ERICSSON WHITE PAPER
Uen 284 23-3166 Rev B | August 2014

ERICSSON

IT ALL COMES BACK TO BACKHAUL

SOLUTIONS SUPPORTING SUPERIOR END-TO-END QOE IN HETEROGENEOUS NETWORK DEPLOYMENTS

Backhaul plays a critical role in mobile broadband, and is rising in importance on account of the introduction of heterogeneous networks. Deploying vast numbers of small cells to complement improved and densified macrocell layers will require a range of highly scalable, flexible mobile backhaul solutions that support superior user experience.

WHY HETERO-GENEOUS NETWORKS ARE IMPORTANT

Backhaul is being driven by the rising popularity of connected devices – smartphones, tablets and laptops – as well as by mobile apps and cloud computing. In the few years since smartphones have been commercially available, shipments have risen drastically. Smartphone users are consuming more data than ever before: an average of about 650MB per month in 2013. In 2013, total mobile traffic generated by mobile phones exceeded that from mobile PCs, tablets and mobile routers for the first time. Smartphone shipments, bandwidth-heavy services and rising popularity of applications are some of the drivers behind the tenfold increase that is expected in mobile traffic during the coming years – reaching a projected global monthly total of almost 12 exabytes by the end of 2019 [1]. Most operators will be able to meet these rising traffic demands for some years to come by deploying more advanced HSPA and LTE technologies; gaining access to additional spectrum; implementing techniques that are more spectrum-efficient; and densifying the macro layer. However, continued enhancement and densification may not always be the most cost-efficient way to boost capacity at hotspots and improve performance indoors and at cell edges. In such situations, additional capacity can be provided by deploying small, low-power cells that cover less extensive areas. Tens of thousands of these cells could potentially be deployed in dense mobile networks in urban areas. Radio cells that are effectively integrated, coordinated and synchronized enable the delivery of high-capacity, high-quality mobile broadband services to large numbers of users.

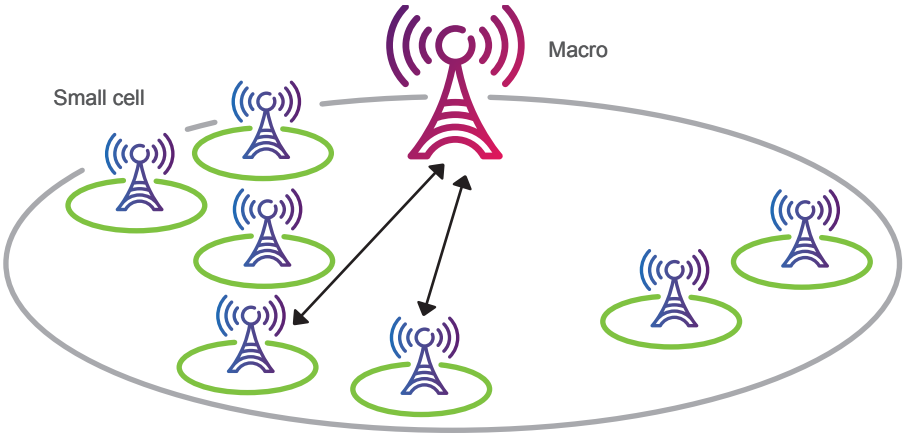

Figure 1: The macro layer and a small-cell cluster

Knowledge and experience of matching the capacity and performance requirements of mobile broadband radio networks with the appropriate backhaul resources is relatively well developed. With the arrival of small cells on the scene, backhaul requirements are once again in the spotlight. Deploying small cells to boost capacity in hotspots and inside buildings will off-load the macro layer and support the delivery of ubiquitous, constant connectivity. Overall, the backhaul should not limit the RAN and should have sufficient end-to end performance to meet the desired user QoE everywhere. This is valid for backhaul of mobile networks today, and will be equally important for backhaul in both the macro and micro layers of a heterogeneous network in the future. However, ongoing development of radio networks to maximize the use of available spectrum puts greater demands on delay, delay variation and synchronization – particularly between the macrocells and small cells. Such performance requirements impact the choice of backhaul solution for a given scenario, where the best solution will result from a holistic view of the network.

