaul’ and although operators are looking to small cells to help reduce cost per bit, their choice of backhaul solution needn’t compromise their customers’ quality of experience.

This means small cell backhaul connectivity must continue to be carrier grade, and we must look to improve efficiency in order to cut costs. We’ve worked closely with operators for over ten years to refine our own technology to do just that and have now launched the new VectaStar Metro point-to-multipoint microwave small cell backhaul product.

VectaStar Metro is based upon our proven VectaStar technology which has been deployed in over 37 countries to provide high capacity backhaul for some of the world’s largest mobile networks.

We proved in the 13 years we’ve been working with the world’s leading operators that performance does not have to be compromised by efficiency or cost. Delivering 50% improvements in spectral efficiency\(^1\) and 45% savings in TCO compared to alternative backhaul technologies, the VectaStar portfolio has provided operators with an unparalleled price over performance measure which has taken it to a clear market leading position.

The VectaStar Metro builds upon this and provides operators with a highly efficient solution which can be cost effectively and rapidly deployed to meet today’s insatiable appetite for mobile broadband.

9.1 VectaStar Metro

VectaStar Metro brings high capacity multipoint microwave backhaul down to street level in a compact form factor optimised for deployment with small cells.

Designed for quick, discreet and easy installation on street furniture, the platform provides sectors of backhaul coverage along urban canyons connecting multiple small cells.

**VectaStar Metro highlights**

- High gain integrated antenna
- Zero indoor footprint
- 300Mb/s per small cell site and up to 2.4Gb/s per hub site.
- The future generation of VectaStar Metro offers enhanced 750Mb/s per small cell site
- Future proofed and guaranteed quality of service compared to non-line of sight technologies
- Low latency: sub 1ms round-trip
- Supports all-IP backhaul
- Gigabit Ethernet interfaces
- Current frequencies supported: 26, 27, 28GHz
- Quick to deploy
- Simple mounting bracket
10 Conclusion

With the first commercial rollouts of public access small cells underway the industry is experiencing the steepest part of the learning curve as all the practical details are ironed out. We now have a better understanding of the operator motivations to deploy, which go further than just capacity enhancement.

Although originally perceived as one of the most significant challenges, the backhaul industry has worked together to show how different solutions picked from a toolbox can together meet the requirements of the different use cases envisaged.

Whilst operators have very stringent TCO targets for small cell deployment, backhaul is still backhaul, and nothing less than carrier grade performance is acceptable. Cost savings must therefore be obtained by increased efficiency and utilisation of resources rather than sacrificing performance or features.

Our TCO analysis compares the two key wireless approaches and shows fundamentally why point-to-multipoint solutions are able to reduce costs by 45% compared to point-to-point solutions, whilst delivering the capacity, flexibility and speed of deployment needed to meet operator’s requirements.

To find out more about CBNL’s market leading carrier grade point-to-multipoint microwave products and the new VectaStar Metro small cell backhaul solution, visit www.cbnl.com/smallcells
**VectaStar: a complete network solution**

The VectaStar portfolio offers operators a carrier-class backhaul, enterprise access and small cell network solution, or any mixed configuration.

- **VectaStar Hub**
- **VectaStar Gigabit Remote Terminal**
- **VectaStar Metro Remote Terminal**
- **Mobile data devices**

**Managed services**

VectaStar can be deployed within our managed services portfolio. This is delivered directly by our team of highly-skilled engineers and through partnerships with the industry’s leading system integrators. Though technical expertise, proven methodology and local market knowledge, we offer customers the reliability and guarantee of complete network delivery and support.

**Welcome to next generation thinking**

**Welcome to CBNL**

Pioneering the development and deployment of next generation microwave transmission equipment since 2000, CBNL is the global market leader in multipoint microwave backhaul and access solutions. Our carrier-class VectaStar platform serves over 50 communication providers across 36 countries, including 7 of the top 10 world’s largest mobile operators.