ERICSSON

ERICSSON MICROWAVE OUTLOOK

TRENDS AND NEEDS IN THE MICROWAVE INDUSTRY

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EXECUTIVE SUMMARY

From daily life experiences, such as streaming videos, to smarter cities associated with the Internet of Things (IoT), more and more aspects of life depend upon a fast, reliable network connection. LTE is evolving rapidly and 5G is emerging as the next step to providing enhanced and diversified services and use cases, putting new demands on backhaul. Networks will evolve incrementally to higher throughput and lower latency, depending on available radio spectrum and service demands.

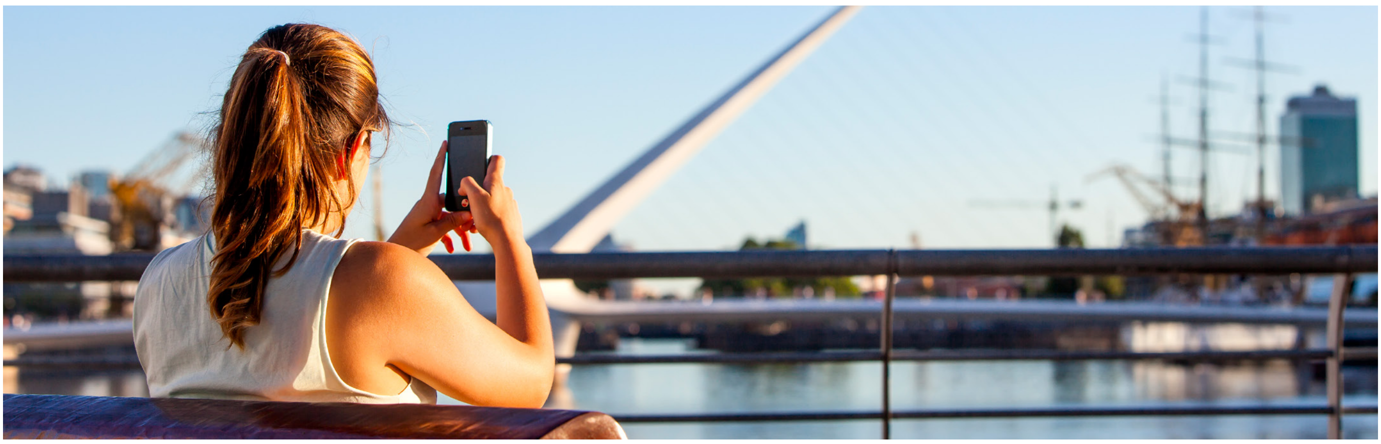
With the introduction of 5G, backhaul capacity needs will evolve further. Towards 2025, extreme capacity radio sites could require as much as 10 Gbps. However, the majority of radio sites will require less than 1 Gbps. Multiband solutions, which enable enhanced data rates by combining resources in multiple frequency bands, already constitute an essential part of modern radio access systems. In the coming years multiband will also be increasingly used in backhaul to enable the efficient use of diverse spectrum bands, and meet the performance and availability requirements over wide geographical areas.

Microwave is well prepared for 5G

Added to this, the low spectrum fee approach for E-band is dominating and will support the dramatic growth of E-band in the future. One illustrative example of this is the Polish market, where the spectrum fee in E-band is 4 to 10 times lower than traditional bands. This has had a dramatic effect on which frequencies are used. Subsequently, existing links in traditional bands are being replaced by E-band links and, over just 3 years, the E-band share of all installed microwave links has gone from 0 percent to 9 percent. This shift in frequency use might facilitate the future introduction of 5G in bands between 24 and 43 GHz.

The ultimate goal of software-defined networking (SDN) is to obtain an end-to-end view of network conditions that span across multiple technologies and different vendors' equipment. This to efficiently automate network provisioning and end-to-end services. As a result, unified management systems, along with open and standardized node interfaces, are vital pre-requisites. This drives the need for a microwave node interface standard that aligns with existing packet standards, which the industry is pursuing.

Microwave is a very flexible technology and will connect 65 percent of all radio sites by 2021. Today it already supports 10 Gbps capacities and very low latencies, and is very well prepared to support the future evolution of LTE and of 5G.



CAPACITY REQUIREMENTS AND SITUATION

The demand for mobile broadband backhaul capacity will continue to grow. In 2021, high capacity radio sites will typically require backhaul in the 1 Gbps range, and towards 2025 in the 5 Gbps range. Microwave backhaul technology is now able to support 10 Gbps, and is very well prepared to support the evolution of LTE and introduction of 5G networks

Mobile broadband networks, including backhaul, will evolve to satisfy ever increasing user needs. Today, LTE networks commonly support 150 and 300 Mbps downlink speeds, according to the Ericsson Mobility Report from June 2016. However, in late 2016 a long anticipated milestone is being passed, with the first commercial LTE networks supporting downlink peak data speeds of 1 Gbps. New LTE capabilities provide greater spectral efficiency and make the delivery of commercial LTE peak data rates of 1 Gbps feasible using 60 to 100 MHz of carrier aggregated spectrum. These higher speeds will enhance the user experience and app coverage both indoors and outdoors.

Figure 1: Backhaul capacity requirements per radio site for operators at two different stages of mobile broadband evolution

Mobile broadband introduction	2016	2021	Towards 2025
80 percent of sites	15 Mbps	25 Mbps	100 Mbps
20 percent of sites	25 Mbps	150 Mbps	300 Mbps
Few percentage of sites	90 Mbps	300 Mbps	600 Mbps

Advanced mobile broadband	2016	2021	Towards 2025
80 percent of sites	90 Mbps	300 Mbps	600 Mbps
20 percent of sites	300 Mbps	1 Gbps	3–5 Gbps
Few percentage of sites	1 Gbps	3–10 Gbps	10–20 Gbps

Source: Ericsson (2016)

5G will extend the range of frequencies used for mobile communication

The road to 5G

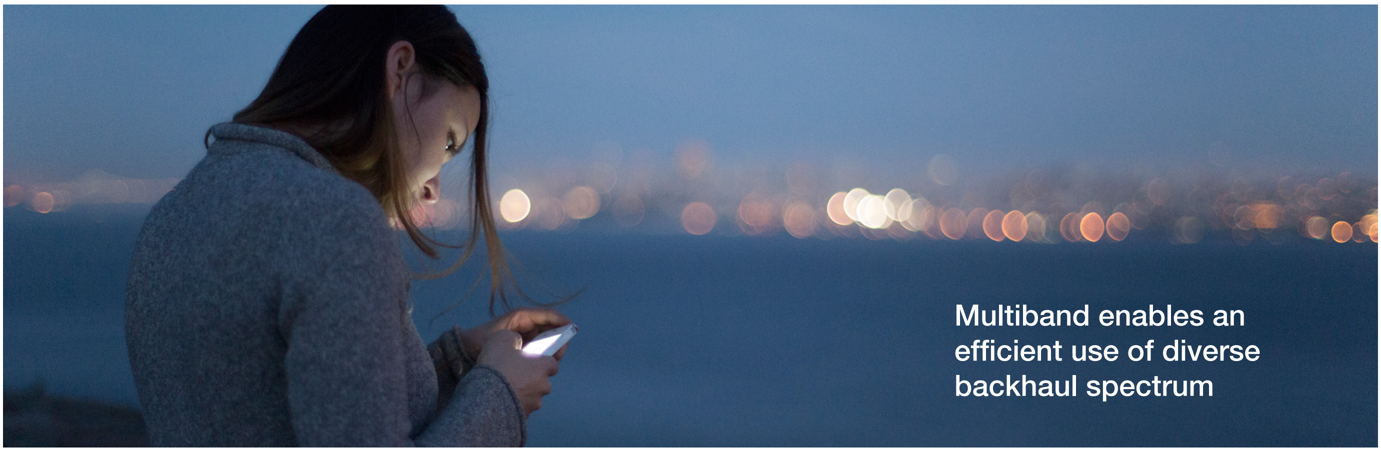
5G is the next step in the evolution of mobile communication and will be a key component of the Networked Society. It will provide enhanced mobile broadband services, as well as enable a widening range of use cases for massive and critical IoT. 5G will extend the range of frequencies used for mobile communication including new or existing spectrum below 6 GHz, as well as future spectrum at much higher frequencies. The higher frequency bands have adverse propagation characteristics, but provide much larger available bandwidths. They will serve as a complement to lower frequency bands, to provide extreme data rates in indoor and dense outdoor deployments. Data rates beyond 10 Gbps will depend on available spectrum and targeted user needs, with a focus on what can actually be provided in real-life conditions, not theoretical limits under ideal conditions. 5G New Radio (NR) is expected to be deployed commercially in a few pioneering markets in 2018, with wider market uptake around 2020. The US, Japan, China and South Korea are expected to be the first countries with 5G services.

The majority of radio sites will require less than 1 Gbps backhaul towards 2025

Differing capacity needs

The typical radio site backhaul capacity needed for two different deployment scenarios towards 2025 can be seen in the table above. The upper table represents an operator that today is in the mobile broadband introduction phase, while the lower table shows an operator in the advanced mobile broadband phase. Most operators are somewhere in between these two examples. In 2021, high capacity radio sites are expected to require backhaul in the 1 Gbps range, whereas low capacity is in the 100 Mbps range. The most extreme capacity sites are expected to target backhaul with fiber-like capacity. With the introduction of 5G the capacity evolves further, but will depend on radio access spectrum availability and local needs.

Towards 2025, high capacity radio sites are expected to require backhaul in the 5 Gbps range, with extreme capacity sites in the 10 Gbps range. However, the majority of radio sites will require less than 1 Gbps towards 2025.