HETEROGENEOUS NETWORKS NEED HIGH-PERFORMING, FLEXIBLE BACKHAUL

The main driver for heterogeneous networks is users' need for high-quality mobile broadband services everywhere – a requirement that can be met by boosting capacity at hotspots and improving performance both at the cell edges and in buildings. Operators need to support users' rising quality demands, while at the same time minimize the cost of deploying and running the network – implying that backhaul solutions should not limit the performance of heterogeneous networks, and must be cost-efficient and easy to install. Network performance should be uniform across the entire network, so that users do not experience a drop in performance when covered by small cells – resulting in a negative QoE perception of the whole network and operator brand.

THREE WAYS TO BOOST PERFORMANCE

Designing a heterogeneous network in the most effective way means improving, densifying and adding to the mobile broadband infrastructure as follows:

- Improving existing macrocell sites – by enhancing macrocells with more spectrum, advanced antennas, increased order of diversity on the receiver and/or the transmitter, and greater baseband processing capacity within and between nodes.
- Densifying the macro network – targeted addition of strategically located macrocells can improve capacity. This approach keeps the total number of sites relatively low, while network performance becomes less sensitive to traffic location. A simple way to densify a network could be a cell-split, which enables a site to transition from a three-sector site to a six-sector site. These strategic cells could use macro equipment or even micro equipment.
- Adding small cells – complementing macrocells with small cells and dedicated indoor solutions based on the 3GPP standard. This approach can include the use of microcells, picocells or low-power remote radio units (RRUs), as well as Wi-Fi.

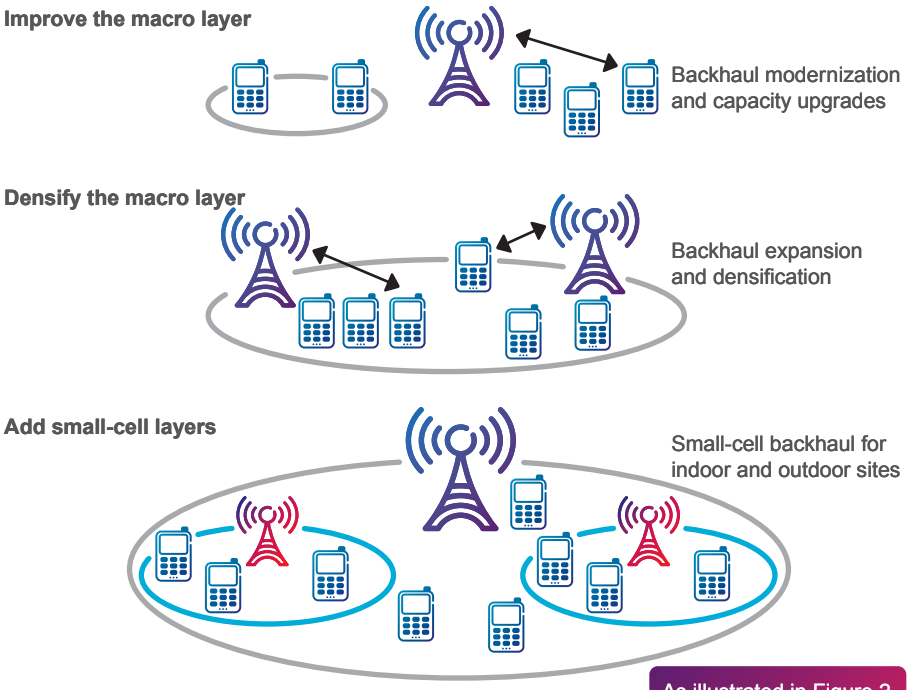

Figure 2: A combined approach to improving hotspot capacity and enhancing performance at cell edges

As illustrated in Figure 2, each step creates backhaul-specific considerations

The most effective way to increase overall network performance is to improve existing radio sites in the macro layer through, for example, carrier aggregation. In this scenario, the main requirement

for backhaul is that it must be able to deliver more capacity on existing links. This can be done with higher modulation schemes, bonding several radios and different compression techniques if using microwave-based backhaul. The second way to increase overall capacity and throughput is to add additional macro sites. Site densification is an attractive solution, as it keeps the total number of sites low, while network performance is less sensitive to traffic location. To simplify site acquisition in this case, the backhaul solution should provide low-footprint options. All outdoor solutions running on the 70-80GHz bands enable gigabit speeds to the new site with zero footprint.

When and where it is not feasible to improve or densify the macro network substantially within the time and cost constraints dictated by the market, the macro layer can be complemented with small, low-power cells and dedicated indoor or outdoor solutions. The performance advantage delivered by these low-power cells (the amount of traffic they are able to handle) will depend on the performance of each one, on how effectively each is integrated with the macro layer, and on the backhaul option used.

