Small Cell Backhaul: design and deploy in synergy

Mobile operators, in their constant effort of bettering customer's quality of experience (QoE), are looking at HetNets as a way to improve their ubiquitous data coverage.

WhitePaper – May 2013
WP.SC.01.13

Data growth in mobile networks

Smartphones and tablets are quickly becoming the most adopted devices in the market. According to *comScore* in western European countries have crossed the 50% mark of smartphones penetration[1].

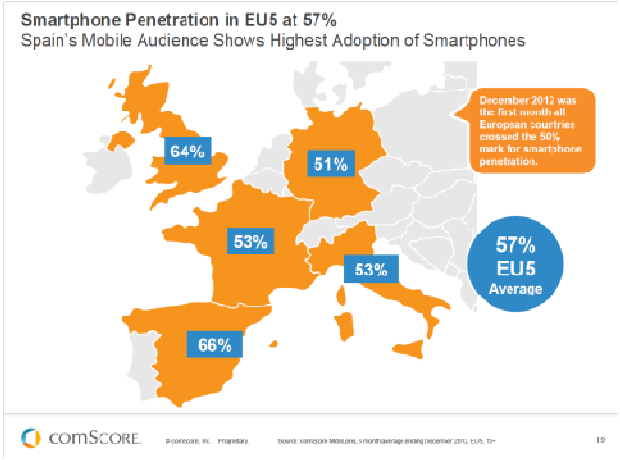

Figure 1: Smartphone penetration in Eu

These always connected smart devices are the first driver of data growth in mobile networks thanks to the application ecosystem revolving around them. In the period between 2008 and 2011 over 31,12 billion applications have been downloaded (the four major mobile application stores: Apple Inc., Google Inc., Nokia Corp. and Research In Motion Ltd)[2]

High data traffic requests from users during peak time saturates the radio access network (RAN) bandwidth lowering the customer's Quality of Experience (QoE) and congesting the network and the local macro cell (MC). Mobile operators look for ways of improving their network performances.

QoE is a mixture of several contributing factors including:

- network coverage: services are used in any location, users are expecting the same level of service whether indoor or outdoor. A study made by Google in 2012[3] on US Smartphone penetration/usage and mobile behaviour shows the distribution between indoor and outdoor usage. [Figure 2]

[1] According to: comScore "Europe digital Europe in Focus" - March 2013 – Figure 1

[2] According to: press release "Revenue for Major Mobile App Stores to Rise 77.7 Percent in 2011" from IHS/iSupply

[3] According to: "Our Mobile Planet: United States, Understanding the Mobile Consumer" from Google – May 2012 – Figure 2

- data capacity: to satisfy among other services the ever growing demand for video. In the same report Google reports 34% of the connections are for accessing video services.
- end-to-end network performances: that includes latency of delivery, uninterrupted and seamless service while on the move and while changing environments (e.g. walking outside or inside a building).

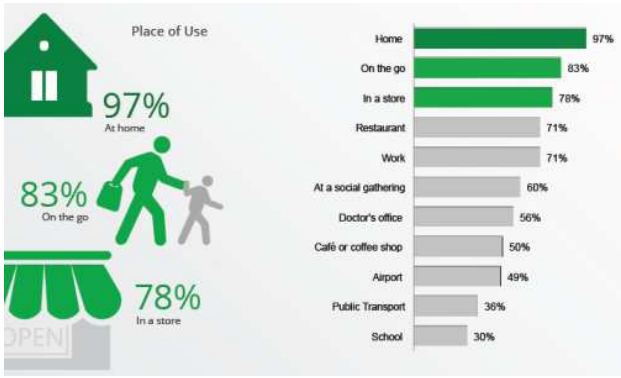

Figure 2: Smartphone data service usage per location

Network performances can be improved by several means.

- Increase the macro towers: densifying the macro cell by introducing new sites to the access network. The deployment of a new site brings important consideration the operator needs to take like the high costs of hardware and deployment not considering the difficulties in founding locations when addressing urban or dense urban areas.
- Improving the existing sites: for instance LTE-A introduces in its technology evolution smart antennas and MIMO configurations allowing with a limited investment compared to a whole new site to increase sector capacity.
- Deploying HetNet: Adding a metro layer solution offers to mobile operators the opportunity to address customers with a patchy network providing relief to congested macro sites without impacting on the macro layer. This low cost base solution (most operators talk about target costs of 10% in respect to a macro site total cost) has the advantage of targeting only the specific identified critical area, maximizing therefore the performances in the wanting region.