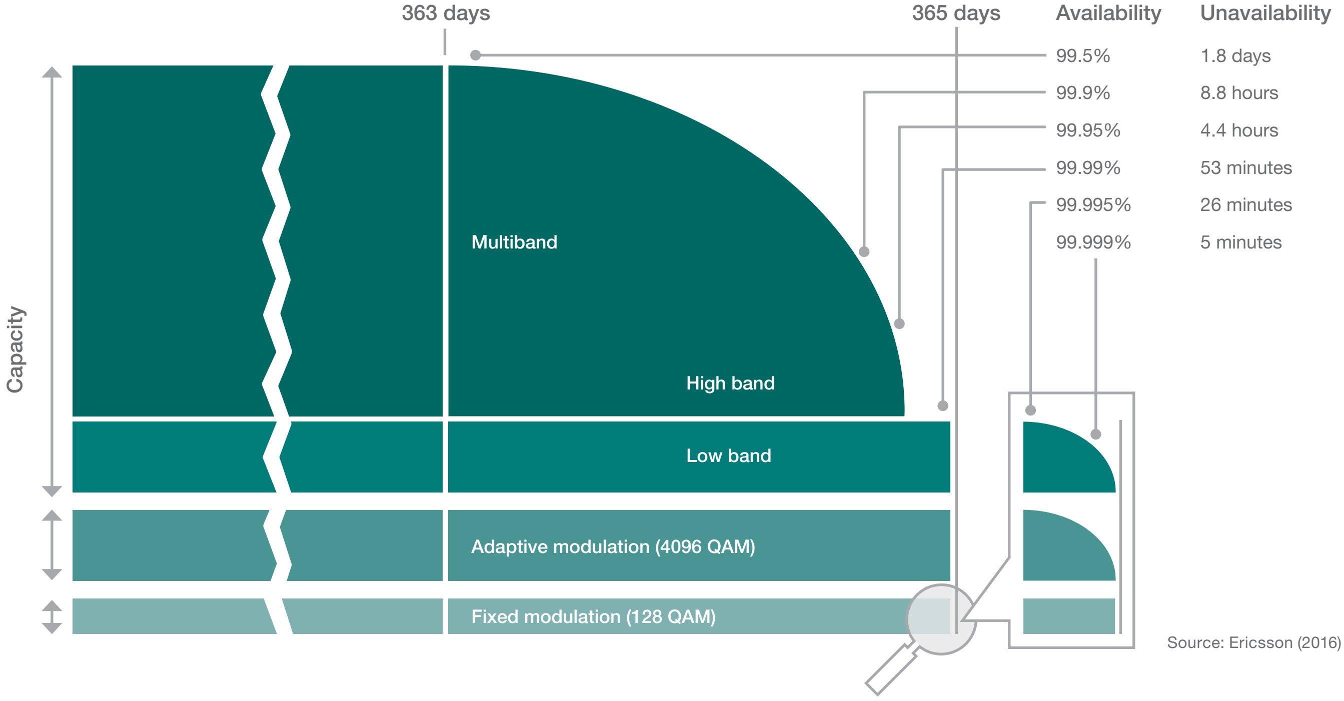
Microwave capacity evolution

As capacity needs have grown, the use of backhaul spectrum has shifted towards higher frequencies where larger channel bandwidths are more easily found. The attractiveness of the 70/80 GHz band is rapidly increasing. It offers very wide bandwidth, at a generally low spectrum fee, enabling capacities in the order of 10 Gbps or more over distances of a few kilometers.

Multiband solutions[1], which enable enhanced data rates by combining resources in multiple frequency bands, already constitute an essential part of modern radio access systems and in the coming years will also be increasingly used in backhaul. They enable an efficient use of diverse backhaul spectrum bands, meeting the performance and availability requirements for evolved LTE and future 5G services over wide geographical areas (Figure 2).

The performance of microwave backhaul has evolved continuously with new and enhanced technologies and features that make even better use of available spectrum. Microwave backhaul technology will continue to evolve and be able to handle 100 percent of all radio access sites' capacity needs, today and towards 2025.

Figure 2: Evolution of microwave backhaul technology to multiband solutions



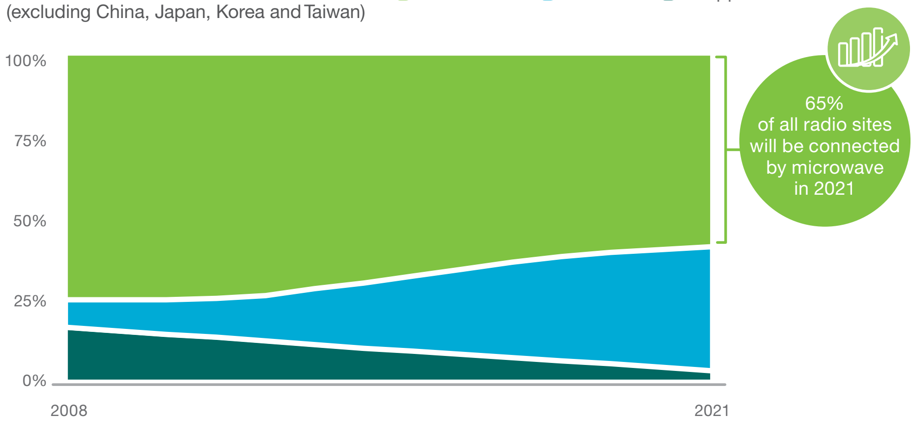
Source: Ericsson (2016)

[1]www.ericsson.com/thecompany/our_publications/ericsson_technology_review/archive/microwave-backhaul-gets-a-boost-with-multiband

MICROWAVE AND FIBER BACKHAUL

Microwave continues to be a key enabler for mobile broadband deployments in developing areas. Many large 3G/HSPA and LTE deployments will be in regions where microwave is the obvious choice. Another key factor is the use of wider channels and new spectrum, which in several countries comes with a lower cost, thereby building a business case for microwave

Figure 3: Backhaul media distribution (excluding China, Japan, Korea and Taiwan)



Source: Ericsson (2016)

When it comes to using fiber instead of microwave solutions as last mile access in mobile broadband solutions, there will be no dramatic changes over the coming five years. The substitution is declining and expected to start to flatten out (Figure 3).

When looking at the Ericsson Mobility Report from June 2016, the regions with the highest growth in terms of mobile broadband subscribers are the regions with high microwave usage: Middle East and Africa, Latin America, Central and Eastern Europe and Asia Pacific (Figure 4).

Asia Pacific is a divided region – the fiber-heavy parts already have a large penetration of 3G/HSPA and LTE. Thus greater growth can be expected in other parts of the region where microwave is utilized to a high degree.

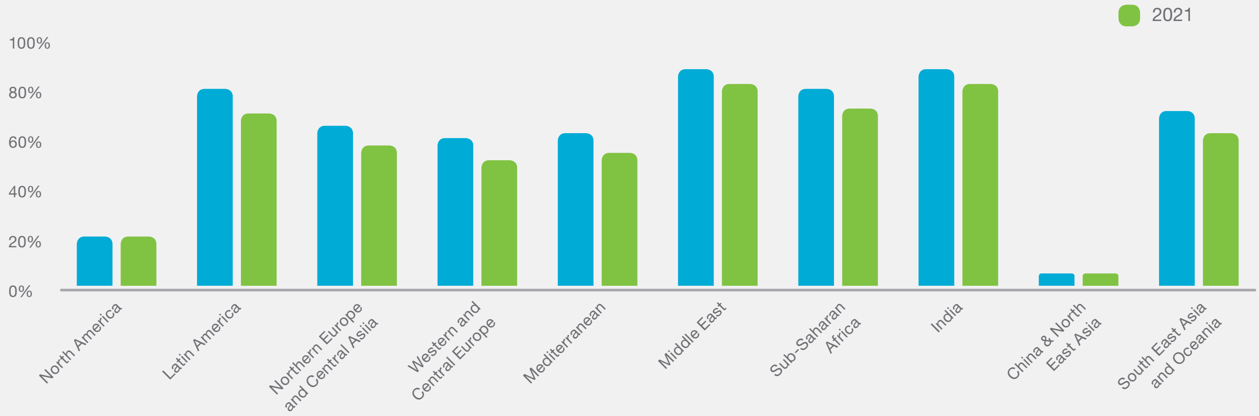
For microwave technology to stay relevant as a backhaul medium, its ability to support today's and future capacity needs is essential. Major advances mean that today microwave is already capable of supporting backhauling of any macro site.

Technologies such as new frequency bands, wider channels, better frequency reuse and higher modulation have been proven to support the high capacities. To even further enhance microwave capabilities, different alternatives of multiband solutions have been explored. With multiband solutions, the capabilities in terms of capacity and propagation lead to better use of the available spectrum.

Another important consideration in the choice of media is the Total Cost of Ownership (TCO). In parts of Europe, the introduction of E-band frequencies has come with a lower administrative fee compared to traditional frequencies. This has led to a rapid uptake of E-band as well as a tipping point for more microwave deployments in specific markets.

The advancement in technology and capability has, in combination with rapid time to market and cost efficiency, also led operators to start using more microwave networks in their enterprise service offering. Operators are looking at solutions with short payback time, as the service contract terms are typically three years or less.

Figure 4: Microwave backhaul share in different regions



Source: Ericsson (2016)

CHARTING THE FUTURE OF SPECTRUM

There is a long term global trend of microwave spectrum usage moving up in frequency. So far, the reason for this has been to access wider channels. However, new factors are now coming into play that will accelerate this shift up in frequency and in particular, the usage of E-band. The shift might facilitate the future introduction of 5G in bands between 24 and 43 GHz

Changes in society and the telecoms industry are occurring faster and with shorter cycles. But when looking at spectrum trends, a long-term view is needed. Infrastructure investment cycles and spectrum regulations are slow processes, and so a 10-year perspective or more is needed. Long-term statistics and global knowledge are crucial to draw the right conclusions.

