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Wireless backhaul in future heterogeneous networks

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Wireless backhaul in future heterogeneous networks

Deploying a heterogeneous network by complementing a macro cell layer with a small cell layer is an effective way to expand networks to handle traffic growth. For rollout to be successful, however, relies on being able to provide all the additional small cells with backhaul capability in a flexible and cost-efficient manner.

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A number of proprietary wireless small cell backhaul solutions have been adapted to provide carrier-grade performance in non-line-of-sight (NLOS) conditions. These solutions typically operate in both licensed and unlicensed spectrum in the crowded sub-6GHz frequency range. However, to cope with predicted traffic load increases, the need to exploit additional spectrum at higher microwave frequencies has been identified.

This need led to Ericsson researching how NLOS wireless backhaul could be used at 28GHz. This research[1] showed how wireless small cell backhaul could be implemented in an urban scenario without a direct line-of-sight (LOS) path between the deployed small cells and the macro radio base station (RBS) providing backhaul connectivity[1, 2]. The Ericsson research showed how point-to-point (PtP) microwave in licensed spectrum could be used for small cell NLOS backhaul, and[2] showed that point-to-multipoint (PtMP) could also be used for the same purpose.

Building on this research, Ericsson has investigated the impact on user performance in a heterogeneous network of providing small cell backhaul over a wireless link – by comparing it with a system in which small cell backhaul is provided over (ideal) fiber. To do this, a study was carried out using system simulations that captured the joint impact of backhaul and access technologies on user performance. Two different NLOS wireless backhaul technologies were tested: a commercial high-end PtP microwave backhaul and an LTE-based PtMP concept – at 6GHz and 28GHz. Both technologies were assumed to operate in licensed microwave bands.

The results of the simulations show that wireless backhaul technologies can provide user performance on a comparable level to a fiber-based (ideal) solution. The results demonstrate that NLOS backhaul deployed in licensed spectrum up to 30GHz is a future-proof technology that can manage high volumes of traffic in heterogeneous networks.

BOX A Terms and abbreviations

EIRP	equivalent isotropic radiated power
EPC	Evolved Packet Core
EPS	Evolved Packet System
IMT	International Mobile Telecommunications
ISD	inter-site distance
LOS	line-of-sight
MIMO	multiple-input multiple-output
MTC	machine-type communication
NLOS	non-line-of-sight
O&M	operations and maintenance
PtMP	point-to-multipoint
PtP	point-to-point
QAM	quadrature amplitude modulation
RAT	radio-access technology
UE	user equipment
WRC	World Radiocommunication Conference

Challenges created by small cells

Heterogeneous networks built by complementing a macro-cell layer with additional small cells in the RAN impose new challenges on backhaul. For example, the best physical location for a small cell often limits the option to use wired backhaul. In urban areas, small cell outdoor nodes are likely to be densely deployed, mounted on lampposts and building facades about three to six meters above street level. If fiber exists at the small cell site, it is the best option for backhaul. But if fiber is not readily available, deploying wireless backhaul is both faster and more cost-effective.

Wireless backhaul is in itself nothing new, but small cell deployments create new challenges for conventional wireless backhaul, which was originally designed for LOS communication from one macro site to another. In urban environments and town centers, propagation paths between small cells and macro sites are likely to be obstructed by buildings, traffic signs and other objects. Clear line-of-sight is highly improbable. The number of users connected to each small cell might be just a few, yet delivering superior and uniform user performance across the RAN still requires a large number of small cells. As a result, small cell backhaul solutions need to be more cost-effective, scalable, and simpler to install than traditional macro backhaul.

The dominant technology used in backhaul networks today is based on microwave – and predictions indicate that this will continue to be the case. In 2019, microwave is expected to encompass about 50 percent of global backhaul deployments[3]. The popularity of this technology can be explained by the fact that a microwave backhaul network can be deployed quickly and in a flexible manner – two critical factors for adoption.

The popularity of microwave has also led to its extensive development over the past few decades. For LOS deployments, microwave is capable of providing low cost, compact and easily deployable backhaul capacity in the order of several gigabits per second [4].

As mentioned, due to their placement between street level and rooftop, a substantial portion of deployed small cells will not have access to wired backhaul, or have a clear LOS path to a macro site with backhaul connectivity. These factors create a need for NLOS backhaul.