The backhaul solution required in this latter case represent a new challenge to the transport network which in line with the small cell (SC) needs to be equally flexible and cost effective.

Small Cell deployment and network design

Small cells are low power metro cell offering multi technology services. Although the vast majority of applications address patchy network coverage to relief congested macro sites increasing spectrum utilization, small cells could also be used to better network coverage.

Small Cell deployment is subject of several conditions.

Location

- Due to the small form factor they target lamp posts, building sides, advertisement boards, roof tops
- Due to their low transmit power they can be deployed quite close to the living environment and could be placed as close as 4 to 5m meters from ground to over 10m

Power

- Due to the urban environment deployment the units will be main powered
- While no issue is present while deploying at lamp posts, deployment at roof tops and building sides may prove harder to get power to

Backhaul

- Ideally single hop connectivity is envisage to connect a SC to adjacent MC or fibre point of presence (POP) and use that as aggregation site, liaising on the existing backhaul to connect to the mobile network.
- Several wireless technology solutions P2P/PMP LOS/NLOS can be employed according to city morphology and desired availability
- Availability of fibre by the curb

All the above factors also play a direct role during the network design phase.

In this phase the best location for SC deployment is sought. However the best location may not be so straightforward to identify as it depends by several variable that will define a successful deployment.

BEST LOCATION FOR SMALL CELL
Is the coexistence of these points

Best coverage for users	Suitable location for power and size	Permit for installation on public ground	Capacity and backhaul availability	Interferences with other small cell
Distance from venues, and distance from the ground. Best street coverage.	Aesthetically pleasing, possibly out of sight, as small as possible. Need to be powered	Not all location can be accessed, (e.g. Historical buildings). Also limited number of SC can be deployed in a given space. *First come first serve?*	The more build-up the city, the harder to get wireless LOS connectivity. Fibre is hard to terminate at every location and expensive. PMP and NLOS offer limited transport capacity	Adjusting SC deployment site impacts all the previous points as well as changes interference plan

Figure 3: best location for small cell deployment

Focusing on how the backhaul can be implemented, many technology options are available and can ideally be positioned to provide connectivity as part of the HetNet backhaul tools

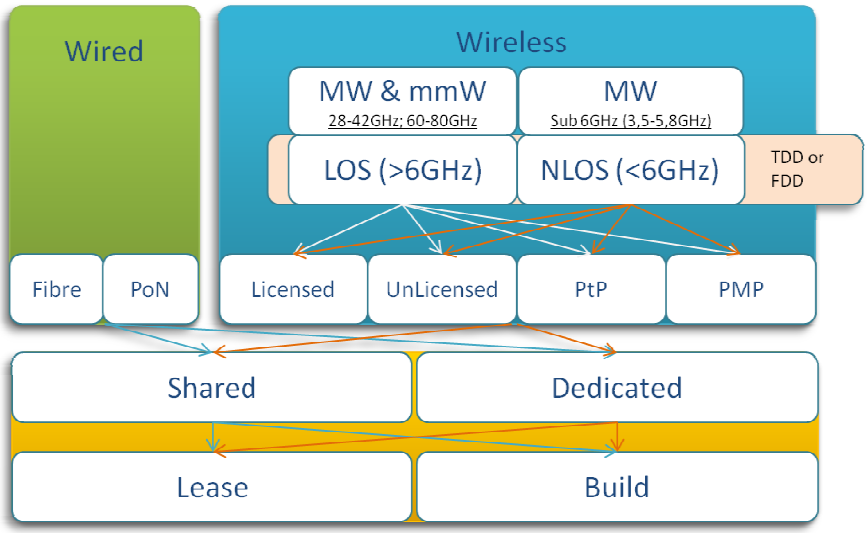

Figure 4: small cell backhauling options

Fibre PoP, for fibre owners, may prove to be an invaluable asset however wired connections lack the necessary location-flexibility proving harder and costly to extend at each locations a small cell is planned to be deployed to. Consequently while it offers capacity, scalability and low latency it also has a limited degree of deployment freedom tightly bound with costs.

Wireless solutions is the natural choice offering capacity, scalability and low latency like fibre as well as highest degree of freedom in deployment, fast service set up with contained costs.

