MICROWAVE TOWARDS 2020

DELIVERING HIGH-CAPACITY AND COST-EFFICIENT BACKHAUL FOR BROADBAND NETWORKS TODAY AND IN THE FUTURE

September 2015

CONTENTS

EXECUTIVE SUMMARY

Network demands and maturity vary around the world, and differences can even be seen within individual countries. Regardless of the situation, operators want to achieve the same goal – to provide the best possible performance and quality of experience in the most cost-efficient way.

Microwave networks are a vital ingredient for operators to meet this goal, and will continue to be the dominant backhaul technology in the future. Rising capacity needs have led to the belief that fiber is a requirement, but in reality microwave backhaul technology is already able to handle 100 percent of all radio access sites' capacity needs. It will continue to do so in the future, and it will evolve to support multi-gigabit capacities in traditional frequency bands and beyond 10 gigabits in the millimeter wave.

In 2020, 65 percent of all cell sites will be connected with microwave solutions (excluding China, Japan, South Korea and Taiwan). The choice between fiber and microwave in backhaul networks will not be about capacity, it will be about fiber presence and total cost of ownership (TCO).

In supporting microwave to meet the capacity increase for backhaul as well as fronthaul, E-band (70/80 GHz) spectrum is the key. It will experience major growth and represent up to 20 percent of new deployments in 2020, with traditional bands still accounting for 70 percent.

A paradigm shift in microwave planning when introducing multiband use is anticipated. A sevenfold capacity increase can be achieved using a wide low-availability link in E-band to boost a high-availability link in traditional bands. Capacity needs will continue to increase on the road to 5G, and keeping up requires a continued technology evolution and re-imagining of network efficiency.

CAPACITY REQUIREMENTS AND SITUATION

The demand for mobile broadband backhaul capacity will continue to grow. In 2020, high capacity base stations will typically require backhaul in the 1 Gbps range. Microwave technology is able to handle 100 percent of all radio access sites' capacity needs, today and in the future.

Backhaul plays an important role in providing a good user experience and overall network performance. The backhaul capacity needed per base station differs substantially, depending on target data rates and population density. Looking at today's networks, three levels can typically be seen, reflecting mobile broadband maturity:

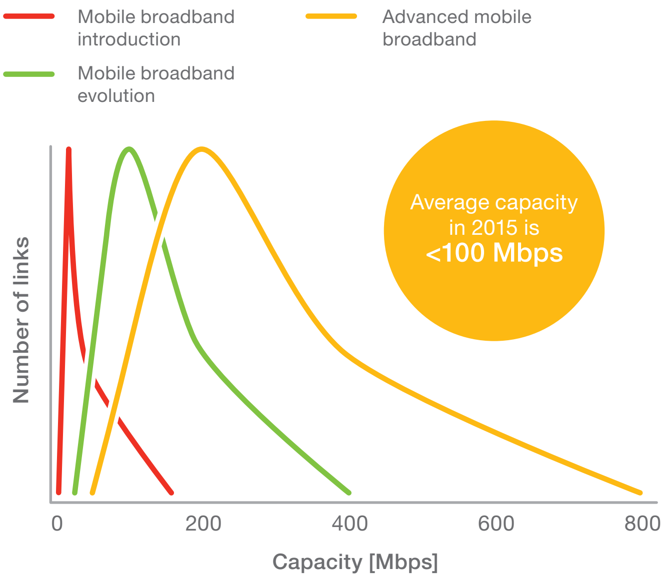
> Mobile broadband introduction: WCDMA is under deployment and the introduction of LTE is planned towards 2020

> Mobile broadband evolution: LTE is under deployment and will be more widely deployed towards 2020

> Advanced mobile broadband: LTE Advanced is being introduced and evolving towards 5G for 2020

Figure 1 shows the typical distribution of deployed microwave link capacities today, based on collected data from a large number of networks.

Figure 1: Typical distribution of deployed microwave link capacities today



Source: Ericsson (2015)

Mobile broadband networks, including backhaul, will evolve to satisfy increasing capacity needs. Carrier aggregation will grow in importance to efficiently use spectrum assets across several high frequency bands in densely populated cities, and some lower frequency bands in less populated rural areas.

Some operators have recently aggregated up to 40 MHz of radio access spectrum, requiring about 360 Mbps in backhaul. There are plans to support 1 Gbps peak rates by aggregating more spectrum (licensed or in combination with unlicensed) and using more antennas.

Figure 2: Backhaul capacity requirements per base station for operators at two different stages of mobile broadband evolution

Mobile broadband introduction	2015	2020
80% of sites	8 Mbps	25 Mbps
20% of sites	25 Mbps	90 Mbps
Few % of sites	90 Mbps	180 Mbps

Advanced mobile broadband	2015	2020
80% of sites	90 Mbps	270 Mbps
20% of sites	360 Mbps	1 Gbps
Few % of sites	1 Gbps	5/10 Gbps

Source: Ericsson (2015)

Figure 2 shows the typical base station backhaul capacity needed for two different deployment scenarios up to 2020. 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 2020, high capacity base stations are expected to require backhaul in the 1 Gbps range, whereas low capacity is within the 100 Mbps range. The most extreme capacity sites are expected to target backhaul with fiber-like capacity.

Microwave will support beyond 10 Gbps capacity in the millimeter wave by 2020

Microwave backhaul technology is able to handle 100 percent of all radio access sites' capacity needs. This is true for today as well as in 2020, when it will evolve to support multi-gigabit capacities in traditional frequency bands and beyond 10 gigabits in the millimeter wave.

MICROWAVE AND FIBER BACKHAUL

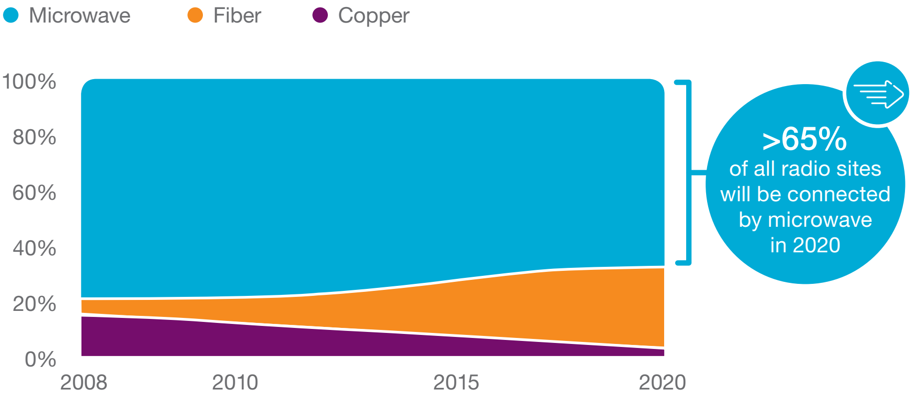
Networks continue to be modernized using a combination of microwave and fiber backhaul. Choosing what media to deploy will not be about capacity, rather it will be about fiber presence and TCO.