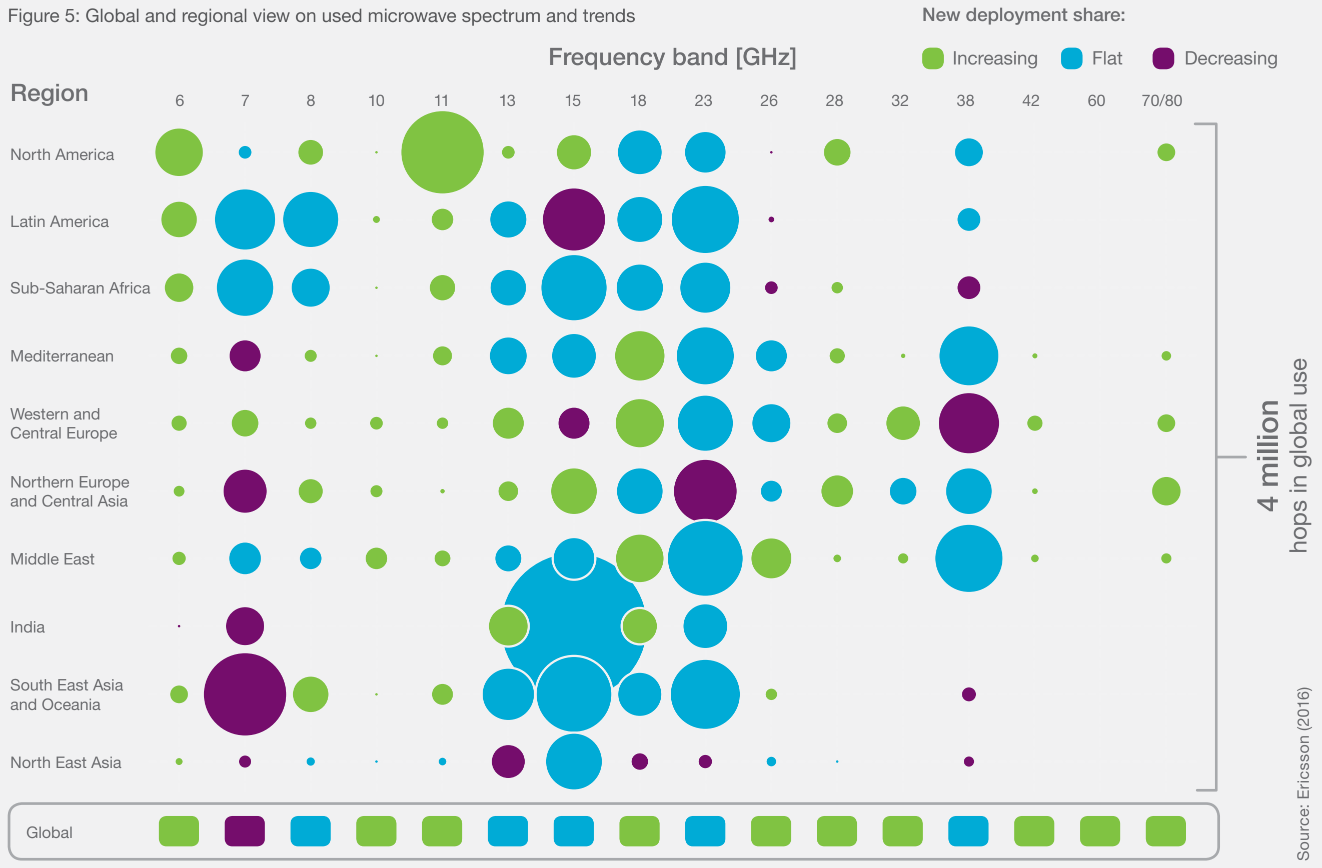
Backhaul spectrum status

Fixed microwave links use spectrum in different frequency ranges to support communication in a variety of locations, from sparsely populated rural areas to ultra-dense urban environments. Lower frequency bands are needed for longer distances, while higher frequencies are suitable for shorter distances. The installed base of microwave hops per region and frequency band can be seen below (Figure 5). The size of the circles shows the installed base and their color shows the 10-year trend for new deployment share. Globally about four million hops are in operation today. On a regional level there are large variations, but some global trends are still visible. Several popular bands (e.g. 15, 23 and 38 GHz) have reached saturation point. These bands still have high volumes of new deployments, but their relative shares are not growing. Some bands have even started to shrink (e.g. 7 GHz). Growth today is instead seen in the underutilized higher bands, where wider channels are available.

Even though the main growth is in the higher bands, some of the lower bands are also growing in popularity (e.g. 6 and 11 GHz) due to local regulations, underutilization and good propagation properties in high rain rate regions.

However, the band with the highest growth is E-band (70/80 GHz). After just a few years, there is now a substantial installed base with a solid footprint, and the band's growth is accelerating.

Figure 5: Global and regional view on used microwave spectrum and trends



The momentum of E-band

Up to this point, the main reason for moving up in frequency has been to access wider channels that are only available in the upper part of the traditional bands. Since spectrum fees per MHz typically decrease with increased frequency (Figure 6), it has been possible to increase capacity, whilst at the same time maintaining the absolute spectrum fee for a link. However, wide channels, such as 112 MHz, are not yet generally available in traditional frequency bands in most countries. With the introduction of E-band the shift to wider channels (≥250 MHz) can continue.

Operators can also now start to use the E-band spectrum to drastically lower their spectrum fees. This can be achieved by using channel widths in the same range as in traditional bands (62.5–125 MHz), and will accelerate the usage of E-band even further.

One illustrative example from the market is what has happened in Poland. Here, the spectrum fee in E-band is 4 to 10 times lower than for the traditional bands. This has had a dramatic effect on which frequencies are used. Existing links in traditional bands are being replaced by E-band links, and over just 3 years, the E-band share of all installed microwave links has gone from 0 percent to 9 percent (Figure 7). The same pattern has also been seen in other Eastern European countries and other markets, where the E-band spectrum fees are very low.

When looking at the E-band spectrum fee in several countries, most regulators have adopted a low fee approach (Figure 8). This will boost the usage of E-band with efficient spectrum use. However, countries with a no-fee approach might risk an efficient use of spectrum in the long term, while countries that have a very high fee will limit the usage of E-band, making the build out of mobile broadband more difficult.

Figure 6: Yearly average spectrum fee per MHz

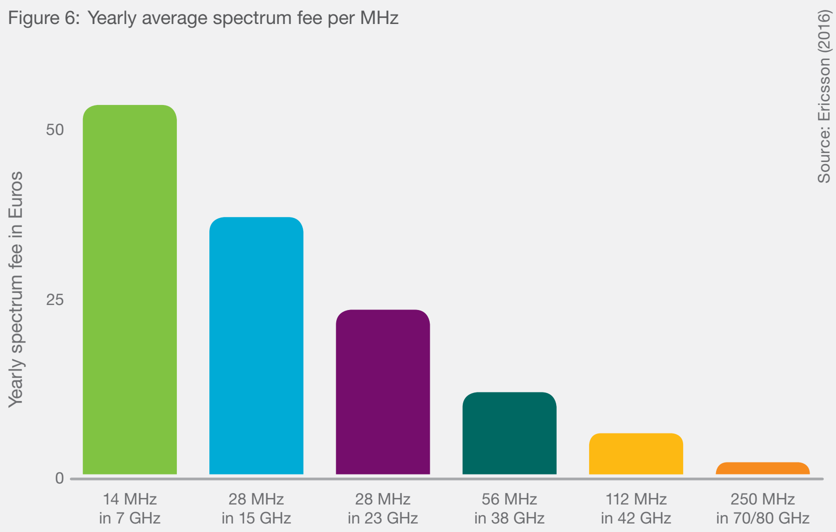


Figure 7: E-band share of installed microwave links in Poland

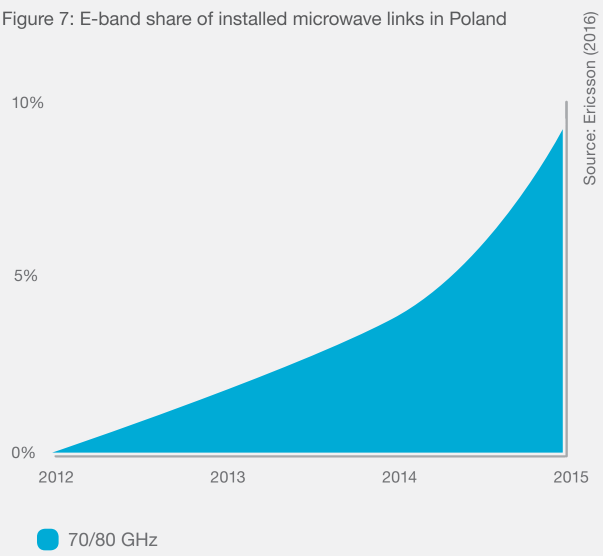
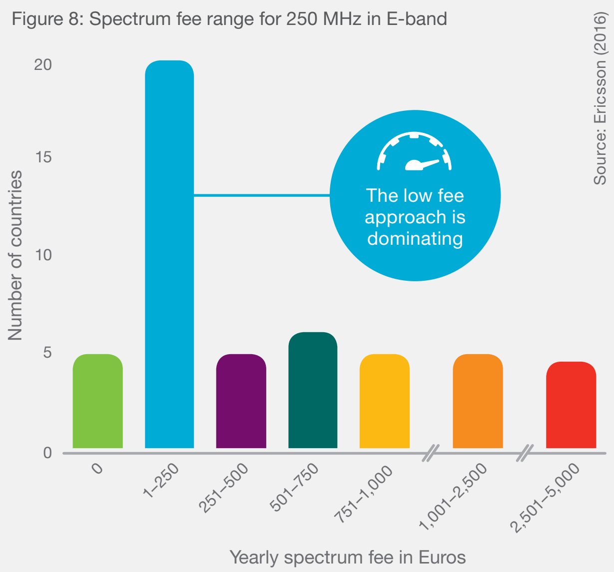


Figure 8: Spectrum fee range for 250 MHz in E-band



Enter 5G

5G radio access technology – New Radio (NR) – will take on a much larger role than it has in previous generations and will be a key enabler of the Networked Society. It will adapt and scale to provide wireless connectivity for a wide range of applications, use cases and deployment types. In general, lower bands are crucial for the provisioning of deep indoor coverage and extended outdoor coverage, while the higher bands are crucial for extreme bandwidths. A single frequency band cannot provide a solution for all the 5G use cases, given the diversity of future applications and their different requirements for wider bandwidth, shorter latency and extended coverage. LTE is evolving to support some of the new use cases in frequency bands below 6 GHz. This will be further enhanced and refined in these bands by 5G NR; a scalable technology that will support all frequency band types – from low bands below 1 GHz and mid bands from 1 GHz to 6 GHz, to high bands up to 86 GHz.