IT'S ALL ABOUT SCALE

The deployment of small cells as part of a heterogeneous network solution could involve the installation of many thousands of new sites. Managing the deployment of such a large number of radio and backhaul sites will be a key challenge as operators work to deliver additional capacity and coverage quickly and on budget.

SUPPORTING THE BUSINESS CASE

Deploying a vast number of new small cells highlights the need for cost-efficient solutions that support the overall business case. The chosen backhaul solution must not be costly to plan for, install, operate or maintain. It must match the anticipated volume of data traffic that the site will have to handle, as well as support the network performance required. Developing mobile backhaul options that can serve any site location will maximize return on investment for existing sites and active equipment – this is particularly important for small cells that have limited reach and may serve a small percentage of an operator's subscriber base. Different sites will pose different challenges. Having the flexibility to choose between dedicated high-performance backhaul and the reuse of existing resources on site will be essential to support short time to market at the right cost. This is easier said than done, and it will be increasingly difficult to achieve without a holistic approach to radio, backhaul and installation services.

HIGH QOE EVERYWHERE

To obtain the maximum performance from the radio network, it is important to have an end-to-end backhaul solution that does not limit users' QoE. The challenge is how to strike the best balance of performance, cost, market timing and location.

BACKHAUL FOR VARYING SCENARIOS

Good heterogeneous network backhaul solutions must scale easily in order to ensure high-quality user experience throughout the network, while keeping costs to a minimum.

SOLUTIONS THAT SCALE

When operators roll out small cells as part of a heterogeneous network, potentially tens of thousands of new sites can be involved. To simplify outdoor site acquisition, planning and installation, small-cell radio and backhaul nodes will have to be extremely compact, unobtrusive and highly integrated – including WCDMA, LTE and Wi-Fi, for example – and all in a form factor that enables installation on, say, a wall or lamppost. The level of integration between radio and backhaul equipment is likely to be much higher – perhaps with easily swappable backhaul interface units enabling radio units to be adapted, or upgraded, to the preferred backhaul option for the site. Scalability on a network level will be achieved only through the use of a well-defined and carefully selected toolbox of backhaul technologies to manage both outdoor and indoor deployments on a large scale. The technologies included in this toolbox are line-of-sight (LOS) and non/near LOS (NLOS) microwave on the higher frequency bands [2] and NLOS microwave on the sub-6GHz frequency bands, along with point-to-point (PTP) fiber, point-to-multipoint (PMP) fiber, category 5/6 LAN and digital subscriber line (DSL) technologies.

One way to minimize the effort per small-cell deployment is to use an integrated, verified and proven RAN and backhaul solution. In addition to the toolbox, self-organizing networks (SON) techniques will be needed to drive automation in everything from planning and installation to operational maintenance and optimization. These techniques are applied across nodes and technologies, and solutions must be developed in harmony to avoid duplication and implementation of SON features that interfere with each other, supporting the scalability of the heterogeneous network backhaul solution.

The increased number of nodes in a heterogeneous network directly affects the amount of performance management data – which will increase rapidly. New management models will be needed, so that continuous reporting from small nodes can be reduced or eliminated in favor of on-demand reporting when problems arise. Over time, there will be a natural progression for SON functionality to be distributed to backhaul nodes to meet the requirements for scalability, data availability and response time [3].

SOLUTIONS TO MANAGE COST

To continue to support the mobile broadband business, operators need a backhaul solution that delivers cost-effective and future-proof performance. Limiting the number of new sites, as well as the number of possible backhaul solutions, simplifies network management, which contributes to keeping down the total cost of ownership. The number of sites can be minimized by making each one as efficient as possible in terms of radio planning, with a backhaul solution that supports – without limiting – the radio network with regard to end-to-end performance and synchronization. Efficiency can be ensured by taking a holistic perspective during network design, planning and operation. Radio networks that have a high level of backhaul integration are compact and are efficient in terms of power consumption – deploying such solutions can consequently reduce rental costs and utility bills.

As rental costs alone constitute up to 50 percent of overall site costs [4], total cost per site can be reduced through deploying tightly coordinated solutions. Higher levels of integration result in lower maintenance costs – mainly due to greater interoperability in the operations, administration and maintenance (OAM) systems used in the two domains.