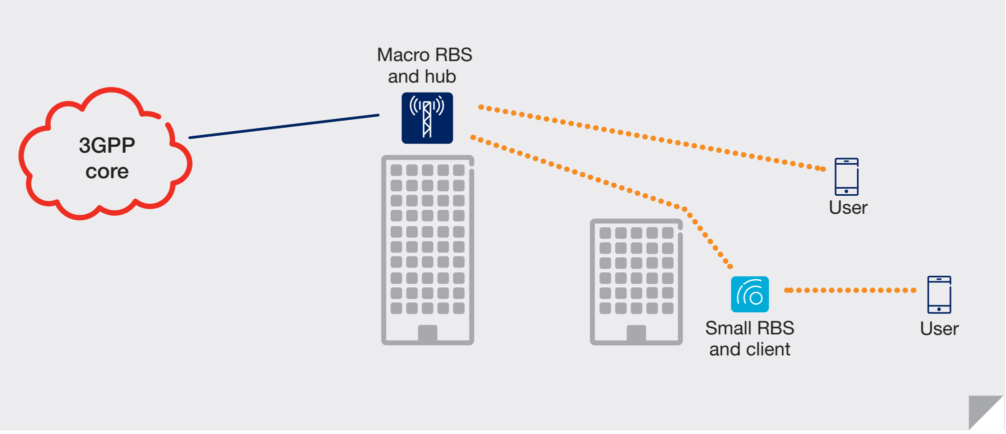
Solutions to the challenges posed by NLOS conditions have already been developed for microwave backhaul. Passive reflectors and repeaters are sometimes used to propagate signals around obstacles in the communication path. However, this approach is less desirable for cost-sensitive small cell backhaul, as it increases the number of sites. Instead, providing single-hop wireless backhaul between a macro site and a small cell site limits the number of sites needed, and is consequently better suited to the small cell case. In urban areas, daisy chaining can be used to reach sites in difficult locations, and this solution can also be used to advantage for small cell backhaul.

The propagation properties at lower frequencies, below 6GHz, are well suited for radio access. Consequently, modern radio-access technologies (RATs) tend to operate in licensed spectrum up to a few gigahertz. Commercial microwave backhaul for macro sites operate at higher frequencies – ranging from 6GHz to 70/80GHz. Operating small cell backhaul at these higher frequencies allows spectrum in the lower frequency bands to be used by radio access, which leads to better spectrum utilization overall.

Joint access and backhaul

In 5G networks, it is likely that access and backhaul will, to a large extent, converge: in some deployments, the same wireless technology can be used effectively for both. This convergence may lead to more efficient use of spectrum resources, as they can be shared dynamically between access and backhaul[5]. For other deployments, a complementary and more optimized backhaul solution might be the preferred choice to support 5G features, such as guaranteed low latency at an extremely high reliability for mission critical MTC, as this is more backhaul critical.

FIGURE 1 **Example of LTE-based PtMP backhaul system architecture**



Another more high-level benefit of convergence is the ability to use the same operations and maintenance (O&M) system for access and backhaul, which can both improve overall system performance and simplify system management. For example, a common network management that can combine KPIs from the entire network can make optimized decisions and take effective action to improve overall performance. Such KPIs include data rates, latencies, and traffic loads experienced by the various nodes in a heterogeneous network; including macro cells, small cells, and backhaul. If not impossible, such network performance optimization becomes extremely challenging if the KPIs are inaccessible and the nodes are uncoordinated. A common network management system is, therefore, an enabler for efficient operation of a heterogeneous network.

Irrespective of convergence, the cost-effectiveness of backhaul connections becomes increasingly important in deployments that include large numbers of small cells. In general, deployments that have less hardware and simplified installation procedures are more cost-effective. So, as PtMP backhaul connections simplify deployment, applying this technology is one way to reduce costs.

In the present study, a system level approach was used to evaluate the joint effect of converged access and backhaul. A complete heterogeneous LTE RAN deployed in a dense urban scenario was simulated encompassing macro cells, small cells, small cell backhaul, users, traffic models, propagation, interference, and scheduling effects. Using such an advanced simulation environment makes it possible to evaluate overall system and user performance for different small cell backhaul scenarios in a way that captures the joint impact of access and backhaul.