Following regulatory decisions made at WRC-15, the International Telecommunication Union (ITU) is commissioning international spectrum studies within its Radiocommunication Sector (ITU-R). The studies concern 5G mobile broadband systems of specific frequency bands in the 24.25–86 GHz range (Figure 9), and will pave the way for decisions in the fall of 2019. Such new spectrum decisions at the ITU WRC-19 will allow for standardized and commercial 5G deployments beyond 2020. Intensive work by ITU-R and 3GPP is also ongoing to finalize specifications and standards for the deployment of 5G networks before 2020. These efforts need to take into account the many different requirements of future 5G users, and the challenges that they present.

Lower bands are crucial for deep indoor coverage and extended outdoor coverage

The current process for WRC-19 focuses on spectrum for commercial 5G deployment beyond 2020. However, some countries are targeting initial deployments well before 2020, and are already identifying pioneering frequency bands. Some are considering early introduction of 5G in low and mid bands, such as 600 MHz, 700 MHz and 3.5 GHz. Others are targeting early deployments of very high capacity services in the new millimeter wave bands, with a particular focus on the 28 GHz band – although this band is not on the ITU-R list for WRC-19. The US, Japan, China and South Korea are expected to be the first countries where 5G subscriptions will be available. The Federal Communications Commission (FCC) recently adopted new rules to facilitate the development of 5G spectrum in the US, with the first decision on the flexible fixed and mobile use of the 28 GHz band and the 37/39 GHz band (Figure 9). The more flexible use of spectrum may create opportunities for sharing among different kinds of users (fixed/mobile; federal/non-federal; terrestrial/satellite; and carrier networks/private networks). The unlicensed 60 GHz band has also doubled in size to cover all of 57–71 GHz. The FCC is further investigating additional bands out of those being studied for WRC-19, such as the 24, 32, 42, 47, 50 and 70/80 GHz bands (Figure 9).

It should be noted that such diverse frequencies have very different characteristics, since propagation becomes increasingly limited as frequency increases. The very highest frequencies (beyond 42 GHz) are therefore considered to be mainly suitable for indoor hot spot scenarios.

Figure 9: 5G and backhaul spectrum

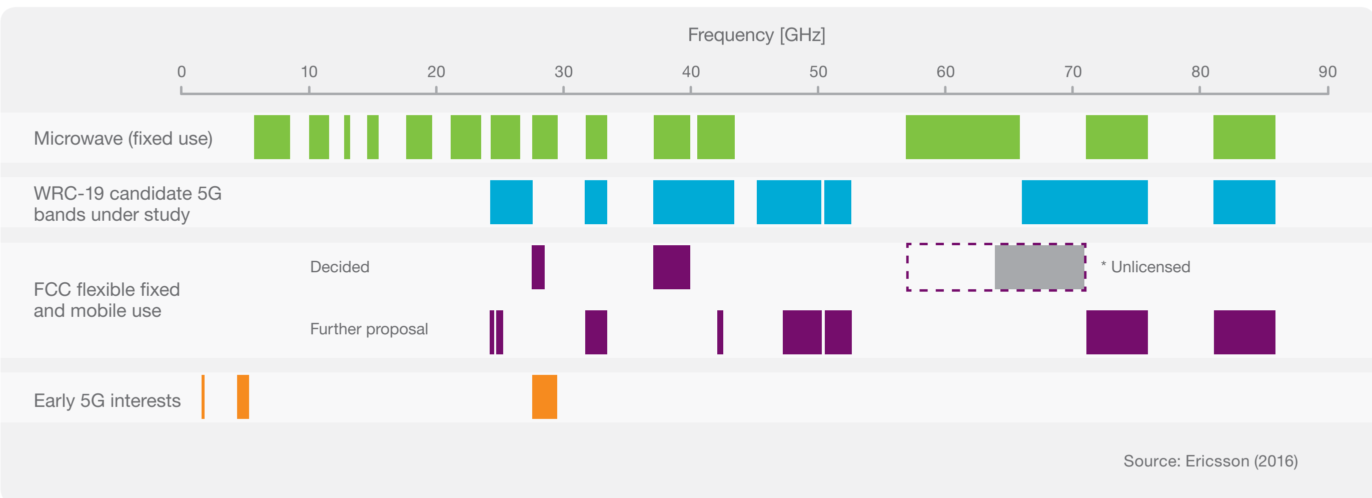


Figure 10: Future use of microwave and spectrum

Source: Ericsson (2016)

Future spectrum outlook

Today, many of the bands studied for 5G use are allocated to the fixed microwave service (Figure 9). Although the dominant use of fixed microwave is for mobile backhaul, it is also extensively used by other industries and societies (Figure 10). Individual spectrum licenses per installation is most common, which provides the ultimate sharing of spectrum for all users of fixed microwave.

Fixed microwave deployments in the 38 GHz band are extensive, especially in the European region. And to some extent, this is also the case for the 26, 28 and 32 GHz bands (Figure 5). However, as communication networks are upgraded for even higher capacities, a shift is expected from the use of the fixed microwave bands in the 24.25–43.5 GHz range to the use of the 70/80 GHz band, which offers very high bandwidth. Multiband solutions for microwave will further accelerate the use of 70/80 GHz, as will low spectrum license fees. If the growth curve continues, E-band will account for 20 percent of new deployments by 2020. This shift in frequency use might facilitate the future introduction of 5G in bands between 24 and 43 GHz.

Some use cases, such as small cell backhaul in ultra-dense scenarios, might be addressed in the future 5G spectrum (Figure 10). Spectrum licenses for geographical areas are advantageous for rapid deployments of small cell backhaul. In areas with unused 5G access spectrum resources, it provides an opportunity for self-backhaul as well as for stand-alone backhaul. In the future, a more efficient use of spectrum and a higher degree of sharing between different types of radio services is expected. An example would be indoor hot spots sharing spectrum with outdoor fixed microwave use, which is already regulated in the 60 GHz band in Europe.

Looking to the future, the industry also has an interest in the use of frequencies above 100 GHz for fixed microwave. This could enable the next leap in capacity towards 100 Gbps, over hop distances of up to a kilometer, supporting many different applications and use cases. Technologies are being investigated, and regulatory studies are examining channel arrangements and deployment scenarios in the 92–114.5 GHz and 130–174.7 GHz frequency ranges, commonly referred to as the W and D-band for microwave backhaul.

Millimeter wave backhaul and multiband solutions support the evolution to 5G networks

5G AND LTE EVOLUTION

The evolution of LTE and 5G NR (New Radio) will support the ever increasing connectivity and performance needs. The high scalability and flexibility of 5G NR will not only support enhanced and diverse services in the future, but will also facilitate the evolution of the network; an evolution that also puts new demands on backhaul

Mobile networks must evolve to meet enhanced as well as diversified demands (Figure 11). New communication requirements pose challenges to existing networks in terms of technologies and business models.

Mobile broadband will continue to evolve to meet the ever growing traffic needs. Enhanced mobile broadband will meet the demand for an increasingly digital lifestyle, and support services that have high requirements for bandwidth, such as high definition (HD) videos, virtual reality (VR), and augmented reality (AR). 5G NR will be a very scalable technology capable of providing 10 Gbps peak rates in some scenarios, but a consistent user experience will be of higher priority than theoretical peak data rates. LTE and 5G NR will also be used as a fast and efficient alternative to wireline technologies, to provide fixed wireless access for residential customers and enterprises. This is complemented with microwave transport solutions, not only as backhaul, but also as virtual fiber solutions to provide multi-gigabit connections to multi-tenants and enterprises.

In the future, all devices that benefit from an internet connection will be connected. In this Networked Society, every person and industry will be empowered to reach their full potential. IoT technology is a key enabler of this vision by delivering machine-to-machine and machine-to-person communications on a massive scale. Massive IoT focuses on services with high connection density, such as smart city and smart agriculture. With new standards specifically targeting connectivity requirements and wide outdoor as well as deep indoor coverage, massive IoT is now set to take off. The traffic from most IoT applications will be relatively small and easily absorbed in existing network infrastructure. Any network extensions can be facilitated using microwave backhaul for rapid deployments.

In addition, new types of IoT use cases are envisioned for LTE and 5G, such as traffic safety and control of critical infrastructure and industry processes. These critical machine type communication (MTC) applications set stringent requirements for performance characteristics, like high reliability and low latency. Here, the number of devices are typically much smaller, but the business value is significantly higher. Although the dominant use of microwave transport is for mobile backhaul, it is also extensively used by many other industries and societies and is well proven in, for example, critical communication networks.