Fiber is becoming more available through governmental and fixed services such as FTTH solutions in the access domain. Microwave is the dominant technology used to connect mobile base stations – it is quick to deploy and is very cost efficient. In addition, capacities supported by microwave continue to grow, securing its place in future networks.

When to use fiber or microwave will be a question of fiber presence and cost of ownership, not capacity limitations in microwave. This will lead to large differences around the world as well as variations within regions, parts of a network and operators in the same country.

As shown in Figure 3, in 2020, more than 65 percent of all cell sites will be connected with microwave solutions (excluding China, Japan, Korea and Taiwan). The relative impact of China on the global market has increased dramatically. Governmental initiatives are driving a fiber-centric approach in the country, which does not reflect how other markets are evolving.

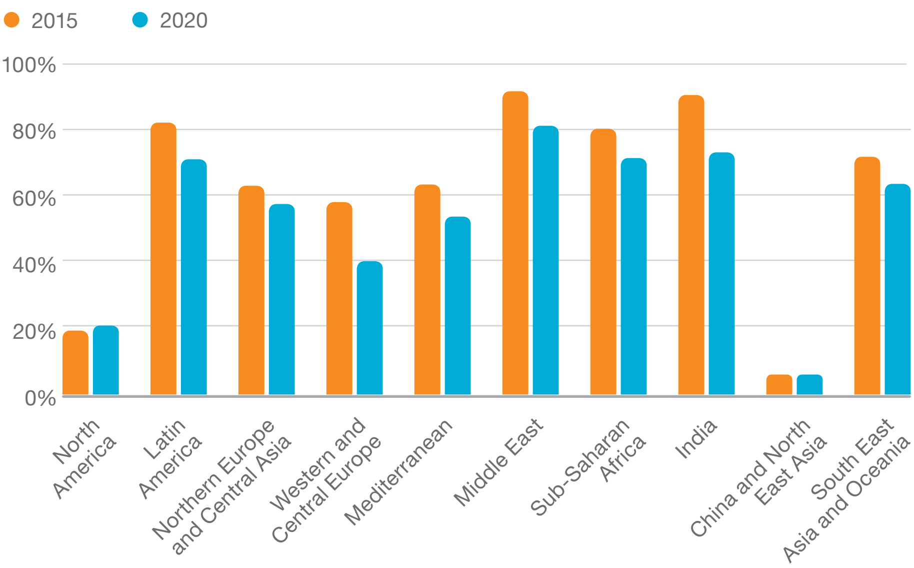
Figure 3: Backhaul media distribution (excluding China, Japan, Korea and Taiwan)



Source: Ericsson (2015)

The uptake of fiber is expected to continue globally, albeit at a slower pace towards 2020. The “easy wins” have been made and the business case will become tougher. In addition, the increasing amount of outdoor mounted small cells in networks will rely heavily on wireless solutions. Microwave is often preferred over fiber for its quick deployment and low TCO, both in self-owned and leased scenarios. If fiber is already available and self-owned, it will be the preferred solution.

Figure 4: Microwave backhaul share in different regions



Source: Ericsson (2015)

Large regional variations

Large variations across different parts of the world will continue (Figure 4). In North America, the number of cell sites connected through microwave is expected to increase to 20 percent by 2020. Whereas in India, 70 percent of sites will be connected with microwave by 2020 to provide high capacity mobile broadband.

The large differences in regions are often due to historical backgrounds and are highly dependent on telecom maturity and the availability of fixed services.

Governmental initiatives to deploy fiber are also happening in many parts of the world, such as in Latin America, Africa and India, but not to the same extent as in China.

In Latin America, government initiatives mainly support the deployment of fiber for the core and aggregation parts of networks. For the access part, where the majority of cell sites are, high capacity microwave is utilized for backhaul.

Middle East deep dive

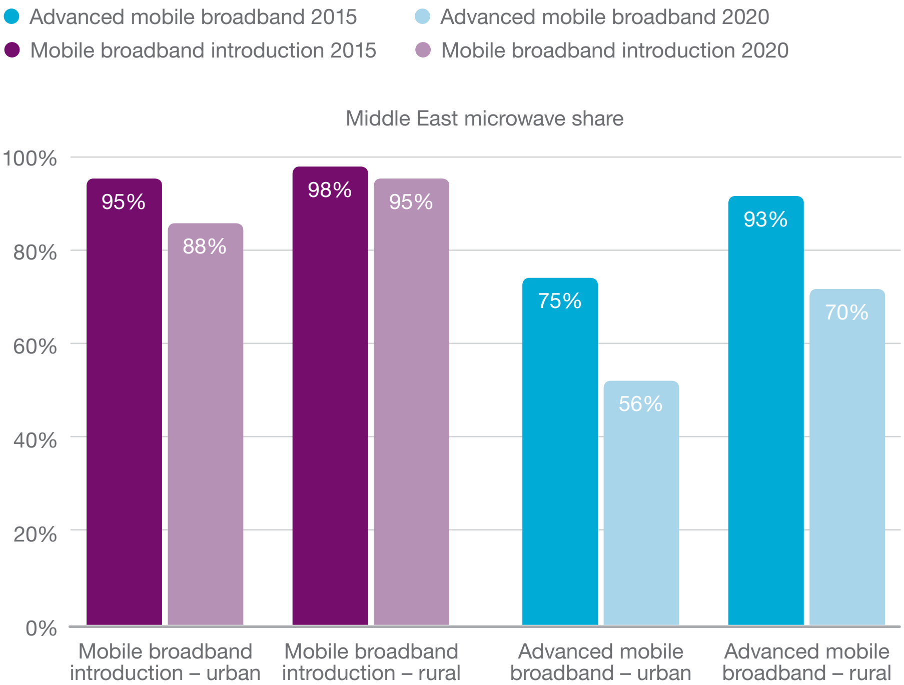
There are also large differences when looking within a region.

Take for example the Middle East (Figure 5), which has countries with both mature and emerging telecom markets. Some countries have highly developed fixed and mobile broadband services, deploying high capacity LTE-A solutions. Other countries have a limited fixed telecom infrastructure and an emerging mobile broadband infrastructure through 3G/HSPA.