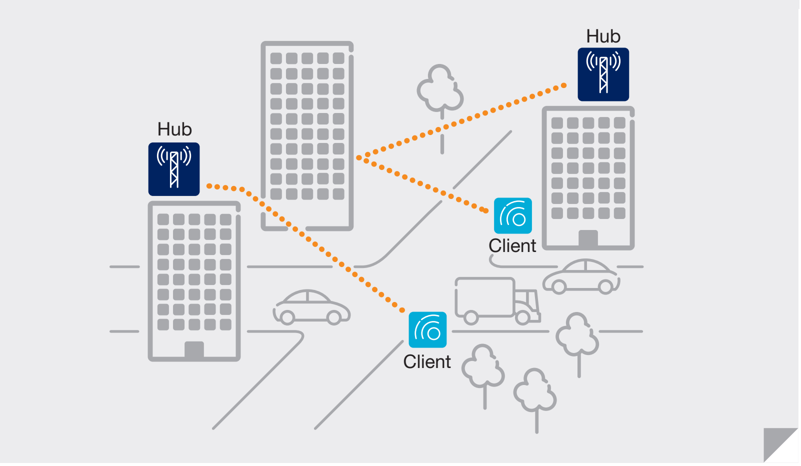
Backhaul technologies for small cells

The various technologies that exist for wireless backhaul can be classified into two main solution groups: PtP and PtMP. A PtP solution uses dedicated radios and narrow-beam antennas to provide backhaul between two nodes. In a PtMP solution, one node provides backhaul to several other nodes by sharing its antenna and radio resources. As illustrated in Figure 1, the nodes in a PtMP scenario are referred to as hub and client, where the hub is typically colocated with a macro site (that has backhaul connectivity) and the client is colocated with a small cell site.

Spectrum

Irrespective of the technology deployed, user performance is directly

FIGURE 2 NLOS wireless backhaul client/hub – urban deployment



related to optimal use of spectrum. The 2015 World Radiocommunication Conference (WRC-15) will focus on the future allocation of additional spectrum below 6.5GHz for radio access. Looking at current spectrum allocation, these frequencies are crowded, which means that the potential for more backhaul bandwidth in licensed spectrum is greater for frequencies above this. Backhaul based on Wi-Fi and LTE are just two of the current technologies operating below 6GHz. Wi-Fi typically operates in unlicensed spectrum and is therefore prone to interference while, for example, LTE relaying exploits licensed IMT spectrum for both backhaul and access.

Using unlicensed frequency bands might be a tempting option to reduce cost, but this approach can result in unpredictable interference issues that make it difficult to guarantee QoS. The potential risk associated with unlicensed use of the 60GHz band is, however, lower than the risk associated with the popular 2.4GHz and 5GHz bands. This is due to very high atmospheric attenuation caused by the resonance of oxygen molecules around 60GHz and the possibility to use compact antennas with narrow beams – which reduce interference effectively.

The conventional and spectrum-efficient licensing policy for PtP microwave backhaul works on an individual link-by-link licensing basis[6]. However, when it comes to rolling out small cell backhaul, simplicity, multipath interference issues, and cost are of such importance that other policies for licensing should be considered.

Light licensing and block licensing are two possible alternatives. In the light licensing case, license application is a simple and automated process that involves only a nominal registration cost. This approach can be used in scenarios where interference is not a major concern or can be mitigated by technical means[6]. It has become popular to use light licensing to encourage the uptake of PtP E-band links. If properly deployed, these communication links do not interfere with each other due to high atmospheric absorption and narrow beam widths.

In block or area licensing, the licensee has the freedom to deploy a radio emitter within a given frequency block and geographic area as long as the radio fulfills some basic requirements, such as respecting the maximum equivalent isotropic radiated power (EIRP). In this case, the licensee is responsible for managing co-channel interference between different transmissions and making it suitable for managing PtMP backhaul and radio access systems[7].

Being able to exploit the spectrum potential offered by higher frequency bands from 10GHz to 100GHz is part of ongoing research for 5G[5,8]. The high propagation losses that are associated with high-frequency millimeter waves typically limit the applicability of such high frequency bands to short-range links. These losses can be partly compensated for with more advanced antenna systems using beamforming. However, this makes mobility at high speeds (such as in cars and on high-speed trains) more challenging, as beams would need to be adapted more or less continuously.

Wireless backhauling of fixed nodes is less of a challenge, as alignment or beam pointing is more straightforward when nodes are situated in predefined fixed locations than when they are constantly moving – and so the application of higher frequencies is simpler.

Capacity and availability

Backhaul capacity is often dimensioned to support the peak capacity of the macro cell[9]. However, in practice, the trade-off between cost and the need for capacity usually results in a more practical level for backhaul capacity being set. This level should, at a minimum, support expected busy-hour traffic, with some margin to account for statistical variation and future growth. Dimensioning in this way makes sense when it comes to cost-sensitive small cell backhaul. However, it is recognized that different operators – to align with their business strategy – are likely to use different approaches for capacity provisioning of small cell backhaul.

Today's minimum bitrate targets for backhauling 3GPP LTE small cells is somewhere in the region of 50Mbps for radio access using 20MHz of spectrum. To support current peak rate demands, however, 150Mbps or more is desirable[9]. These targets for minimum and peak bitrates are likely to increase further over the next few years as traffic volumes continue to rise, and additional spectra and new features for radio access become available. In addition, small cell access points may not only be required to support multiple 3GPP technologies (such as HSPA and LTE) but may also include Wi-Fi, which will further increase the need for backhaul capacity.