For small-cell sites with limited capacity requirements, lower-performance backhaul options such as public DSL networks or unlicensed microwave bands can be evaluated as a cost-effective initial backhaul solution. In this case, the cost of a future capacity upgrade should be taken into

account. The simpler the installation process, the cheaper it is to deploy. Solutions that enable a single person to perform an entire installation on site, for example, by using automated configurations with just one click or push, or through pre-configured settings will be crucial in the bid to maintain costs. Multi-vendor environments are not recommended for small-cell clusters, since they drive OAM and interoperability costs, putting the business case at risk. Instead, operators should standardize a limited number of site options for a specific region or area.

For outdoor deployments, wireless and fiber transmission media are recommended. Each small cell can be connected directly to the macro network via LOS microwave or fiber, as seen in Figure 3. If the operator is building a small network of clustered small cells, wireless transmission media are recommended, and either a LOS microwave link or fiber should be used to connect the clustered small-cell network to the macro network. E-band (70-80GHz) microwave solutions enable gigabit speeds and can be used to aggregate capacities from several small cells. When LOS is not feasible, a high-performing NLOS solution can be used on the higher frequencies to connect small cells [2]. Traditional NLOS solutions are only recommended for application in the final link in the network due to their capacity and delay constraints. Microwave solutions running on the unlicensed 60GHz frequency band should also be included in the toolbox to enable minimized spectrum cost and high capacities in short distances. Using a microwave solution that is equally capable of both LOS and NLOS deployments will bring a cost advantage, leading to freedom in site selection, minimized amount of spare parts and one OAM system.

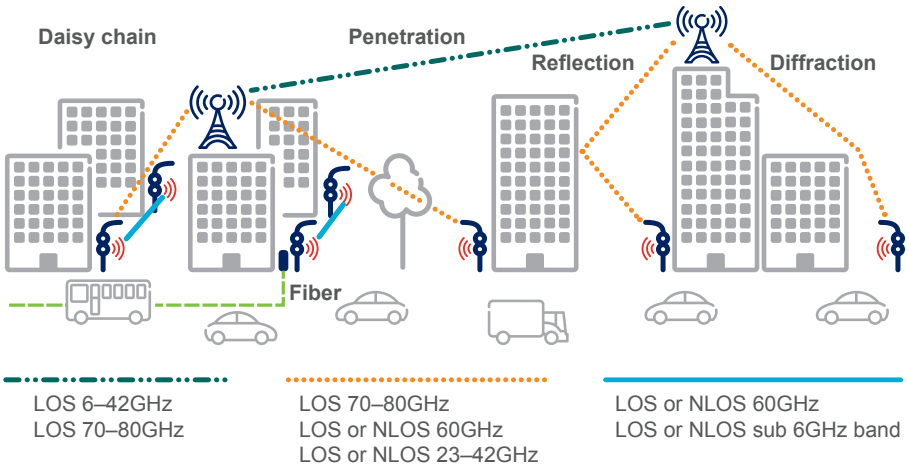

Figure 3: Technology and frequency recommendations

For indoor deployments, reuse of existing copper and fiber infrastructure is recommended wherever possible. Very High-speed Digital Subscriber Line, generation 2 (VDSL2) can be used for backhaul over legacy copper lines, such as PABX infrastructure, and to cover distances greater than those handled by Ethernet over category 5. Recently introduced indoor radio frequency solutions also enable backhaul through the building over category 5, with traditional backhaul then being used to carry this traffic back to the access points. When reusing legacy infrastructure, it is important to secure key features like RAN synchronization and traffic management, especially when combining different radio-access technologies (RATs) over the same shared backhaul.

SOLUTIONS FOR BEST QOE

To provide the best possible QoE for users – and deliver maximum business benefit for operators – small cells need to be deployed where improvement in network performance is needed most. Network performance should be uniform across the entire network, so that users do not experience a drop in performance when covered by small cells – resulting in a negative QoE perception of the whole network.

One way to enable high QoE is to maintain coordination between radio nodes and layers – ensuring that operators maximize subscriber value (and revenue) per allocated spectrum. To implement this level of coordination, high-performance end-to-end backhaul in terms of speed, delay, and delay variation is recommended. To deliver maximum QoE across networks, operators should aim to build backhaul links with high performance – such as LOS microwave and optical links – building out from the macrocells whenever possible. Where no fixed links are available, wireless is the natural choice, as it enables short time to market and more freedom of site placement. For an even greater degree of freedom, high-performing NLOS microwave links may be used.