For the mature countries, close to 80 percent of the sites use microwave backhaul in 2015. This figure is expected to decrease to 56 percent in 2020. Rural and suburban areas will have a higher microwave share compared to urban areas.

In advanced urban areas, the share of microwave will depend on operator type. The incumbent operator will have greater access to fiber, while a competing operator will rely more on microwave.

Figure 5: Share of base station connected with microwave in Middle East 2015 and 2020



Source: Ericsson (2015)

When looking at the situation in emerging mobile broadband countries today, over 95 percent of all sites are connected with microwave. In 2020, 92 percent of all sites will still be connected with microwave. Fiber will become used more across all network segments but at a slow pace. The urban part of the network will carry the highest amount of traffic and have the largest share of the aggregation network. A higher fiber share is expected in these areas, growing from 5 percent to 12 percent in 2020.

Overall, in the Middle East the high usage of microwave will continue. Many of the emerging mobile broadband countries in the region are very large and lacking a cabled infrastructure, and even the most mature areas are using microwave to connect more than 50 percent of all sites.

Microwave enables advanced mobile broadband in the Middle East

Microwave products will continue to evolve and meet the technology and TCO requirements, thereby playing a key role in the development of mobile broadband networks.

MICROWAVE BACKHAUL SPECTRUM

The availability of both radio and backhaul spectrum will impact tomorrow's mobile broadband performance. Spectrum needs to be harmonized and the millimeter wave spectrum is a key backhaul and fronthaul asset going forward.

Total spectrum for microwave backhaul covers around 40 GHz, but it is not available in all countries around the world

New and higher radio access spectrum will be required to cater for the need of higher capacities and emerging applications in a 5G context.

We foresee some changes in current backhaul spectrum due to changes in radio access. It is possible that some spectrum will be lost or shared with radio access, new backhaul spectrum will need to be added and the available spectrum will need to be used more efficiently. Spectrum regulations need to be harmonized and more spectrum-efficient technologies need to be introduced.

Today, the total spectrum for microwave backhaul covers around 40 GHz, but is not available in all countries around the world. It can be divided into five ranges with distinct typical characteristics:

Figure 6: Total microwave spectrum, with typical hop lengths, channel spacings and areas

Range	Amount of spectrum	Hop length	Channel spacing	Area
6–13 GHz	5 GHz	XL	S–M	Rural
15–23 GHz	5 GHz	L	M	Suburban
26–42 GHz	13 GHz	M	M–L	Urban
60 GHz	9 GHz	XS	XL	Urban
70/80 GHz	10 GHz	S	XXL	Urban

Source: Ericsson (2015)

6–13 GHz

Since low frequencies are less sensitive to rain, these bands will continue to be used for long hop distances and are essential in geographical areas with high rain rates. Capacity limitations exist due to their typically narrow channels, unless multiple channels are aggregated. Of the lower bands, the 7 GHz band is very popular in most parts of the world, but also 6 and 8 GHz are quite commonly used. Of the higher bands, the 13 GHz is popular in most parts of the world, while the 11 GHz is especially popular in North America. The 10 GHz band is used much less globally, but used to some extent in the Middle East.

15–23 GHz

These are the most widely used bands globally today and will continue to be very important in the coming years. The introduction of wider channels has started, which, together with new spectrum-efficient technologies, will further boost capacity.

26–42 GHz

In this range, both underutilized and highly utilized bands exist. Currently, only the 38 GHz band is highly utilized, especially in Europe, and it will remain a core band in the future. The 26 GHz band is also popular while the use of the 28 GHz and 32 GHz band is still limited but on the rise. The new bands can provide wider channels, such as 56 MHz and 112 MHz, and thus gigabit capacities, which is often difficult in the popular bands.

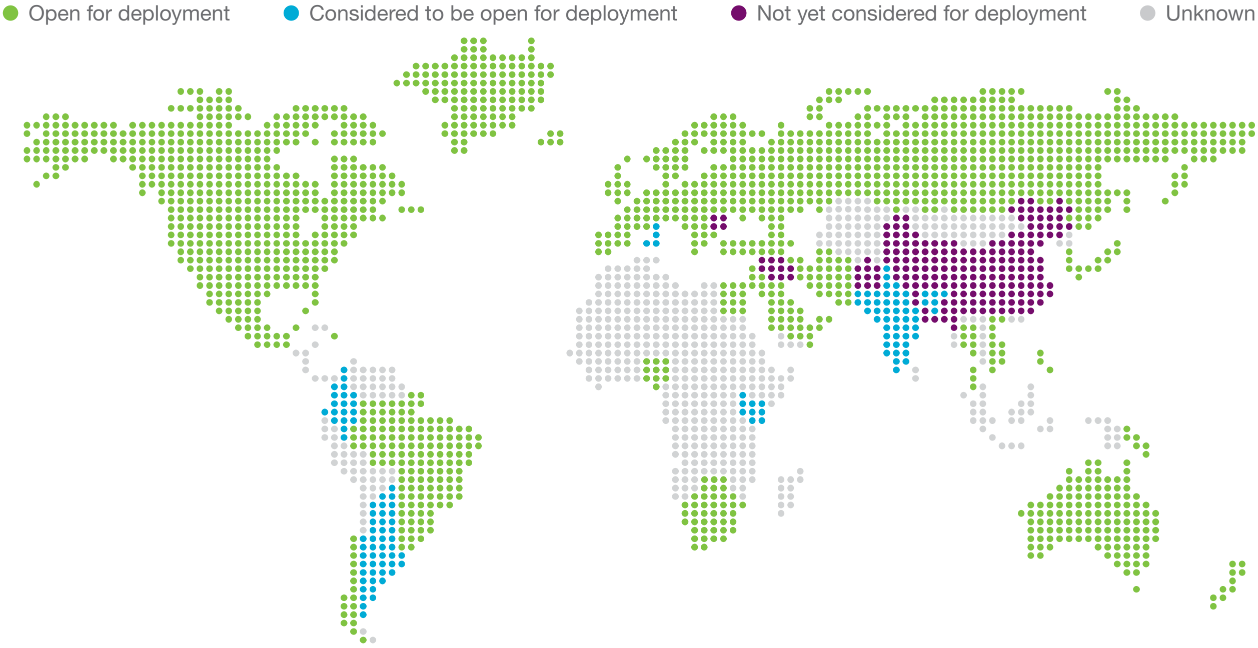
60 GHz

The V-band is ideal for small cell backhaul, with high capacity from wide channels and interference reduction from the oxygen attenuation. So far the outdoor small cell market has not taken off in high volumes, and consequently the 60 GHz band has not been used extensively. The band has been deployed in several countries but its status is still unknown in many parts of the world. A harmonized regulation of the band globally will be important so that different services can coexist without interfering with each other.