Availability requirements may differ between small cell and macro cell backhaul, depending on the deployment scenario. The availability requirement for macro backhaul can be as high as 99.999 percent (which corresponds to a maximum of five minutes of outage per year). For small cell backhaul, such high availability requirements may not be necessary. If the small cell is deployed to boost data rates or capacity in an area with existing macro coverage, the backhaul requirements could be relaxed significantly to, for example, 99-99.9 percent (which corresponds to anywhere from 12 hours up to several days of outage per year)[8].

From a user perspective, the performance of an individual backhaul link is less relevant. What matters is the overall performance of the combined backhaul and access links. If the access link at a given time and place provides a certain level of service, the corresponding backhaul link does not need to be significantly better. Hence, the access and backhaul links could be jointly optimized. To reflect this in the present study, the joint effect of access and backhaul on user performance was evaluated, using an all LTE-based backhaul concept operating at higher frequencies that is more integrated with the LTE access than conventional wireless backhaul.

Antennas

Maximum antenna gain is given by the antenna size in relation to the wavelength of the frequency used. As a result, antennas that are smaller in size than antennas with the same antenna gain at lower frequencies can be deployed at higher frequencies. If aligned correctly, a compact high-gain antenna can compensate for the increased path loss that is usually associated with higher frequencies and NLOS conditions.

A PtP system uses high-gain antennas at both ends of a link, while a PtMP system uses a wide-beam antenna at the hub site and a directive antenna at the client site.

More advanced antenna solutions at the hub site, such as steerable or fixed narrow multi-beam systems, can be deployed, but such solutions will probably not be cost-effective for some time. Carrying out manual antenna alignment with narrow beam widths in NLOS conditions may sound like a difficult task, but it can be a surprisingly simple procedure, even at 28GHz[1]. However, as correct alignment is important, especially at higher frequencies, it may be a good idea to deploy a client antenna that has automatic beam-steering capabilities, so that it can simply align itself to the best signal path. Beam steering can be implemented using mechanical methods, antenna arrays or a combination of the two.

LTE-based backhaul concept

To address the issue of providing backhaul in heterogeneous networks, a new concept is being researched based on the adaptation of LTE technology for small cell backhaul at high microwave frequencies – evaluated at 6GHz and 28GHz.

This concept reuses the LTE physical layer but applied at a higher frequency band – up to 30GHz. As LTE physical-layer numerology was originally designed to operate with a carrier frequency of around 2GHz, operation in higher bands requires some modification of the original concept. But if top-of-the-line hardware is in place, the need to change the numerology (by increasing the subcarrier spacing, for example) for frequencies below 30GHz in a backhaul context is small. However, to reduce hardware costs, numerology may need to be adjusted to match higher microwave frequencies. This concept is part of 5G radio access research[5].

With a 3GPP LTE-based PtMP solution, backhaul links can inherit 3GPP functionality already developed for LTE access, as well as features that will be implemented in the future, such as carrier aggregation, reduced latency, advanced schemes for beamforming, MIMO, interference cancellation and radio resource scheduling. When backhaul and access links are converged, operational efficiency can be increased, as the overhead created by managing different technologies is reduced. For example, the control and management architecture as defined by the 3GPP Evolved Packet System (EPS) can be used by both systems.

An example system architecture for LTE-based PtMP backhaul is illustrated in Figure 1. The basic principles of this architecture include interfaces, protocols, the reuse of 3GPP logical nodes, EPS bearer concept, as well as security solutions.

As Figure 1 illustrates, the small RBS is connected to a client. The client provides the wireless backhaul IP-based transport to the core network, which in turn provides functions like bearer management, QoS enforcement and authentication. The client terminates the LTE radio interface and implements UE functions such as cell search, measurement reporting, and radio transmission and reception. The hub implements the eNodeB side of the LTE radio interface. In this example, both the hubs and the clients are controlled by a 3GPP-based EPC network – which can be a core network dedicated to backhaul, or a core network shared between the small RBS and the access links.

While there are similarities between an all-LTE network (backhaul plus access) and the LTE relay solution developed in 3GPP (which also provides backhaul based on an LTE radio interface), there are two main differences between them. First, LTE backhaul has been modeled as a transport network. As such, it is access-agnostic and can be used with any access link technology. LTE relay on the other hand has been designed to use LTE link technology for both backhaul and access. The second difference is that LTE backhaul links and LTE access links typically use separate radio resources (separated in terms of frequency bands), while the (in-band) LTE relay solution shares radio resources between the backhaul and access links.