Figure 11: Network evolution

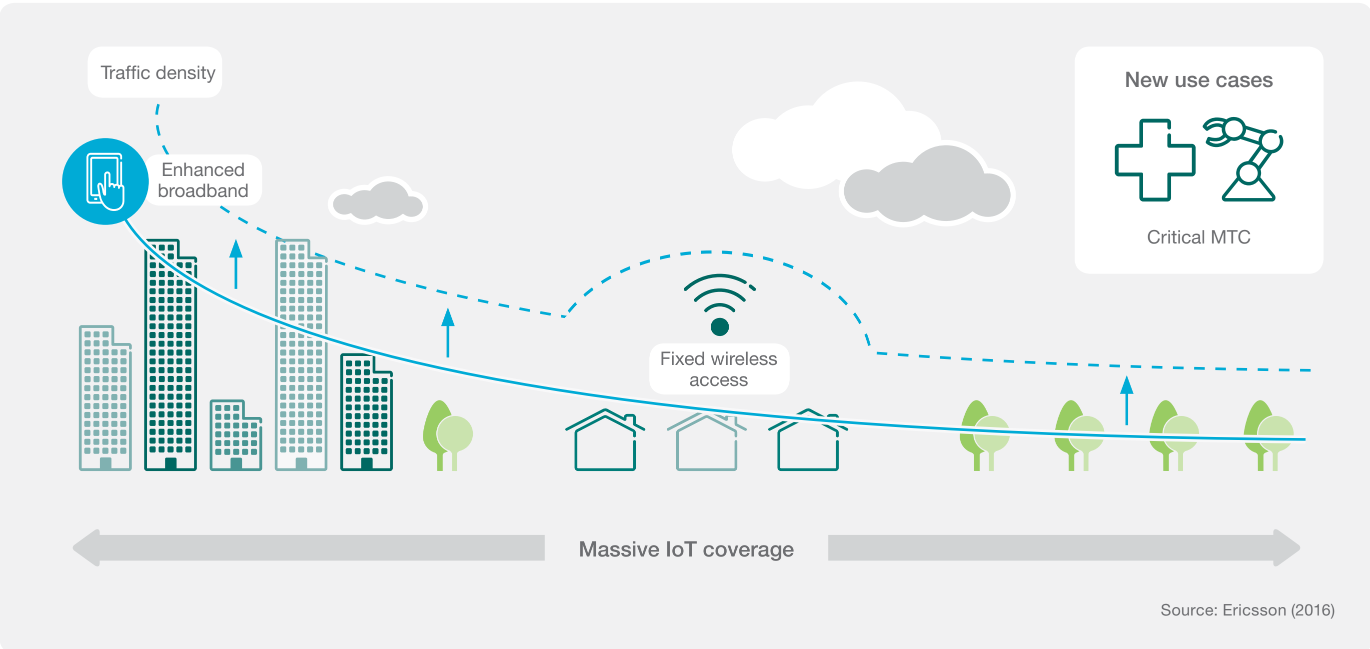
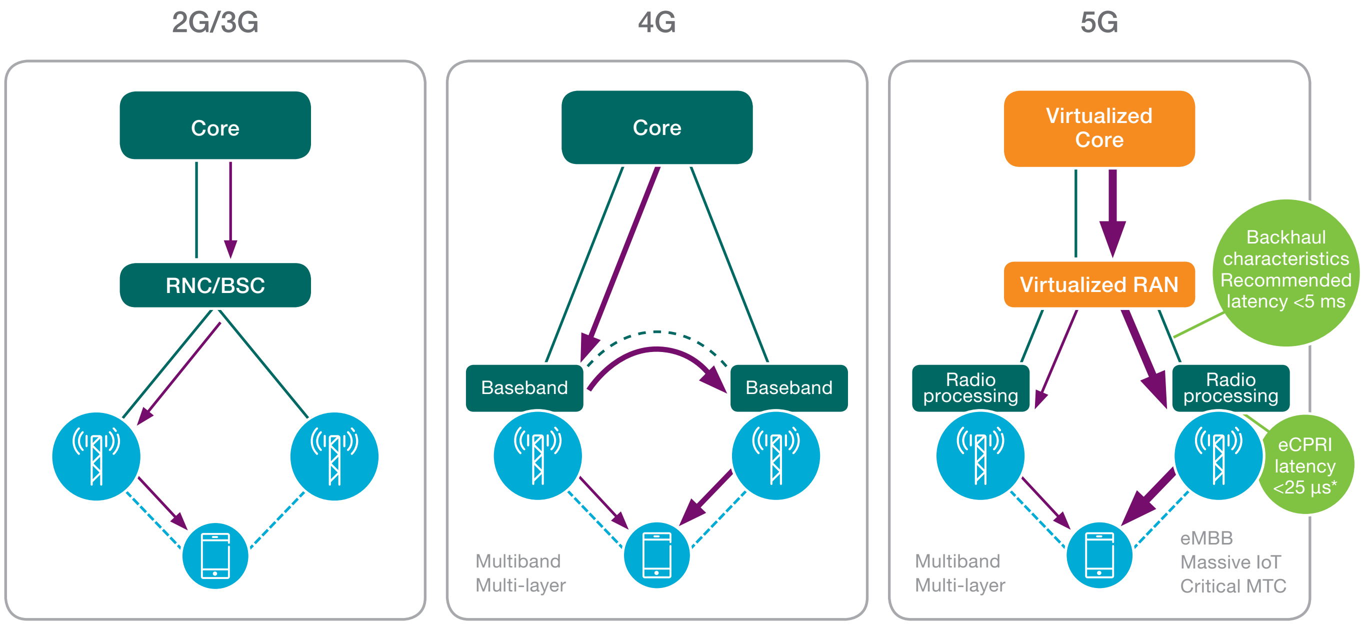


Figure 12: The road to a flexible 5G architecture



*TTI dependent Source: Ericsson (2016)

RAN architecture evolution

The expectations for 5G networks are high – providing support for a massive range of services – including those yet to be innovated and developed. However, the maximum levels of performance will not all apply at the same time for every application or service. Instead, 5G systems will be built to meet a range of performance targets, so that different services with widely varying demands can be deployed on a single infrastructure. Getting networks to provide such different types of connectivity, however, requires flexibility in architecture.

One of the key advantages of 4G LTE has proven to be its flat architecture (Figure 12). This enables quick rollout, ease of deployment and standard IP-based connectivity. Thanks to collaboration between radio sites over the IP-based X2 interface, LTE handovers remain seamless from a user perspective. In addition to basic mobility and traffic management functionality, X2 coordination is evolving to support carrier aggregation and coordinated multipoint reception (CoMP) across sites and layers. The coordination gains degrade with increasing latency; therefore an X2 latency of less than 5 milliseconds is recommended. This is already achievable today in most networks.

With the evolution of 4G and the introduction of 5G, RAN architecture is undergoing a transformation to increase deployment flexibility and network dynamicity. This enables networks to meet increasing performance requirements, while at the same time keeping a lid on TCO. Deployment flexibility enables an operator to deploy and configure the RAN with maximum spectrum efficiency and service performance regardless of the site topology, transport network characteristics, and spectrum scenario. This is achieved through a correct split of the RAN architecture into logical nodes, combined with the future-proof freedom to deploy each node type in the sites that are most appropriate given the physical topology and service requirements.

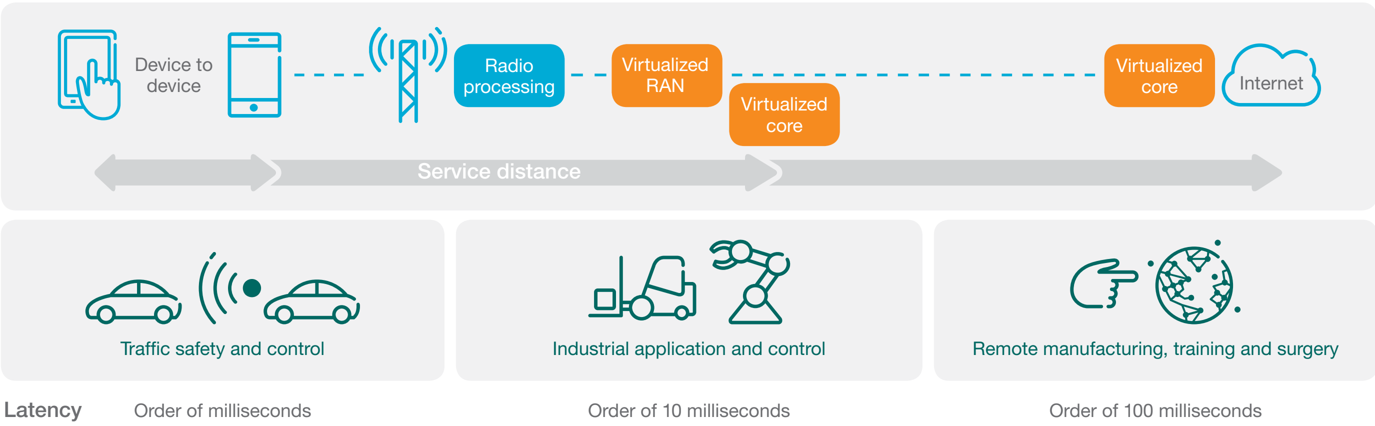
The core functions are virtualized (Figure 12) so you can scale capacity and introduce new services much faster and more cost-effectively at any location in the network, from small-scale local to large-scale data center deployments. Some of the non real-time RAN functions that were previously hosted on the baseband units, are also becoming virtualized (Figure 12) – for example, the multipath-handling function that is the anchor point for dual connectivity in 5G. By having this function higher up in the network, tromboning of traffic is avoided. The IP-based interface between the virtualized RAN and the real-time radio processing functions has a characteristic similar to backhaul. It scales with user data and has a recommended latency of less than 5 milliseconds. The new fronthaul for 5G, eCPRI, is being standardized and will use ethernet over dedicated fiber connections. It will encompass increased bandwidth efficiency, increased capacities and lower latencies in order to meet the needs for 5G. The latency requirements are more stringent than today – less than 25 microseconds for eCPRI (dependent on 5G TTI) as compared to less than 150 microseconds today for CPRI.