70/80 GHz

Until a few years ago, E-band was not used. However the market is now growing fast and the microwave footprint is solid. The advantages of E-band are its wide spectrum and channels that enable very high capacities. Many countries also use a light licensing regime and/or low spectrum fees to encourage the use of this band. Even though it is used for relatively short hop lengths of a couple of kilometers, this is long enough for inter-site distances in urban environments. E-band has already been opened in many countries and additional countries are rapidly being added (see Figure 7).

Figure 7: E-band world map, June 2015



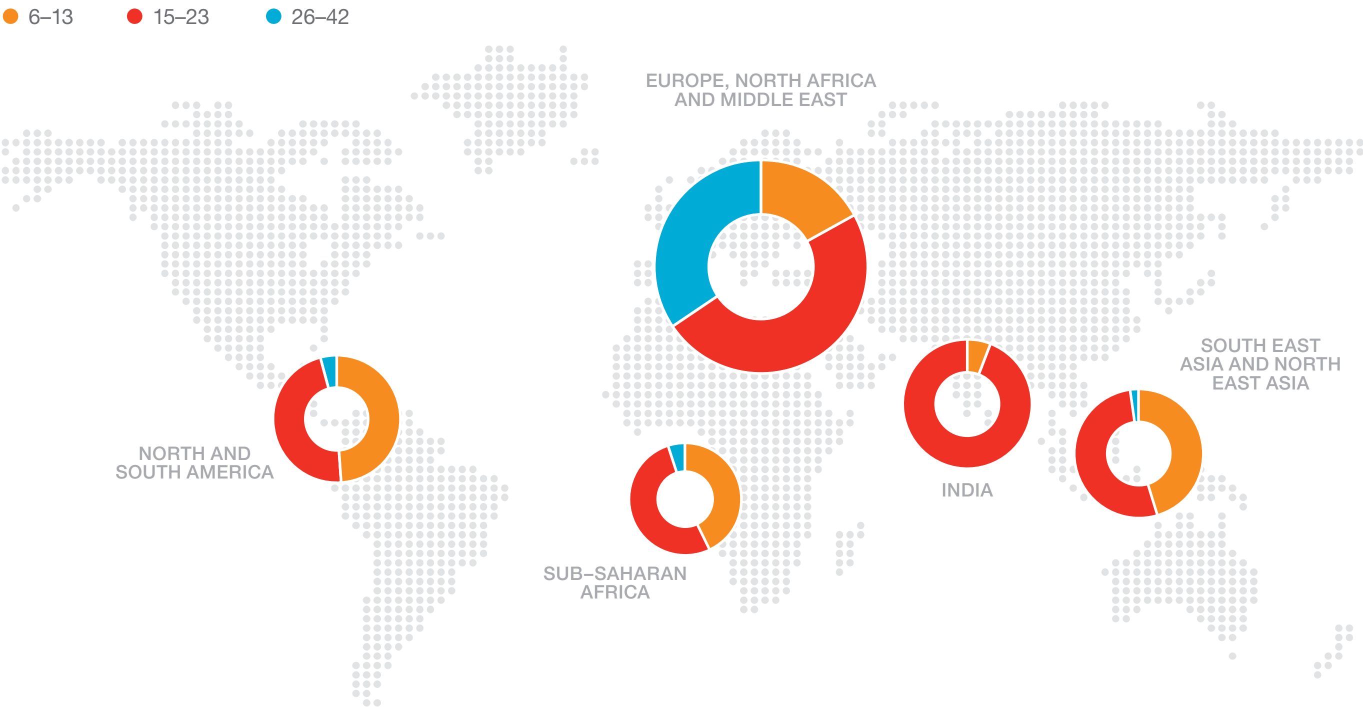
Source: Ericsson (2015)

As Figure 8 shows, there are large regional and national variances on how much different frequency ranges and frequency bands are used today.

This is due to local parameters such as climate, inter-site distances and national spectrum regulations.

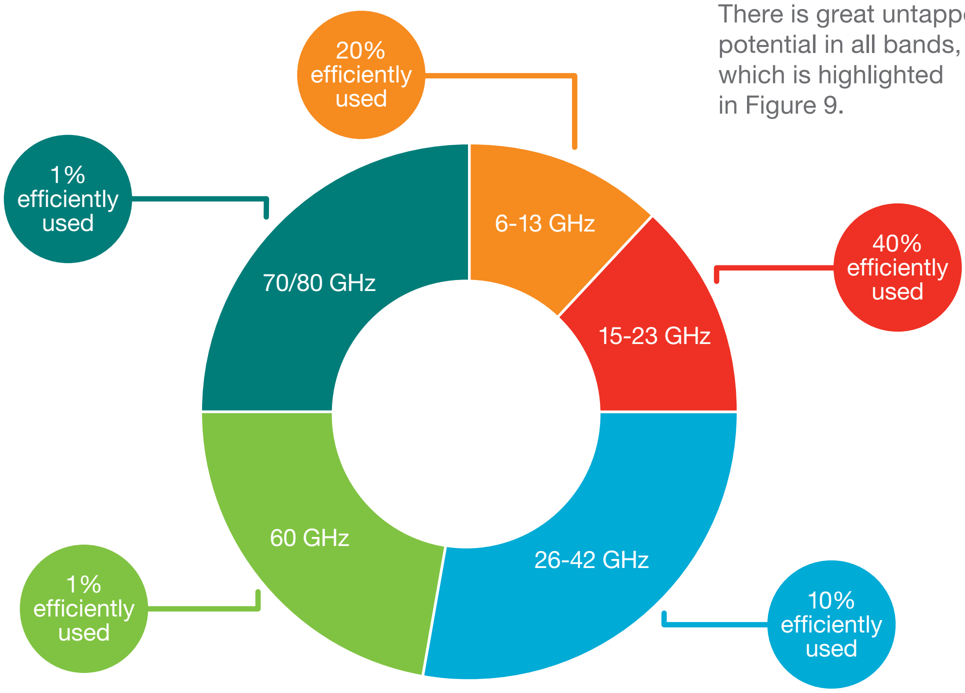
For example the frequency range 26–42 GHz is today extensively used in Europe and the Middle East, but much less in the rest of the world.

Figure 8: Regional deployments per frequency range [GHz]



Source: Ericsson (2015)

Figure 9: Relative amount of spectrum per frequency range
(Usage relative to 15 GHz, which is the world's most deployed band)



Source: Ericsson (2015)

Managing spectrum efficiently

There is great untapped potential in all bands, which is highlighted in Figure 9.