To support multi-standard radio deployments – where, for example, WCDMA, LTE and Wi-Fi traffic share backhaul – the backhaul solution will need QoS functionality. This functionality then

needs to be aligned with the radio solution to give operators control over system performance in the event of backhaul overload or link degradation.

APPLICATIONS

As mentioned earlier, flexibility is key when addressing backhaul challenges in a heterogeneous network context. For every small-cell deployment situation, several potential options are possible, each with their own merits. Site-specific performance requirements, such as time-to-market considerations and the quality of available backhaul assets, will determine the best solution on a case-by-case basis. The following examples illustrate how backhaul challenges can be met using different options in a variety of situations.

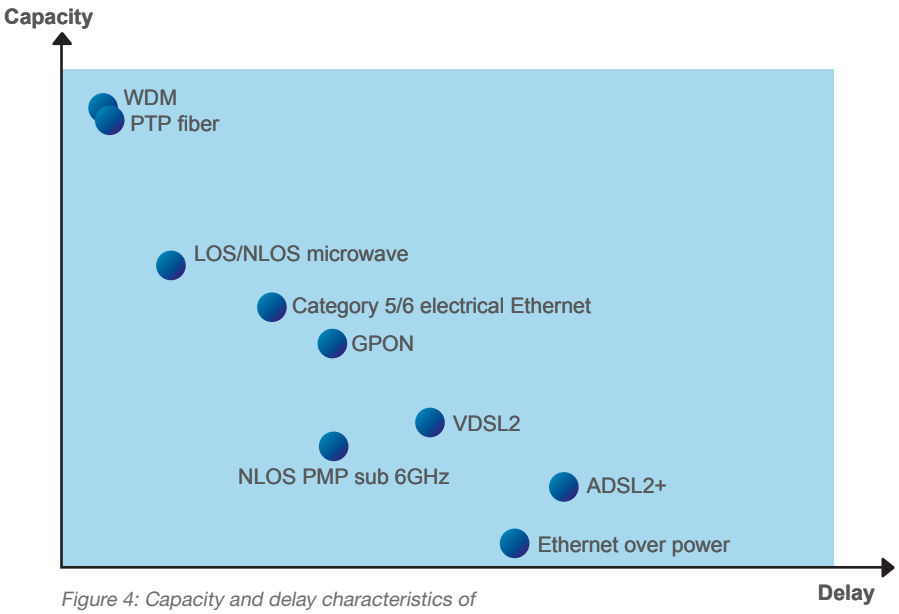

Figure 4: Capacity and delay characteristics of various transmission technologies

As shown in Figure 4, different backhaul options exhibit a wide variety of transmission characteristics – this variation affects the levels of coordination and synchronization possible in a heterogeneous network

CITY STREET

Two main deployment scenarios occur on city streets: an indoor environment such as a café – an indoor hotspot; and an outdoor environment such as a bus stop – a localized outdoor hotspot. Both locations need better mobile broadband coverage and higher capacity, especially at busy times, but there are times when traffic demand is low. The café can be served by a picocell, which provides good data capacity as well as 3G-integrated voice. To keep costs to a minimum, the picocell is connected to the macrocell network over the existing DSL line.

Almost any available transport medium can be used for indoor small cells, as distances are short and the required level of coordination is likely to be relatively low, assuming the cells are isolated from the macrocell layer. Copper – category 5/6 cable or telephony cable – will be the most likely backhaul medium available within the building and, to a lesser extent, fiber.

The available transport media to the building will be a mix of DSL copper, passive optical network (PON) fiber and LOS microwave, preferably on the E-band for high capacities. Fiber is the preferred option when available, as it offers low delay and high capacity.

For hotspots on the street, the operator can deploy a microcell to off-load the macrocell. As performance is key, the microcell should be connected to the nearest macrocell using an LOS or a high-performing NLOS microwave link; if available, a fiber or leased-line service can also be used. Since it is the last link to a microcell, NLOS could also be used on sub-6GHz frequencies, if it is not possible to use the microwave solutions running on the higher frequency bands.

RAILWAY STATION

Large, open, indoor hotspots such as railway stations and shopping malls tend to be characterized by very high capacity demands, high rates of mobility and a lot of interference. To provide good mobile coverage in such locations, operators can deploy a centralized baseband solution – a central main unit with a number of RRUs, and localized distributed passive antennas – in combination with Wi-Fi for areas where people tend to spend longer periods of time, such as waiting rooms and cafés.