Low latency services

Since the introduction of LTE, the main focus has been to enhance throughput, while improvements in latency have lagged behind. However, lower latency is now driven by the ambition to support many new applications. Some envisioned 5G use cases, such as traffic safety and control of critical infrastructure and industry processes, may require much lower latency compared with what is possible today. Latencies of the order of 30 milliseconds would achieve the illusion of instant response, while for the most extreme use cases, such as for the operation of fast-moving machine parts or scenarios that require accurate real-time control, latency should not exceed a couple of milliseconds.

Networks will incrementally evolve to higher throughput and lower latency, and efforts are ongoing to significantly reduce LTE latencies. Smart applications that adapt to the performance that the networks actually provide are also common. 5G NR is being developed with these requirements in mind and will be very flexible and scalable. The flexibility of the 5G architecture is also essential to shortening the distance and the associated latency between the low latency service end points (Figure 13); for example, to enable factory machines or vehicles to communicate directly with each other, device to device, and to locate virtualized RAN and core functions to deploy user services on local cloud platforms closer to the antenna sites. As always there will be a tradeoff between investments and value of low latency, which is why some of the most challenging use cases might be more locally deployed.

Figure 13: Low latency service types



Source: Ericsson (2016)

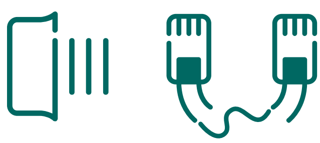
Latency contributions

The speeds at which signals can travel through the air and at which light can travel along a fiber are governed by fundamental laws of physics. The speed of light in fiber is roughly two-thirds the speed of signals in air. The lengths of deployed fiber are typically 1.5–2 times longer than the shortest distance through air. Thus, free space has 34–67 percent lower latency than fiber. This is the reason that microwave transport is extensively used in the most extreme low latency networks that exist today – high frequency stock trading networks.

There are many other contributions to latency in networks beside propagation, such as protocol incurred latencies (TCP), transmission delay, processing delay and queuing delay. To guarantee low latency, transport networks need to provide mechanisms that can apply priorities and enable optimal routing of latency-critical traffic. In practice, such mechanisms might select direct paths to minimize propagation delay or bypass certain nodes to avoid the delay incurred at intermediate hops – allowing overall latency to approach the theoretical limit.

The evolution continues

The standardization of 5G NR has just started and many details remain to be resolved in the coming years. A forward-compatible standardization approach is targeted, as this will be key for phasing-in the necessary features. This will enable all identified use cases in subsequent releases of the 5G NR specification. The flexibility of 5G NR will also facilitate the introduction in existing networks, as the most stringent requirements are only needed in parts of the networks where the most challenging use cases and services are targeted. It is not 5G per-se that puts stringent requirements on the networks, it is the future service requirements that are targeted. Microwave backhaul technology is very well prepared to support the future evolution of LTE and of 5G.



Free space has 34–67% lower latency than fiber

THE VALUE OF SDN FOR MICROWAVE

The dynamic capacity of microwave links, usage of unlicensed spectrum and an increased focus on energy efficiency are microwave-specific examples of how software-defined networking (SDN) functions can increase overall network performance

What is SDN?

As fixed and mobile networks evolve to 5G, using a greater mix of technologies and vendors, there is a growing need to improve operational simplicity, efficiency and cost. From an operator perspective, automated network provisioning and end-to-end network services are the main SDN drivers. The ultimate goal is to obtain a global view of network conditions spanning across different vendors' equipment and multiple technologies. In order to manage equipment from different vendors in an efficient manner, open and standardized node interfaces are an important pre-requisite.

A variety of different SDN functions and architectures are being discussed and proposed within the industry, but what they all have in common is a very clear relationship with network management. In some proposals, the SDN controller completely replaces the role of a network management system (NMS) – while, in others, the SDN controller is seen as an entity managed by the NMS. As such, the SDN functions form part of an overall NMS strategy, regardless of how the functionality is logically partitioned across different units and what terminology is used. Here, we have chosen to define SDN functions as those that primarily deal with dynamic parameters on a network-wide basis.

A number of microwave use cases have been proposed by the industry and below we describe some examples. It is important to remember that these types of use cases alone will not be sufficient to motivate SDN introduction in the networks. However, once an entire network is SDN capable, there are gains to be expected in the microwave domain as well.

Microwave use cases

The elasticity of microwave links is a characteristic that could make SDN functions relevant. A microwave link's capacity varies with propagation conditions and events; for example, rainfall causes fading that reduces capacity. This dynamic information can be used to optimize the overall network performance, as described in use cases one and two below. The microwave bandwidth can be signaled to a router, using the ITU-T G.8013/Y.1731 bandwidth notification message (BNM) protocol, or signaled directly to an NMS/SDN system. Other areas that could drive SDN for microwave are usage of unlicensed spectrum and increased focus on energy efficiency, with examples described in use cases three and four.

1. Flow-based traffic shaping

The principle of this use case is to dynamically adapt high throughput flows to the transport capacity currently available in the network at a given point in time. This will avoid overutilization and reduce delay and packet loss locally over the degraded microwave links. In combination with other mechanisms, such as Hierarchical Quality of Service (HQoS) and flow/traffic re-routing, the overall service quality can be secured on a network level.

2. Flow/traffic re-routing

In cases where redundant connections with spare capacity are available, dynamic management of the load can maximize capacity during peak times and secure traffic during periods of link degradation. Re-routing of traffic on links with limited and/or degraded capacity to other redundant links with spare capacity results in overall service quality improvements.

3. Dynamic frequency allocation

Unlicensed spectrum is attracting the interest of telecom operators. However, it could be subject to interference as new hops are commissioned, leading to reduced network performance. The SDN concept can be utilized to avoid or minimize interference by determining whether any hop should change channel and re-programming the microwave nodes accordingly.

4. Load-sensitive air interface

This use case aims to increase the energy efficiency of the microwave network, resulting in lower operational costs. In particular, this can be achieved when multiple links of a hop are installed with radio link bonding. In this scenario, full capacity may not be required at all times and the SDN concept can be used to determine whether one or multiple links should be active.

Just the beginning

The SDN concept for transport, and microwave in particular, is still in its early stages.

Relevant use cases need to be defined and agreed to understand how microwave fits into the bigger SDN transport picture.

Three categories of network functions

The time scale of network variations is important and can be used to define the SDN domain. All functions in a transport network can be divided into three different categories based on the time scale of their variation (Figure 14). In the first category the functions are static and the corresponding microwave parameters – such as maximum output power, available modulation schemes and mapping between service and transport layer functions – are typically configured manually as part of the initial setup. This static category belongs to the domain of traditional network management, including FCAPS functions (Fault, Configuration, Administration, Performance, Security) and static service provisioning.

SDN functions are applicable to the second, dynamic category, where decisions to re-configure a specific node in the transport network are automated and taken based on network-wide information. The time scale of the variation is down to the order of seconds and examples of such node configurations are QoS settings and forwarding information typically applied in use cases one and two, re-configuration of the frequency in use case three and activation of a link in use case four. In cases where the node itself can make a decision equally well, the preference should be to do so.

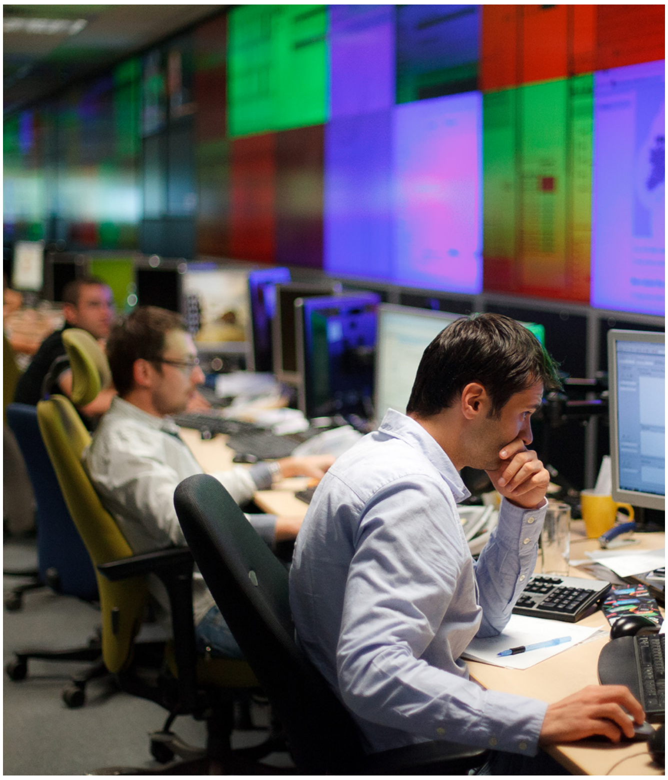


Figure 14: Network functions of different time scales mapped to corresponding use cases and control entities

Function	Time	Use cases	Control
Static	–	Initial set-up FCAPS Static service provisioning	Network management function
Dynamic	>Seconds	Traffic shaping and re-routing Dynamic frequency allocation Load-sensitive air interface	SDN function
Ultra-dynamic	<Seconds	Adaptive modulation Radio link protection ATPC	Microwave node (local control within policies)

Source: Ericsson (2016)

Communication between the node and the NMS/SDN entity needs to be kept to a minimum to reduce the signaling load and network complexity. SDN should be applied only when there is a clear value of centralized control in the network. In many cases there will be a mixed setup where decisions are taken locally by the node, but being based on policies defined by the network-wide SDN functions.