Spectrum utilization can be improved with more harmonized spectrum regulations.

With additional spectrum in V and E bands in combination with denser networks, microwave capacities can grow enormously.

By using spectrum-efficient technologies such as XPIC, MIMO and Super High Performance (ETSI class 4) antennas, even further densification and spectrum utilization can be achieved.

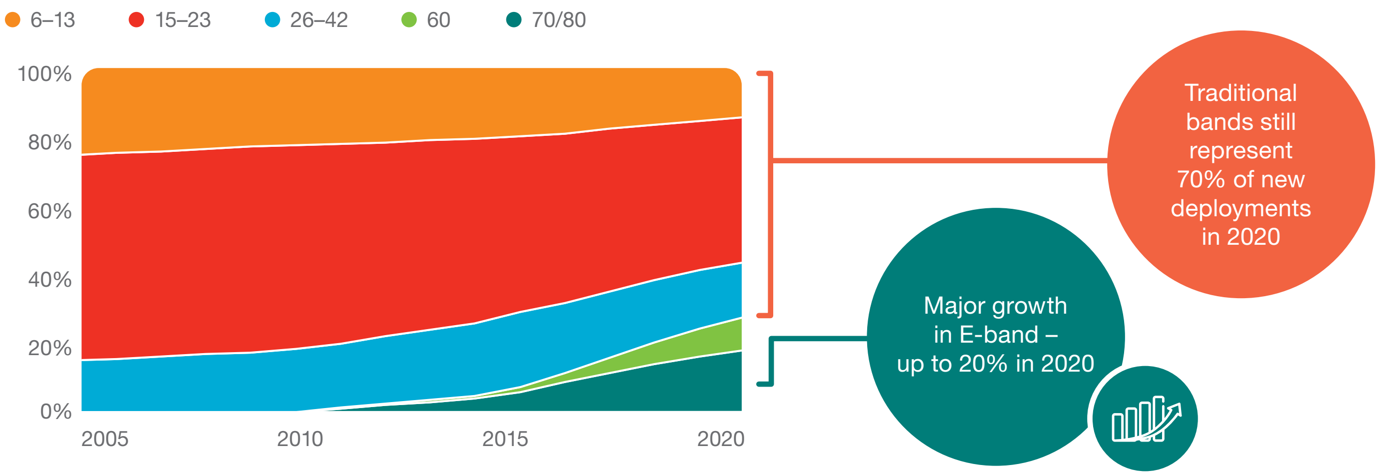
2020 and beyond

By using the microwave spectrum efficiently, backhaul capacity needs in future radio networks will be supported through 2020 and beyond.

Figure 10 shows that traditional frequency bands will still represent a majority of new deployments in 2020.

E-band will experience major growth and represent up to 20 percent of new deployments in 2020. Even higher millimeter wave frequencies are of interest to support the evolution of mobile broadband backhaul beyond 2020. In particular the frequency ranges 92–114.5 GHz (W-band) and 141–174.8 GHz (D-band) are under industry discussion. A chipset supporting 40 Gbps transmission at 140 GHz was recently demonstrated by Ericsson Research and Chalmers University of Technology.

Figure 10: New deployment share per frequency range [GHz]



Source: Ericsson (2015)

MICROWAVE BEYOND MOBILE OPERATORS

The fiber-like capacities in microwave radios and the capability of supporting legacy equipment while migrating networks to packet is a perfect fit for vertical applications.

The easy-to-use, quick deployment and high capacity characteristics of microwave make it the mobile backhaul media of choice. The same characteristics are also attractive beyond mobile operators. For example, governmental applications have been using microwave for many years due to its robustness and flexibility.

Another common user is utilities, which has strict requirements on availability, long lifecycles and low latency for Supervisory Control and Data Acquisition (SCADA) traffic. Recently, the fiber extension market has started to grow due to the fiber-like capacities in new microwave product generations.

Utilities' need for private networks

SCADA traffic has a modest capacity requirement and is dependent on short latency and precise timing. It has been and will continue to be the core communication need for a utility, whether its business is in power, oil, gas or water. With the change from TDM to Ethernet in the transport network, timing becomes a new challenge. Fault tracing in large networks requires time synchronization, usually via 1588v2 with requirements equivalent to operator networks. Further complication comes from fixed operators discontinuing private line services and a replacement needing to be installed. The transport network must support legacy equipment and at the same time be future-proof, otherwise major investments will be needed to upgrade all equipment simultaneously in the network.

Governmental networks

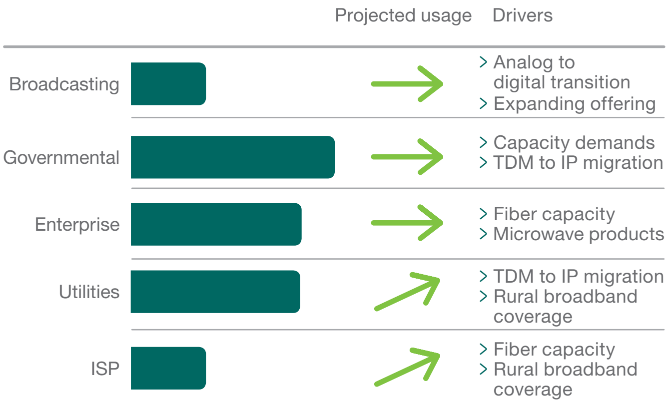
Many governmental networks used by police, defense and public safety agencies are still investing in TDM technology. However, to provide higher capacity, there will need to be a shift in focus to Ethernet. With limited governmental funding, this becomes a real challenge with some technologies, but microwave provides native TDM and native Ethernet in the same product.

Increasing demand for bandwidth drives the use of microwave networks

Enterprise connectivity

The increasing capacity performance of microwave radio boosted by millimeter wave technology has enabled the fiber extension market. Extension of fiber points of presence with radio becomes an easy and quick way to establish connectivity for an enterprise.

Figure 11: Microwave usage in vertical segments



Source: Ericsson (2015)

Internet service provider

The ever increasing demand for bandwidth to residential and enterprise users in rural areas drives the change from copper cable to alternative technologies. Microwave is used for two reasons – it is cost effective and achieves quick time to revenue. Time to revenue is most important for the second-mile application when microwave serves as backhaul for a fiber hub. When serving as the last-mile connection for enterprise users, the cost competitiveness comes into play against fiber.

Broadcasting networks

The main driver for microwave usage in broadcasting networks is the distribution of terrestrial TV even if contribution and production networks also use microwave technology. The distribution of terrestrial TV signals has been digital for a long time, but the transmitters are going through a change from analog to digital. This drives an upgrade of the distribution network for more efficient IP transport or to include more TV channels.