In summary, an LTE-based PtMP backhaul provides several benefits compared with other alternatives:

- **reuse of functionality – inherent multiple access (PtMP), architecture, protocol structure, physical layer, procedures, and security mechanisms are just some examples of functionality already developed in 3GPP;**
- **quick launch of new features – by reusing existing (and future) LTE developments, new features can also be rapidly deployed;**
- **use of the same ecosystem – one system for both backhaul and access links can simplify O&M for operators and increase operational efficiency;**
- **support for multi-RAT access links – compared with LTE relaying solutions, any RAT can be used on the access link;**
- **joint backhaul-access link optimization – added value can be achieved through dynamic optimization and operation of access and backhaul targeting user performance. A high level of integration and potentially shared hardware are**

FIGURE 3 **European deployment scenario**

FIGURE 4 **US deployment scenario**

- other potential benefits of converged links; and
- automated deployment – installation procedures similar to those used to set up a small RBS (which today is automatic) and can also be used to install the backhaul client.

Evaluation scenarios

In this study, heterogenous networks were simulated using macro and small cells for radio access and hubs and clients for wireless backhaul deployed in two virtual cities. These cities aimed to represent a typical European scenario with a dense macro deployment and a typical US scenario with downtown high rises and a sparse macro deployment with a greater number of small cells per macro.

The macro RBSs and backhaul hubs were colocated at the same site, as were the small RBSs and clients. The clients were located above street level and backhauled wirelessly to a serving hub using either PtP microwave or the LTE-based PtMP concept (described in this article). Figure 2 illustrates the simulation scenario, showing two hubs providing wireless backhaul to two clients in an urban environment.

Some assumptions were made about the nature of the virtual cities. For the European city:

- building heights are assumed to be homogenous, ranging from 5m to 40m;
- no high-rises;
- few open areas;
- 19 macro/hub sites with an average ISD of 400m; and
- 76 small RBS/client sites.

The US city environment is more challenging, assuming that:

- a downtown area exists with high-rises as well as surrounding low buildings, with open spaces in between;
- building heights range from 4m to 288m;
- 19 macro/hub sites with an average ISD of 700m; and
- 114 small RBS/client sites.

Figures 3 and 4 illustrate a portion of the deployments for the virtual European and US cities. The left side of each figure shows the results of the macro-only network, and the right side shows the results of a combined macro and small cell deployment that uses LTE-based PtMP backhaul at 28GHz. The colors of the cells indicate average user throughput, according to the scale on the left. The line between a hub and a client shows the strongest propagation path, and the color of the line indicates its path loss. The improvement in throughput, illustrated by the amount of green in the illustrations, due to offloading of the macro in the small cell deployment is considerable. The simulated served traffic levels in the network are 20GB/month/user in the European scenario and 6GB/month/user in the US scenario.

For LTE access, the simulated carrier frequencies were set to 2.1GHz in the European scenario and 700MHz in the US scenario. The access bandwidth was 20MHz in both cases, which corresponds to a peak rate of 108Mbps using 2x2 MIMO. The macro RBS output power was assumed to be 2x30W and the small RBS output power to be 2x5W.

High-gain backhaul antennas were used to compensate for the greater NLOS path loss at higher microwave frequencies. In the PtP evaluations, mechanically steerable high-gain antennas were used at both the hub and client sites, while for PtMP evaluations, the hub was implemented using fixed sector-covering antennas. Antenna parameters and output power of hub and client for the different backhaul systems and carrier frequencies are summarized in **Table 1**. For PtMP, 20MHz of bandwidth at two frequencies were evaluated – 6GHz and 28GHz – while only 28GHz was considered in the PtP case. The LTE-based PtMP used fixed output power in the downlink, while PtP used adaptive power control.

Methodology

User performance including wireless backhaul was evaluated in a static system simulator. In the simulator, LTE access was based on LTE Rel-8 with 2x2 MIMO and 64QAM in the downlink, which corresponds to a downlink peak rate of 108Mbps when using 20MHz of access bandwidth. The wireless backhaul, including LTE-based PtMP and commercial PtP microwave, were also simulated using 20MHz bandwidth. In one simulated case, 40MHz was also used for the LTE-based PtMP backhaul for the more challenging US scenario, to illustrate the use of the LTE feature carrier aggregation on the backhaul.

User-generated traffic for both simulation scenarios was split on an 80/20 basis – 80 percent generated by indoor users and 20 percent by people outdoors. Indoor users were evenly distributed among the floors of the buildings, and traffic load was measured in terms of data traffic consumed by one user in one month. For each scenario and deployment, as traffic load increased, the traffic served by the system increased until the system reached its capacity limit. This limit depends on the scenario and the deployment, including the number of macro RBSs and small RBSs deployed.