The third category is an ultra-dynamic domain where parameters vary on a sub-second time scale; examples of related functions are adaptive modulation, radio link protection and Automatic Transmitted Power Control (ATPC) in microwave nodes. These functions need to be controlled by the node itself because of the rapid time scale, as configuring them via SDN is not viable because of the latency in the network. An important role of SDN functions in this category is to create policies towards the nodes. An example of such policy is min/max output power for ATPC.

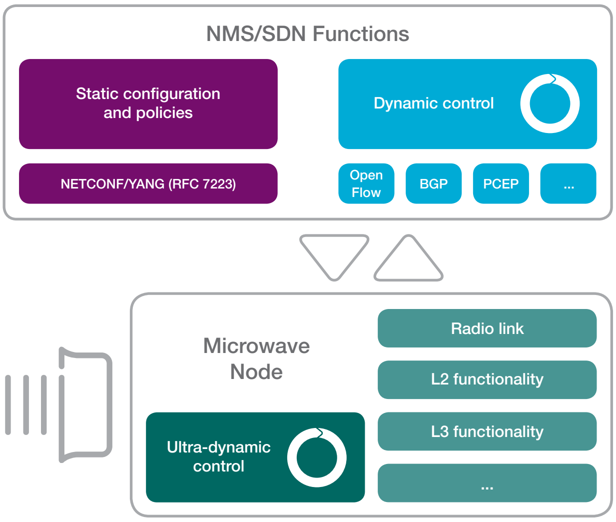
SDN is useful for dynamic node re-configurations based on network-wide conditions

Unified management at node level

As part of SDN introduction, unified management becomes an important cornerstone, being a pre-requisite for handling equipment from multiple vendors in an efficient manner. Hence, open and standardized node interfaces are closely associated with the concept of SDN. For packet functionality, such standards are already in place, both for Ethernet (Layer 2) and IP/MPLS (Layer 3), but standards do not currently exist for microwave radio link functionality.

Ericsson has, together with other vendors, submitted a draft to the Internet Engineering Task Force (IETF), proposing a YANG model for managing microwave networks. The model follows the same structure as existing standards in the packet domain. As a microwave node also contains packet functionality, which is expected to be managed using those models, there are obvious advantages if radio-link interfaces can be modeled and managed using the same approach. This is illustrated in the figure below which shows how different NMS/SDN functions, and the corresponding protocols, are applied towards a microwave node.

Figure 15: Unified management at node level with uniform modeling of all static parameters



Source: Ericsson (2016)

The proposed IETF YANG model covers all relevant static microwave functions, but also leaves room for vendor-specific extensions. These extensions represent a very small part, less than 10 percent of the total model, but are important for different reasons. There will always be certain implementations that differ among vendors and it is, therefore, practically impossible to achieve industry consensus on every design detail. Additionally, a standard that allows for a certain degree of freedom encourages innovation and competition, which benefits the entire industry.

SDN drives the need for a microwave node interface standard that aligns with existing packet standards

Standardization activities

Open network foundation (ONF)

> Maintains OpenFlow protocol specification
> Microwave oriented modeling and PoC activities

OpenDaylight (ODL)

> Open source development of SDN controller
> SNMP, OpenFlow, BGP, PCEP, LISP, etc.

Internet Engineering Task Force (IETF)

> Ethernet and IP/MPLS Yang models
> Microwave Yang model recently proposed by Ericsson and others

European Telecommunications Standards Institute (ETSI)

> New work item on microwave SDN use cases

In summary, SDN is a promising concept that will allow for increased network efficiency. Based on network-wide information, the available resources can be utilized in a more powerful manner and with a higher degree of automation. Microwave networks in particular can benefit from the SDN concept because of the variable capacity of a microwave link, as well as the complex interference situation that may arise with usage of unlicensed spectrum. However, SDN for microwave is still in its early phases and a considerable amount of work is required to define how microwave networks will operate within the overall area of transport SDN.

IMPROVING ENERGY PERFORMANCE

Energy performance regulations and policies are emerging globally and there is an increasing interest in green products and operations. By reducing power consumption in mobile broadband networks, environmental benefits as well as cost savings can be achieved

In the EU, the Energy Efficiency and EcoDesign directives set requirements on energy performance. In India, regulators are implementing the Green Passport policy framework. The first phase includes requirements for measuring energy consumption. The second phase will set energy threshold values as a market entry requirement. In the US, the Energy Star specifications under the Environmental Protection Agency will specify the requirements. Companies also see a strong connection to their brand value by defining targets and commitments on carbon emission improvements.

Microwave systems have an important role to play in improving the overall energy performance in mobile networks now and in the future. Energy cost is one of the top aspects to address, representing 12 percent of the microwave backhaul opex. It's also important to enable the use of alternative power solutions and back-up systems for remote sites. By changing focus from energy performance on individual equipment to a network view, substantial energy savings can be made. When expanding the focus on energy performance to a network view, monitoring real-time power consumption together with site management will increase in importance.

By using capable hardware, energy efficient software features and enabling integrated site solutions, additional improvements in energy performance will be achieved

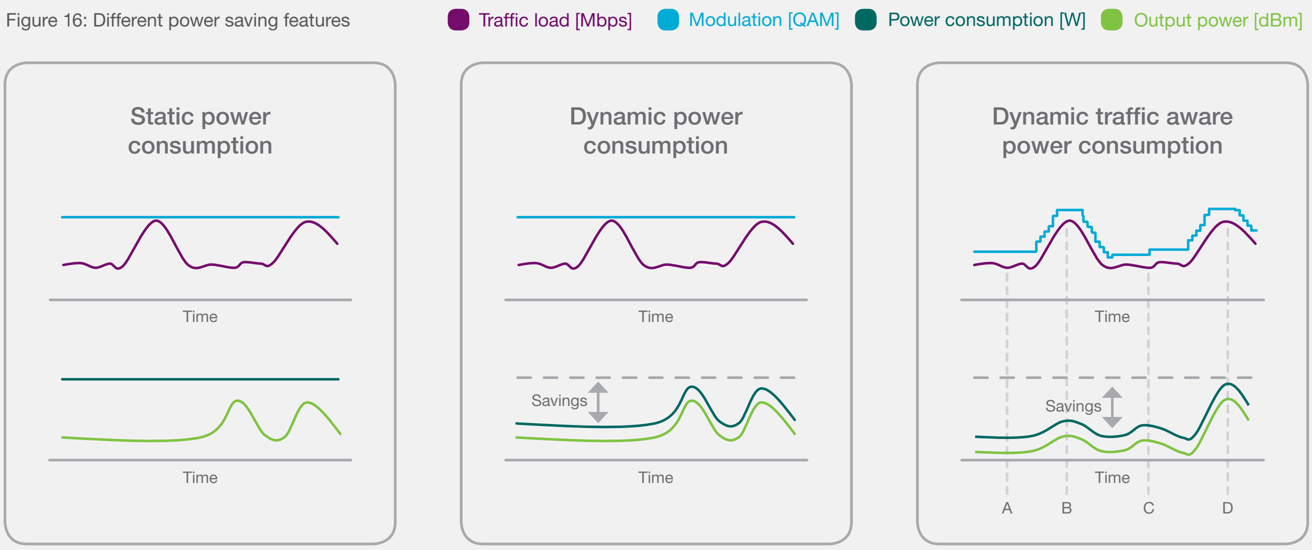
Opportunities to improve energy performance

Microwave equipment has traditionally been optimized for meeting peak capacity and to provide five nines availability. To improve overall energy performance, additional effort needs to be made. By using capable hardware, introducing energy efficient software features and enabling integrated site solutions, additional improvements in energy performance will be achieved.

Capable hardware

Microwave radios are one of the major power consumers in microwave systems, with its power amplifier using the most energy. The introduction of gallium nitride (GaN) technology, opens up opportunities to significantly reduce consumption in the power amplifier. GaN technology enables transistors with power densities that are as much as five times higher than conventional gallium arsenide (GaAs) devices. GaN technology increases the power amplifier energy efficiency by up to 50 percent, thus enabling radio unit power consumption to be reduced by 25 percent.

Figure 16: Different power saving features



Source: Ericsson (2016)

Software features

Conventional microwave systems have static power consumption. This results in high power usage independent of how much output power is used. With dynamic power consumption features, the radio unit can effectively adjust the power requirements according to the used output power in the radio. By comparing static power consumption with dynamic power variation (Figure 16), it can be seen how the power consumption follows the output power. The needed output power varies over time and full output power will only be needed under the worst raining conditions, which occur around 1 percent of the year, represented by the two peaks in output power in the figure.

Substantial energy savings require a network approach

Dynamic traffic aware power consumption combines dynamic power consumption with automatic adjustment of modulation to the throughput needed. When stepping down in modulation, the required received signal strength will be reduced, enabling further reduction of the output power. Comparing dynamic power consumption with dynamic traffic aware power consumption, major savings in three out of four link conditions can be seen:

Dynamic traffic aware power consumption

Major savings 99.9 percent of the time

A. Traffic is outside the peak hour and rain intensity is not severe (~89 percent of the time)

B. Traffic is within the peak hour and rain intensity is not severe (~10 percent of the time)

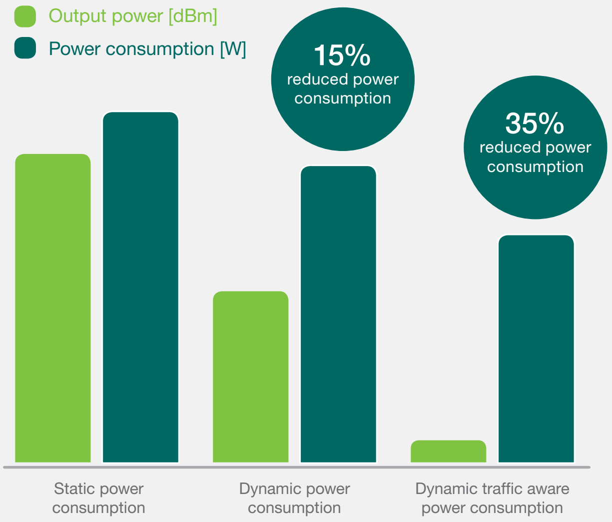
C. Traffic is outside the peak hour and rain intensity is severe (~0.9 percent of the time)

No savings 0.1 percent of the time

D. Traffic load is within the peak hour and rain intensity is severe (~0.1 percent of the time)

By introducing these types of software features in microwave systems, major yearly savings can be achieved when looking at the total microwave network. With dynamic power consumption, 15 percent energy savings can be achieved. With dynamic traffic aware power consumption, the savings can be improved up to 35 percent (Figure 17).