Multi-service networks

To enable a healthy business case for modernizing utility and governmental communication we will see multi-service networks grow in importance and the merging of several vertical market segments. Countries with governmental targets for rural broadband coverage will help to encourage this change. The traffic in such networks will require very high availability and security and the importance of having a trustworthy and stable vendor will be crucial.

UNLEASH THE MILLIMETER WAVE POTENTIAL

Millimeter wave band (mmW) offers numerous possibilities for managing networks in the future by offering greater capacity, efficiency and throughput.

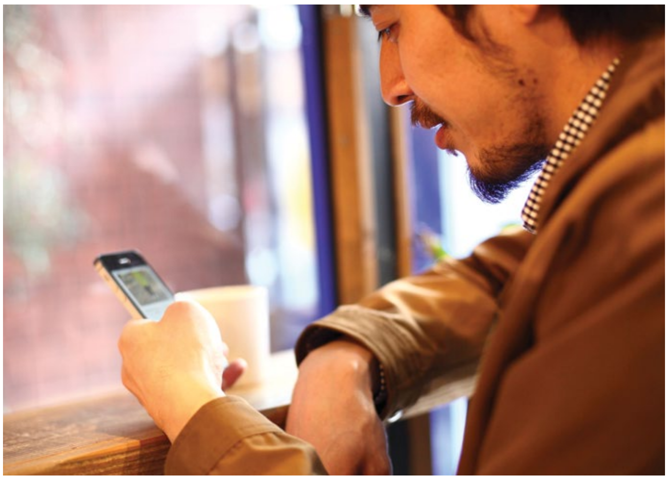
The historic approach to microwave planning is based on time-division multiplexing (TDM) network requirements, which is designed to secure 99.999 percent availability of the total capacity. But modern packet networks, combined with mmW bands, open up new and exciting possibilities.

Radio link planning in 2020

The main issue is no longer the annual availability of a static bit rate, but rather how to get the highest possible Quality of Service (QoS) for the secured total capacity per radio link. This leads to questions such as “How can the mmW spectrum (E and V-bands) help solve the need for capacity growth?” and “What is possible in an all packet environment?”

Packet networks, as opposed to TDM traffic, can handle bit rate changes as long as the minimum bit rate is greater than what is needed for high priority traffic. Adaptive modulation does just this – it offers the greatest possible capacity at all times, but shifts to modulations with higher availability when needed. In combination with the new mmW radio links it is possible to bring this feature one step further.

An mmW channel with high capacities and lower availability, combined with efficient QoS handling and a suitable use of a low capacity channel with high availability, opens up new ways of solving capacity issues, as well as new use cases for microwave. This high availability channel can be a separate radio link in one of the traditional bands with better tolerance to rain. By focusing on the highest annual average capacity, where prioritized traffic is always guaranteed, it is possible to get both better quality of experience (higher total user capacity over time) and a lower TCO compared to traditional link planning.



By planning for the highest annual average capacity and ensuring that the minimum available capacity with 99.999 percent availability is enough for high priority traffic, it is possible to get up to 7 times the minimum traffic (>1 Gbps) for more than 364 days per year, while also securing services for the remaining day (Figure 12). With traditional planning, only 30 percent of this traffic would be possible.

Rethinking microwave planning can increase capacity sevenfold

Figure 12: Paradigm shift in microwave planning

MICROWAVE PLANNING – OPTIMIZED ON:

Availability – TDM planning	Capacity – packet planning
Highest minimum capacity	Highest average capacity
2x23 GHz/28 MHz channel	1x23 GHz/28 MHz channel + 1x70/80 GHz 250 MHz channel
> 320 Mbps – 99.999% > 450 Mbps – 99.9%	> 160 Mbps – 99.999% > 1223 Mbps – 99.9%
320 Mbps capacity guaranteed 365 days a year	1.2 Gbps capacity guaranteed 364+ days a year

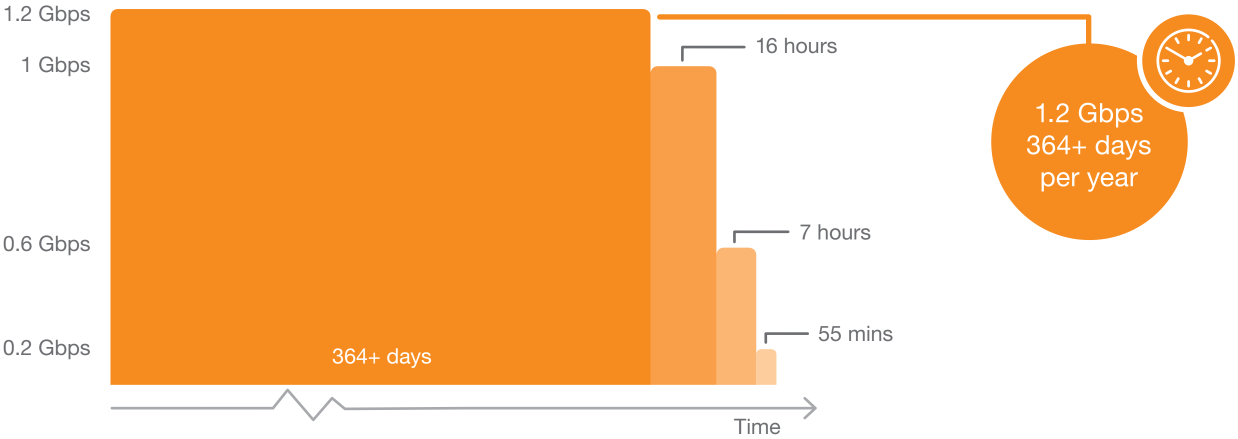
Source: Ericsson (2015)

Boost capacity with multi-band use

For macro cell backhaul, the increased capacity needs also require efficient solutions. When technology such as XPIC with radio link bonding and header compression has been used in traditional frequency bands, more spectrum is the next option to deal with them. The mmW band is the most promising complement. A radio link installation using traditional frequency bands is capable of up to 300–500 Mbps with high availability (99.999 percent). In urban areas the hop length is often less than 1–4 km.

By adding an E-band radio link with 250–750 MHz channels and combining it with the existing radio link, while using QoS mechanisms for prioritization, it is possible to boost capacity by an additional 500 Mbps to 5 Gbps. Having done this, it is possible to achieve 99.8–99.99 percent availability while still securing 99.999 percent availability for high priority traffic (Figure 13). The annual average of available traffic capacity will reach very close to the maximum for the bonded links, typically around 96–98 percent of the theoretical maximum peak capacity.