To put some perspective on the traffic load, 2014 levels for actual mobile traffic are in the region of 1.5-2GB /user/month in Europe and the US. Mobile data traffic is expected to grow globally by 45 percent annually 2013-2019, so by the end of 2019, mobile traffic will be somewhere around 10GB /user/month[3].

User throughput is given by the size of a data packet and the total transmission time of the packet. The transmission time takes into account any delay due to resource sharing: multiple users accessing the same radio resources. Each user is served either by a macro or by a small RBS. For those served by a macro, only resource sharing on the access side has an impact on throughput. For users served by small RBSs, aside from the resource-sharing delay on the access side, there is also a resource-sharing delay associated with the wireless backhaul. Resource sharing in the backhaul results from either multiple users connected to the same small RBS – which means they share its backhaul connection – or from users connected to different small RBSs that share a common backhaul connection in a PtMP situation. As each PtP backhaul link has an individual (not shared) backhaul resource, PtP backhaul is only shared by users connected to the same small RBS. However, the PtMP backhaul may be shared by users connected to different small RBSs that are connected to the same hub sector. Hence for small RBS users, user performance depends not only on the access but also on the type of backhaul that carries the small RBS traffic.

Wrap up

European city scenario

Figure 5 shows user throughput (in the downlink) against served traffic for the European scenario. The curves represent the macro-only network (blue curves) as well as heterogeneous networks with three different small cell backhaul technologies (yellow, red and purple curves), according to:

- yellow – PtP microwave at 28GHz with 20MHz bandwidth;
- red – LTE-based PtMP at 28GHz with 20MHz bandwidth; and
- purple – LTE-based PtMP at 6GHz with 20MHz bandwidth.

The reference performance levels for fiber backhaul (green curve) are also shown. The 10th percentile represents the 10 percent worst case rates experienced by users, the 50th represents the median, and the 90th percentile represents the top 10 percent downlink performance rates.

The immediate conclusion from this is that small cell deployment can radically improve user throughput, especially at high traffic levels where the macro-only network cannot meet the demand.

When looking at the served traffic levels, the network has a very good macro deployment, as it alone can serve 10GB/user/month while maintaining a 10th percentile downlink user throughput of about 10Mbps. By deploying small cells, the corresponding user throughput is increased to 30Mbps, or the 10th percentile at 10Mbps is maintained, while the network serves as much as 23GB/user/month.

Table 1: Antenna parameters and output powers for the different backhaul systems

Node type	Frequency [GHz]	Antenna type	Azimuth HPBW[1] [degrees]	Elevation HPBW[1] [degrees]	Max. gain [dBi]	Aperture size	Max. power [dBm]
PtMP hub	28	Sector	65°	5°	20	1.5 x 12.5 [cm²]	23
	6	Sector	65°	5°	20	6.5 x 54 [cm²]	23
PtMP client	28	Parabolic reflector	3°	3°	34	Diameter = 20 [cm]	23
	6	Patch array	14°	14°	22	20 x 20 [cm²]	23
PtP client and hub	28	Parabolic reflector	3°	3°	34	Diameter = 20 [cm]	23