Figure 17: Average output power and power consumption



Source: Ericsson (2016)

Site solutions

Another opportunity to reduce power consumption is by focusing on the complete site. The key opportunity is then to use equipment that can be integrated in a single cabinet design. This solution saves power by sharing cooling, power supply, batteries, cabling and accessories, among others. When using a common cabinet cooling control, all units in the cabinet can request more or less cooling, resulting in the cabinet fan speed and and at the same time noise levels will be significantly reduced. One use case example shows that power consumption can be reduced from 70 W to 15 W (80 percent) and noise levels are significantly reduced.

By introducing more energy efficient technologies such as GaN, different software features for energy efficiency and energy-efficient site solutions, microwave networks can contribute to the overall energy performance and reduce TCO.

CLOSING THE DIGITAL DIVIDE WITH MICROWAVE

Microwave is the true enabler for rural broadband in emerging markets. It is popular because it is reliable and provides fast and low-cost deployment, compared with wired solutions. Microwave is used to carry both fixed and mobile traffic, and with the higher capacities provided by the new E-band, this is expected to continue. Today, there are five trends in rural backhaul

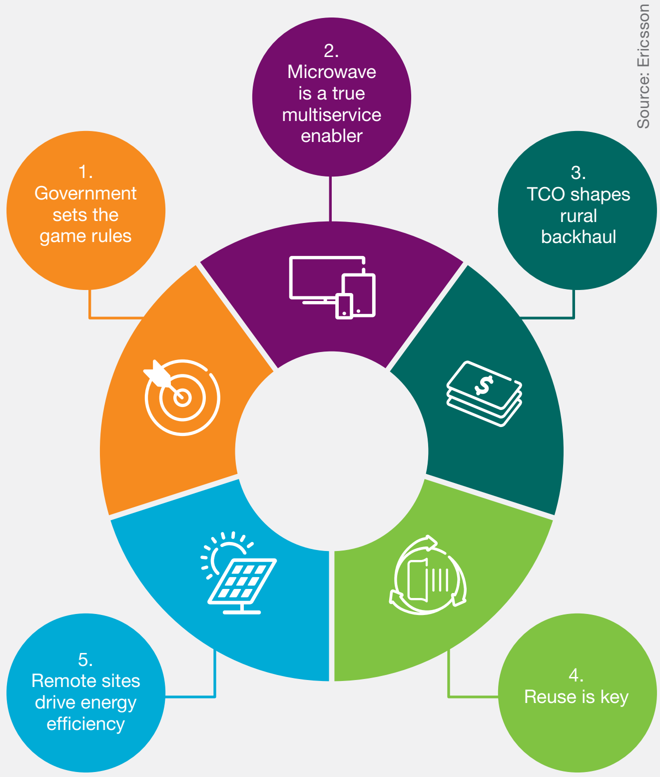
1. Governments set the game rules

In emerging markets, there is a clear connection between economic growth and broadband availability. Education, mobile payment and medical services are some areas where a broadband connection can really impact society. Governments have different ways to stimulate its development – for example, handling the spectrum asset in a smart way, setting coverage demands and giving economical funding to special projects.

In order to stimulate growth in rural areas, regulatory coverage demands for both voice and mobile broadband are increasingly being bound to the radio access spectrum license. One example is Brazil, where the frequency authority, Anatel, put rural coverage obligations onto 4G licenses when operators acquired them in 2012. According to a roll-out plan starting from 2014, the aim is to have coverage in smaller cities, with a focus on applications for public safety, machine-to-machine (M2M) and coverage for schools and hospitals.

Fast roll-out over large distances makes microwave the ideal rural backhaul solution. It is important that operators get the necessary microwave spectrum at a reasonable cost, in order to fulfill the Radio Access Network (RAN) coverage plan and to support the increase in capacity. This is to support economic growth in emerging markets.

Figure 18: Five trends in rural backhaul in emerging markets



2. Microwave is a true multiservice enabler

Microwave is capable of carrying both fixed and mobile traffic as it supports the requirements for traffic separation and security. E-band makes microwave an even stronger fiber alternative to be used as a complement or as fiber extension. A major E-band growth for these applications is foreseen.

In Africa, for example, large operators carry all their fixed and mobile traffic over the same microwave network. In these networks the last mile access for fixed broadband connections is primarily done in two ways; by using dedicated microwave links or by using RAN. The method to use wireless technology for fixed broadband is sometimes called Fixed Wireless Access (FWA) and is quicker and less costly to deploy, compared to wired solutions.

FWA with dedicated microwave links primarily targets connectivity for enterprises, hospitals and schools. As an example, an operator in Africa has 9,000 business customers connected like this in one country. The majority of them are in urban areas, but the solution is also used in rural areas. 80 percent of the connections are capacities of 2–50 Mbps and the rest are connections up to 100 Mbps. This solution also offloads the capacity from the RAN, and is expected to grow in the coming years.

In many emerging markets, microwave is seen as a more reliable media, compared to wired solutions. In some parts of Africa for example, operators are often affected by fiber or copper cable cuts, some accidental due to construction activities, and some due to sabotage. Flooding, landslides and other natural disasters are also common in some of these countries, and can also cause cable cuts.

3. TCO shapes the rural backhaul

In low ARPU markets, cost is a challenge when expanding the network, especially in rural areas. TCO is high on the agenda and will continue to be so, shaping how backhaul is deployed. There are several TCO areas in focus:

- Tower companies see an opportunity in changing business models by leasing backhaul to the operator. Aggressive plans can be seen to both acquire sites and build new ones, where backhaul is part of the site solution. Some operators have seen this as an opportunity to finance their network expansion by selling their sites. In these cases, shared backhaul with higher capacities and traffic separation is essential, as well as low power consumption.
- In very remote rural sites, site visits are kept to a minimum in order to lower the cost. Cooling is often insufficient in these sites. This has led to an increased demand for a higher temperature range for the equipment, and this requirement is expected to rise.
- There is a greater interest in all outdoor solutions which minimize the floor space and thereby the rental cost. In addition, outdoor solutions change the cooling requirements on the site, which lowers the cost.
- High spectrum cost for the traditional frequency bands (6–42 GHz) is a major issue in some markets. It can be a significant part of the expansion cost and limits the network build-out. Operators find ways to overcome this obstacle by looking at other frequency bands with lower costs. E-band (70/80 GHz) is an interesting alternative in many markets due to its lower license cost and easier license application.

[1] Ericsson Mobility Report (2015)

4. Reuse is key

Mobile networks are going through an enormous transformation. In Sub-Saharan Africa, it is projected that between 2015 and 2021, mobile data will grow 15 times.[1] This will of course also affect the microwave links that need to upgrade in capacity.

Reuse of already installed equipment is key to minimize costs, but also to minimize downtime. This is done by adding new modems, radios and software licenses to existing equipment. Upgrade of protected 1+1 hops to 2+0 is also a popular method to double the capacity while retaining the level of protection.

In some markets state-of-the-art networks are built in urban areas, and the old equipment is being reused to expand the network in rural areas. This puts new requirements on longer service agreements, spare parts handling and product compatibility. Expanding networks in this way is expected to continue in the coming years.

Microwave is more reliable compared to wired solutions

5. Remote sites drive energy efficiency

Power supply is a major issue for many remote sites. Many sites are not connected to the power grid and rely solely on diesel generators. Also for sites that are connected to the grid, power failures are very common which makes batteries or diesel generator backup important. Solar power is not commonly used, as the prices for batteries for power at night are high. One of the larger operators in Africa supplies 100 percent of their sites with diesel generators, even though 70 percent of the sites are also connected to the power grid.

A diesel-supplied site has around a five times higher power cost than a site connected to the power grid. Therefore, power savings in telecom equipment is even more important for these types of sites. As an example, a 20 W power saving in microwave equipment on a site gives a yearly saving of USD 175. The focus on power-efficient solutions is expected to increase in the coming years.

Ericsson is the driving force behind the Networked Society – a world leader in communications technology and services. Our long-term relationships with every major telecom operator in the world allow people, business and society to fulfill their potential and create a more sustainable future.

Our services, software and infrastructure – especially in mobility, broadband and the cloud – are enabling the telecom industry and other sectors to do better business, increase efficiency, improve the user experience and capture new opportunities.

With approximately 115,000 professionals and customers in 180 countries, we combine global scale with technology and services leadership. We support networks that connect more than 2.5 billion subscribers. Forty percent of the world's mobile traffic is carried over Ericsson networks. And our investments in research and development ensure that our solutions – and our customers – stay in front.

Founded in 1876, Ericsson has its headquarters in Stockholm, Sweden. Net sales in 2014 were SEK 228.0 billion (USD 33.1 billion). Ericsson is listed on NASDAQ OMX stock exchange in Stockholm and the NASDAQ in New York.

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