Figure 13: Availability of capacity; traditional frequency band plus E-band



Source: Ericsson (2015)

Fiber extensions

This is the area where the comparison to a fiber connection is most obvious. The required bandwidth is usually 1 or 10 Gbps.

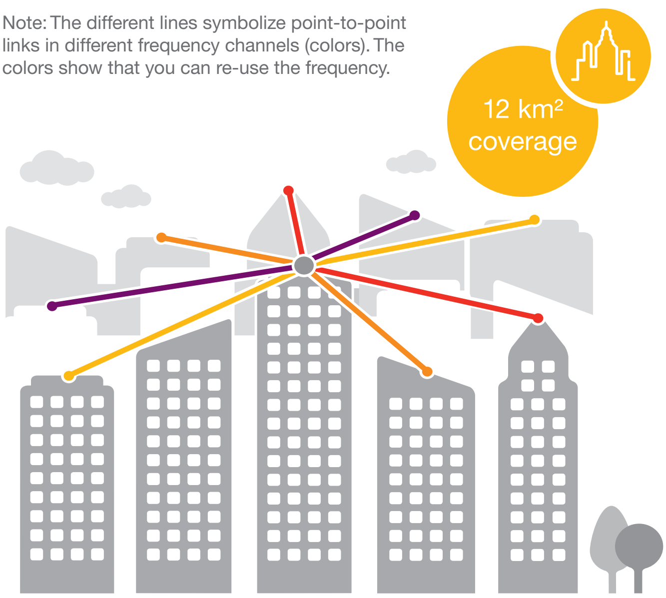
Modern microwave solutions make it possible to extend the existing fiber network to have a 2–3 km reach using E-band equipment (Figure 14). Using 250–1,000 MHz channels easily allows for capacities of 1–10 Gbps depending on the need and distance.

These solutions are very robust even for heavy rain (35–50 mm/hour). Therefore they have the same availability and throughput as fiber, but are quicker to roll-out, and have easier site acquisition/right-of-way and lower deployment costs.

E-band frequency also enables dense access points without interference, due to narrow beam antenna lobes and a broad spectrum. Up to 15–30 access points per square kilometer from a hub site should also be possible when using wide channels (5–10 Gbps). With a reach of 2 km, the business case for fiber extension looks promising.

Figure 14: Urban fiber extension

Note: The different lines symbolize point-to-point links in different frequency channels (colors). The colors show that you can re-use the frequency.



Source: Ericsson (2015)

NETWORK NODE BENEFITS

Microwave networks can be built in many different ways. Their design will affect everything from site and maintenance costs, to network performance and evolution.

One way to build microwave networks is to deploy microwave hop-by-hop with "pizza boxes" (boxes with fixed configurations), based on requirements at that time.

E-auctions could guarantee the lowest price per hop but as a consequence may result in a mix of different vendors and equipment throughout the network or even on the same site. Another approach is to plan ahead and make deployments on the basis of future network requirements so as to gain the best TCO. A network node is modular, making it very easy to expand with additional directions and higher capacities. Building an efficient microwave backhaul network with end-to-end performance in mind requires high node capacity, compact and modular building practice, advanced packet functionality and features that are aligned and backward-compatible across different network nodes. The microwave nodes also need to be capable of handling single hops as well as advanced hub sites for larger networks.

Case study in real networks

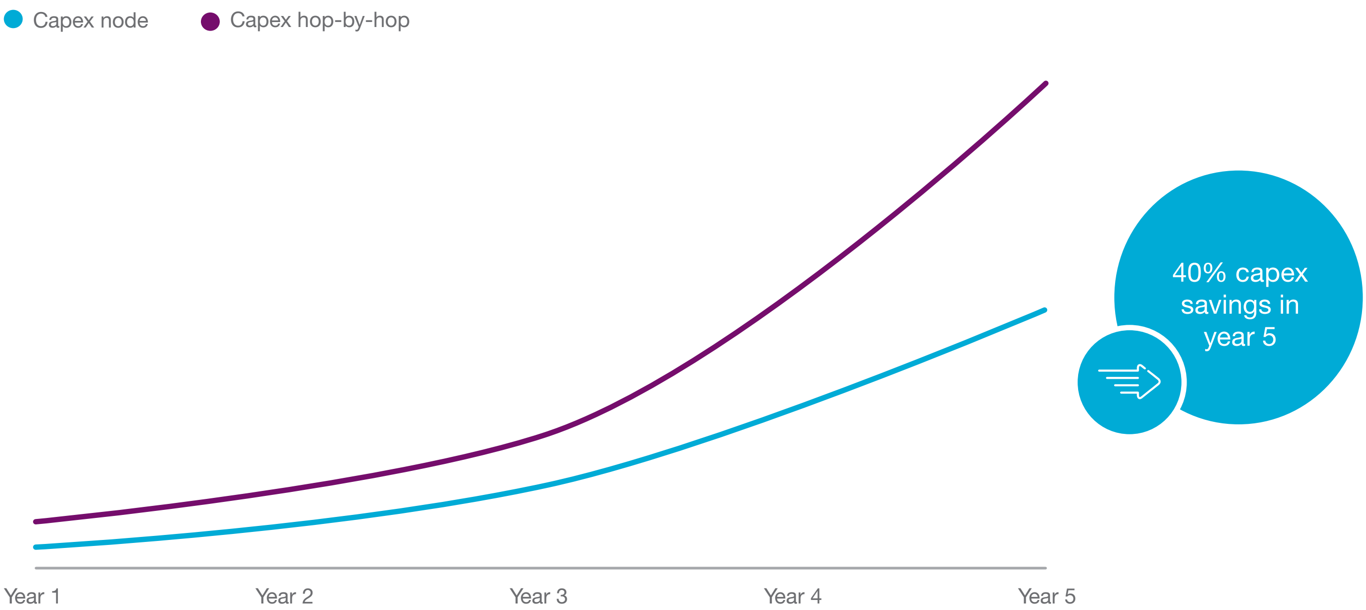
To explore the benefits of a network node concept, a case study was carried out studying a typical network cluster that is operational with 6 different microwave vendors for 109 hops. A star topology was used, with a central node aggregating all traffic from all microwave nodes. The cluster had a 5 year evolution plan, where only existing sites were upgraded and modernized to support 3G and 4G traffic evolution. Three scenarios were then applied – a hop-by-hop approach, a network node approach and finally a mix of the two.