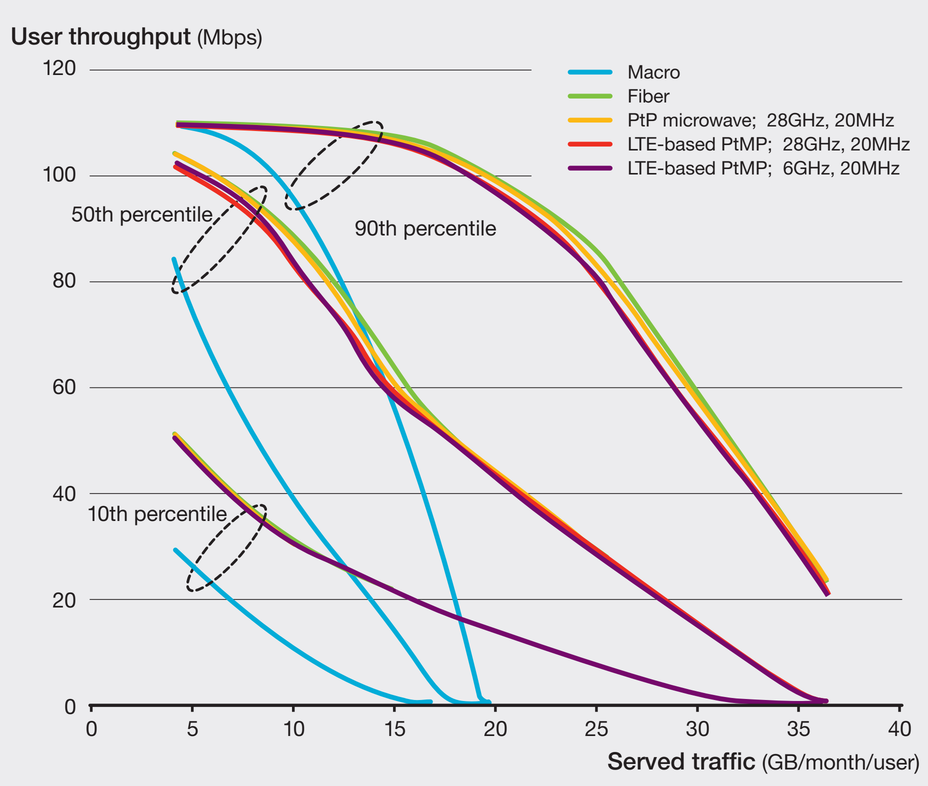
[1] half power beam width

As expected, the choice of small cell backhaul has almost no impact on the worst case 10th percentile, as these users are more limited by the access network than by the backhaul. Small backhaul limitations only occur for the median (50th percentile) and best (90th percentile) users connected via PtMP backhaul – observed by small penalties compared with fiber. The PtP backhaul shows close-to-fiber performance for all users and served traffic levels. It is also noticeable that all backhaul options can cope with the user peak rates (108Mbps) achieved at lower loads (90th percentile and below 10GB/month/user).

The variation in performance between PtP and PtMP wireless backhaul is due to two primary differences in these systems. Firstly, two different antenna systems are used, where PtMP has wide-beam sector antennas at the hub, while PtP has directive high-gain antennas at both ends of each link. The PtMP sector antenna has a much lower antenna gain than the narrow beam PtP antenna – 14dB lower, as shown in Table 1. Secondly, there is less sharing of resources in the PtP backhaul, where each client has its own dedicated resource, while the PtMP system may also share its resources over multiple clients. In the simulated PtMP case, a hub has three sectors and each sector may serve one to five clients depending on the traffic load in that sector.

Finally, the performance levels of the PtMP backhaul operating at 6GHz and 28GHz are almost identical. Both systems have identical antenna gain and beamwidth at the hub, while the 6GHz system has 12dB lower antenna gain and wider beamwidth at the client. On the negative side, a lower antenna gain results in worse system gain and a wider beamwidth is more prone to interference. However, on the positive side, the 6GHz system experiences less path loss, which compensates the negative side.

FIGURE 5 European scenario



US city scenario

Figure 6 presents the downlink user throughput against served traffic in the US city. The network capacity in this scenario is limited by the macro network since the macro network is much sparser than the European city. This is observed in the much lower served traffic values and the poor macro-only performance. Deploying small cells improves the network performance substantially.

Also in this scenario, worst case user perfomance (10th percentile) is limited by access and not by backhaul, so the choice of backhaul has no impact on worst case user throughput. But when looking at best case user performance (90th percentile), there is a clearer backhaul limitation when using PtMP backhaul with 20MHz bandwidth at higher served traffic levels. A remedy for improving PtMP performance for high performance users is to apply the LTE feature carrier aggregation in the LTE-based PtMP backhaul. Figure 6 shows the result when a 40MHz bandwidth is applied to the backhaul at 28GHz and the user performance is improved and PtMP with carrier aggregation is on a par with PtP microwave and fiber. Thanks to reduced resource sharing and high-gain antennas at both ends, the PtP backhaul also shows close-to-fiber performance for all users and served traffic levels in this scenario.

When comparing PtMP at 6GHz to 28GHz, some degradation for high throughput users is observed in the 90th percentile at high traffic levels in Figure 6. This is due to the different antenna characteristics, where the antenna gain at 28GHz is 12dB higher at the client side than it is at 6GHz and the wider client antenna beam at 6GHz has less spatial filtering of interference compared with the 28GHz client antenna.