As the centralized baseband solution requires tight coordination between the main unit and the RRUs, fiber links should be used. The backhaul to the main unit and Wi-Fi unit is aggregated in an indoor pico gateway, and typical backhaul options to the building would be fiber or LOS microwave, preferably on the E-bands.

OFFICES AND HIGH-RISE BUILDINGS

In offices – including small, medium and large enterprises, hotels and high-rise buildings – a key challenge is to offer excellent speech quality, high data rates and high capacity for indoor users. Coverage from the macro network is often limited on lower floors but good on top floors of high-

rise buildings. As a result, interference from macrocells can be a challenge. Radio isolation between floors is often good (around 20dB), so a Distributed Antenna System (DAS) or multiple small cells can provide the indoor coverage needed to deliver a good user experience and high capacity. Backhaul for the base station in the basement, hotspot picocells and Wi-Fi can be connected to the building's main backhaul via a packet-based connection using an indoor pico gateway. Typical options for the building's backhaul are fiber or LOS microwave.

TOWN SQUARE

Typical of large outdoor hotspots, a town square is characterized by very high capacity demand and is subject to high levels of interference. Consequently, high-power, highly coordinated radio solutions are required.

The operator can deploy a small macrocell to cover the square, using an antenna-integrated radio solution, which is small and unobtrusive enough to be installed on a building, complemented with a microcell and a micro RRU solution to provide street-level capacity. Owing to the need for good radio network coordination, fiber backhaul (leased or self-built) or LOS microwave options connected to the macro backhaul with sufficient capacity and short delay are typically used. If distributed radio units were connected to the baseband unit (main-remote installation), it would be necessary to use the internal Common Public Radio Interface (CPRI). These connections need to be high-bandwidth (several gigabits per second) and involve low delays (in the millisecond range), so dedicated fiber links to each radio unit are used.

CONCLUSION

The introduction of heterogeneous networks will increase the number of radio nodes greatly. Backhaul, as a consequence, is crucial in a heterogeneous network scenario, as it constitutes a much larger share of the total cost of ownership. Backhaul solutions should not limit the performance of heterogeneous networks, and must be cost-efficient and easy to install.

Network performance should be uniform across the entire network, so that users do not experience a drop in performance when covered by small cells – resulting in a negative QoE perception of the whole network and operator brand. Adding radio network capacity and coverage through the deployment of small cells as part of a heterogeneous network requires a higher degree of backhaul flexibility. To minimize costs, small-cell sites will need to be connected using a well-defined range (manageable number) of physical transmission media, and allow for a wide variation in link characteristics. The bandwidth requirements and delay characteristics of each connection can differ greatly, and the total cost of the backhaul solution must match the business model of the small-cell site – which may serve just a few subscribers at any given time.

Operators should strike a balance between installing sites in the right place with sufficient backhaul capacity and delay, and the need to deliver additional capacity and coverage in the right timeframe and at the right cost. Ericsson is currently working on solutions that provide cost-efficient, high-performing backhaul for heterogeneous network scenarios.

Backhaul availability determines the feasible placements of cells, and impacts installation costs and the time needed for site acquisition and installation. When deploying a new radio site, operators will need a well-defined variety of backhaul options and combinations of complementary technologies to meet the business case. Adopting a holistic perspective when evolving today's networks to heterogeneous networks will help operators address network evolution efficiently.

GLOSSARY

ADSL2+	Asymmetric Digital Subscriber Line, with doubled data rates
CPRI	Common Public Radio Interface
DAS	Distributed Antenna System
DSL	digital subscriber line
GPON	gigabit passive optical network
LOS	line-of-sight
NLOS	non/near LoS
OAM	operations, administration and maintenance
PABX	private automated branch exchange
PMP	point-to-multipoint
PON	passive optical network
PTP	point-to-point
RAT	radio-access technology
RRU	remote radio unit
SON	self-organizing networks
VDSL2	Very High-speed Digital Subscriber Line, generation 2
WDM	wavelength division multiplexing

REFERENCES

1. Ericsson, May 2014, Ericsson Mobility Report, available at: http://www.ericsson.com/ericsson-mobility-report

2. Ericsson, February 2013, Ericsson Review, 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

3. Ericsson, September 2013, Ericsson Review, The benefits of self-organizing backhaul networks, available at: http://www.ericsson.com/res/thecompany/docs/publications/ericsson_review/2013/er-son-transport.pdf

4. Ericsson, September 2014, White Paper, Heterogeneous networks, available at: http://www.ericsson.com/res/docs/whitepapers/WP-Heterogeneous-Networks.pdf