Wireless backhaul

Wireless solutions will play a major role in small cell backhaul. The complexity and density of this metro layer network is foreseen to reach N:1 the macro cell network, and although will address a patchy coverage, as not all macro cell areas will be densified, the number of small cells may well exceed the number of macro cells 4 to 1 in the short/medium term[4]. [Figure 5]

In this scenario or in even more dense cases that will take place further in time or big metropolis' city centres, careful planning of deployment sites, backhaul technology and capacity requirements will be decisive for a positive outcome.

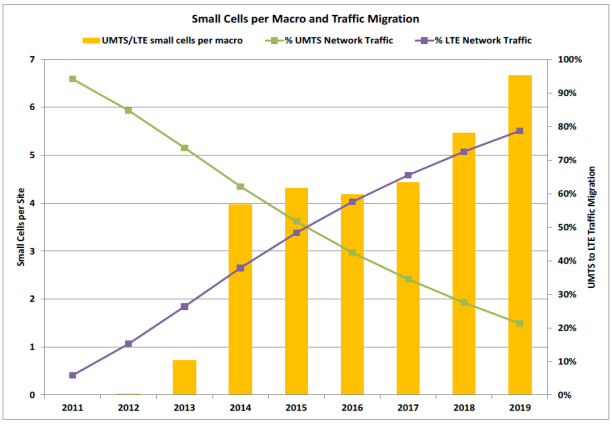

Figure 8-4 Small cell per macro and traffic migration

Figure 5: small cell per macro cell

Line of sight (LOS) microwave radio technology offers one of the most flexible solution and bring undisputed advantages to operators for the backhauling of small cell. As network complexity increase (due to either high density cells, city morphology of small narrow streets like in historical cities, or due to urban canyon of well build up cities) wireless technologies offering Near/Non line of sight (NLOS) will also offer an agreeable alternative solution that may prove invaluable to maximise the backhaul coverage.

LOS microwave radio:

- High capacity throughput: can easily reach 1Gbps throughput capacity, well above single SC requirements, ensuring once deployed it will cover any future capacity need. Including the option of backhauling a second cascaded SC, chained topology aggregated capacity.

[4] According to: Small Cell Forum "Backhaul Technologies for Small Cells" document 049.01.01 – February 2013 – Figure 5

- Spectrum efficiency: thanks to the specific propagation condition offered by high frequency bands like 60GHz an operator can maximise the reuse of these unlicensed or lightly licensed links. Other suitable frequency band would be 38/42 and 80GHz that could address longer hops exceeding 500 metres, into the 1,2 or 3 km length.
- Low latency: microwave provides extreme low latency and delay spread
- High availability: links can easily reach 99.995% availability, well above forecasted SC requirements. With reliability that this will not change in time.

NLOS radio:

- Connectivity in poor to non LOS conditions: offering the capability to reach sites that otherwise may not be reached.
- Moderated capacity: due to the narrow band filter and the nature of the technology the capacity offered are limited hundreds megabits. This may suite single SC .
- Limited reliability: due to its unlicensed nature, availability may prove difficult to foreseen, and subject to changes as new NLOS unlicensed links are deployed in the area, due to interferences. This may also impact capacity. Also in the licensed part of the spectrum reliability results difficult. The low directivity of the antennas at this frequency are cause of high interferences, making it harder to use the bandwidth available in an effective manner.
- High latency and delay spread: due to the technology nature, NLOS link is established by collecting the reflected rays off buildings and existing structures. These reflections introduce delay spread that may vary according to the environment, and may in some cases to exceed the minimum tolerated requirements.

Small Cell backhaul case study results

SIAE MICROELETTRONICA has conducted a real case study for small cell deployment using both LOS and NLOS technologies, to quantify the number of addressable SC sites.

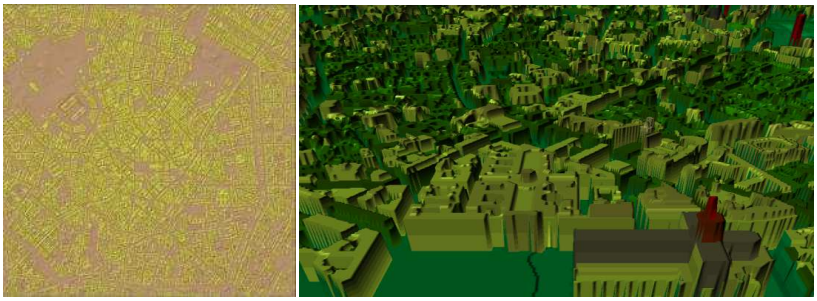

Figure 6: high definition map 10Km2

The study has been made over a 10Km^2 area using high definition map (2m resolution) that captures the detailed shape of the buildings enabling the calculation of reflected rays for NLOS analysis and most accurate LOS design. The analysis has been made with different small cell distribution going from 100 (1,5:1) to 1000 (14:1).