Summary

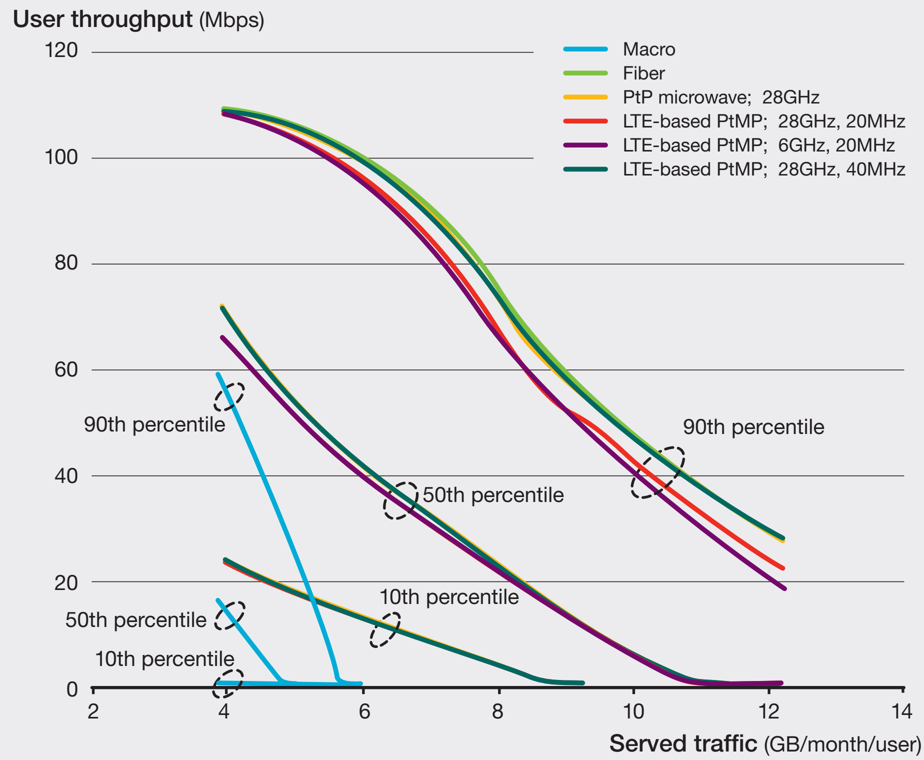
Deploying small cells provides a means for handling future traffic growth and enables a substantial improvement in network performance. It is therefore of great importance to enable small cell deployments by providing cost-effective backhaul. The study carried out addresses some of the challenges created by small cell backhaul. By using system simulations that capture the joint effect of access and backhaul, it has been shown that NLOS microwave backhaul in licensed spectrum up to 30GHz is a viable solution for dense small cell deployments in urban environments.

A novel LTE-based NLOS PtMP backhaul concept operating at high microwave frequencies, up to 30GHz, has also been evaluated. This concept is a potential step toward using LTE at higher frequencies and converging access and backhaul networks, which is also foreseen in 5G networks.

System simulations for two different deployment scenarios show that degradation in user performance is minimal when wireless backhaul is compared with (ideal) fiber backhaul – for lower to medium throughput users. For high throughput users, the performance of the LTE-based NLOS PtMP backhaul concept is not as good as the PtP microwave backhaul – which shows close-to-fiber performance for all users and served traffic levels due to greater numbers of radio and antenna resources. The LTE-based NLOS PtMP backhaul was evaluated both at 6GHz and 28GHz, and 28GHz works just as well or even better than 6GHz.

In the more challenging US deployment scenario, the performance degradation with LTE-based PtMP was rectified by applying larger bandwidth in the microwave backhaul by using carrier aggregation, which is inherent in LTE, bringing it up to par with NLOS PtP and fiber backhaul.

FIGURE 6 **US scenario**



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References

1. Ericsson Review, 2013, Non-line-of-sight microwave backhaul for small cells, available at: http://www.ericsson.com/res/thecompany/docs/publications/ericsson_review/2013/er-nlos-microwave-backhaul.pdf
2. IEEE Communications Magazine, 2013, Non-line-of-sight small cell backhauling using microwave technology, available at: http://dx.doi.org/10.1109/MCOM.2013.6588654
3. Ericsson Mobility Report, June 2014, available at: http://www.ericsson.com/res/docs/2014/ericsson-mobility-report-june-2014.pdf
4. Ericsson Review, 2011, Microwave capacity evolution, available at: http://www.ericsson.com/res/docs/review/Microwave-Capacity-Evolution.pdf
5. Ericsson Review, 2014, 5G radio access, available at: http://www.ericsson.com/res/thecompany/docs/publications/ericsson_review/2014/er-5g-radio-access.pdf
6. Electronic Communications Committee (ECC), Report, Light licensing, license exempt and commons, Report 132, 2009, available at: http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCRep132.pdf
7. Electronic Communications Committee (ECC), Report, Fixed service in Europe – current use and future trends post, Report 173, 2012, available at: http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCRep173.PDF
8. IEEE Access, vol. 1, May 2013, Millimeter wave mobile communications for 5G cellular: It will work!, available at: http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6515173
9. NGMN Alliance, White Paper, 2012, Small Cell Backhaul Requirements, available at: http://www.ngmn.org/uploads/media/NGMN_Whitepaper_Small_Cell_Backhaul_Requirements.pdf

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