As expected using LOS microwave a high percentage of deployed sites can be covered, with initial assumption of single hop 500m link form the MC aggregation site. Only MC sites have been considered. This percentage can be improved by the use of 2 or 3 chained links achieving a net 15% to 20% improvement depending on the assumed density. [Figure 7] Furthermore we have another 15% to 20% SC sites that could be reached by single hop form the aggregation site by exceeding the 500m length link.

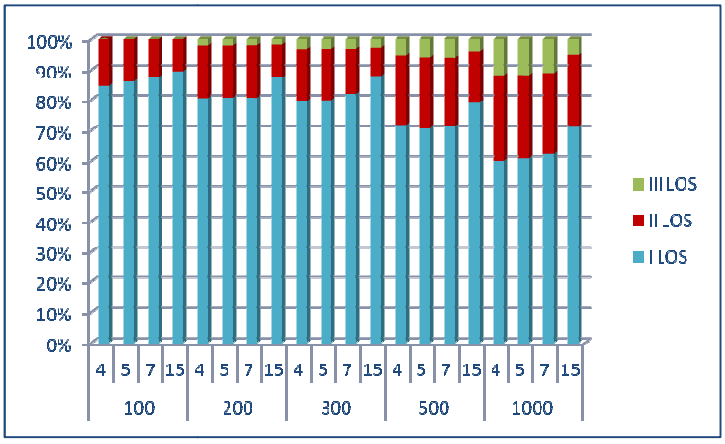

Figure 7: Percentage distribution of LOS links with multiple links

The result of single hop connectivity could be even further improved if we identified the SC site also based on backhaul LOS visibility. In this study this has been calculated by allowing a range of movement of the small cell site between 5m to 40m from its original position, reaching a net improvement of 10 to 20%. [Figure 8]

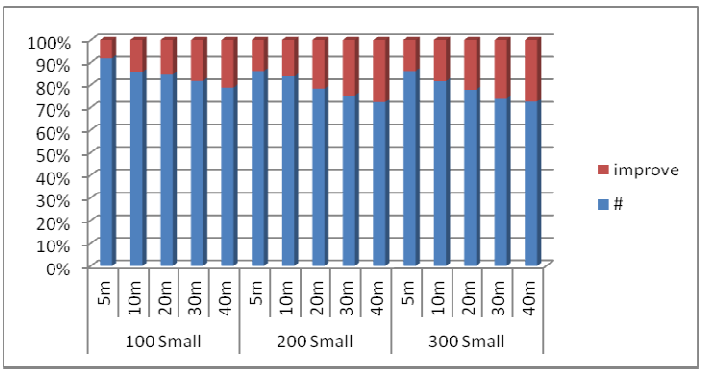

Figure 8: Percentage distribution of LOS link with smart positioning

The results of the study shows how LOS microwave can offer right from the start an excellent coverage for backhauling small cells, even exceeding the 70% of the deployed cells depending on the deployed scenario, assuming they have been positioned without any backhaul consideration. It also shows that with some careful planning the LOS microwave coverage can improve reaching important percentage of coverage close to the totality of sites. This approach has to be preferred.

The study also showed that NLOS was able to cover in all the cases the remaining sites, although with much limited capacity, and in some cases with little capacity due to the complexity of the city geometry.

Conclusions

HetNets deployment will require a comprehensive set of backhauling tools providing connectivity to all the possible scenarios. Ensuring consistent network performances across the entire network with ease of deployment and costs are the main requirement for the backhaul network.

Undoubtedly wireless backhaul represents the best technology with LOS microwave as first choice. It offers the necessary freedom in site deployment, optimal performances associated to contained form factor and costs.

As seen from the case study it is possible to achieve optimal access and backhaul coverage by careful designing the access and the backhaul concurrently, maximizing the use of point to point microwave links.

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