The capacity evolution of the network includes:

> Evolution of 3G traffic: 30 Mbps in year 1, with annual growth of 10 percent

> Evolution of 4G traffic: 10 MHz in year 1, 10+10 MHz in years 2 and 3, 10+20 MHz in years 4 and 5

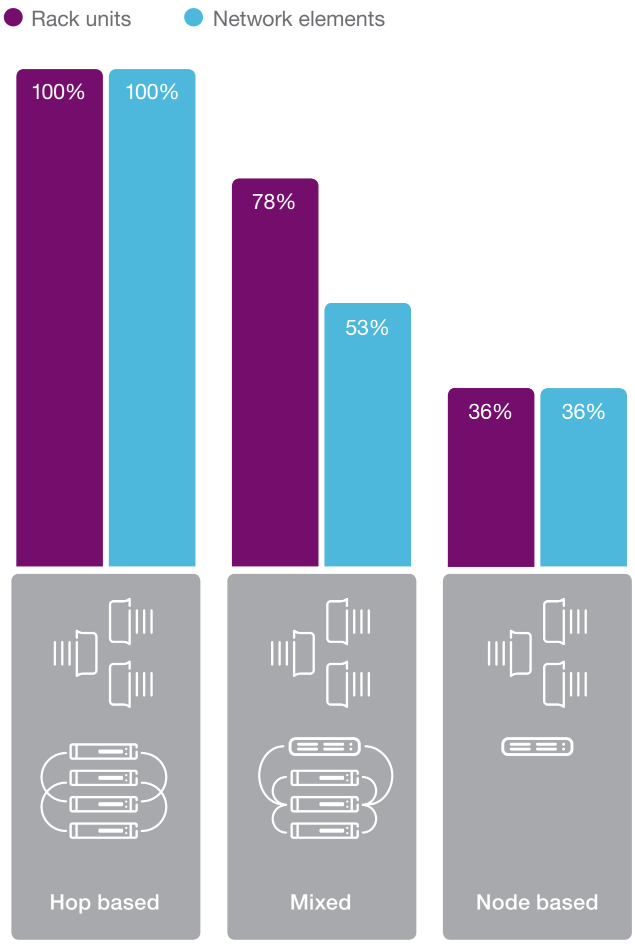
Figure 15: Customer case – investment during network upgrade



Source: Ericsson (2015)

As seen in Figure 15, the results from the case study showed that the node approach was the most efficient and least expensive way to add capacity and new functionality step-by-step. A total of 40 percent savings can be achieved after five years when the network node approach is used. This is accomplished by reusing equipment and thus substantially reducing cost for new equipment and accessories. The hop-by-hop solution will require all equipment to be replaced when network functionality and capacity evolves, as well as upgrades of the site solutions and cables. Sharing hardware resources like Switch, Fan, Power Supply, Processor etc. in the network node approach reduces power consumption and equipment cost when expanding existing sites.

Figure 16: Footprint and network element reduction



Source: Ericsson (2015)

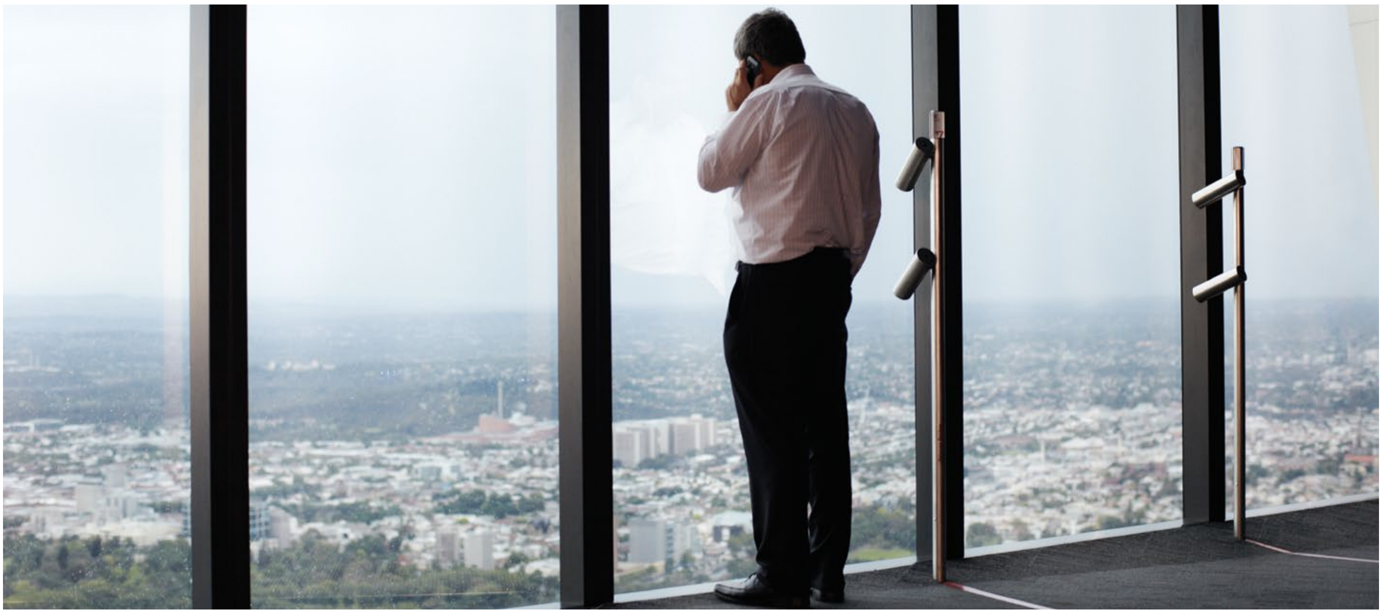
3X Network node approach is almost three times more efficient in terms of utilizing indoor space

Simplified network operation and maintenance

The case study also showed that the number of network elements is reduced by a factor of almost three with the network node approach (Figure 16). As a result, operation and maintenance is simplified, which significantly reduces work effort and costs. Other savings are achieved by reducing the time required for trouble-shooting, performance management and fault management as well as introducing new features, adjusting existing features and performing software upgrades. On top of cost reduction, having fewer network elements improves the quality of fault management and performance monitoring, thereby minimizing network downtime and improving user performance.

Reducing site cost

It was also found that the network node approach is almost three times more efficient in terms of utilizing indoor space than the hop-by-hop approach. Reducing the number of rack units in the network node solution results in far less investment in transmission cabinets. An outdoor cabinet investment can exceed the actual transmission equipment investment on many sites. However, such unnecessary investments can be avoided by building with network nodes. Opex can also be reduced, since less equipment means less rental costs for space and lower power consumption, generating significant savings over a five year period.



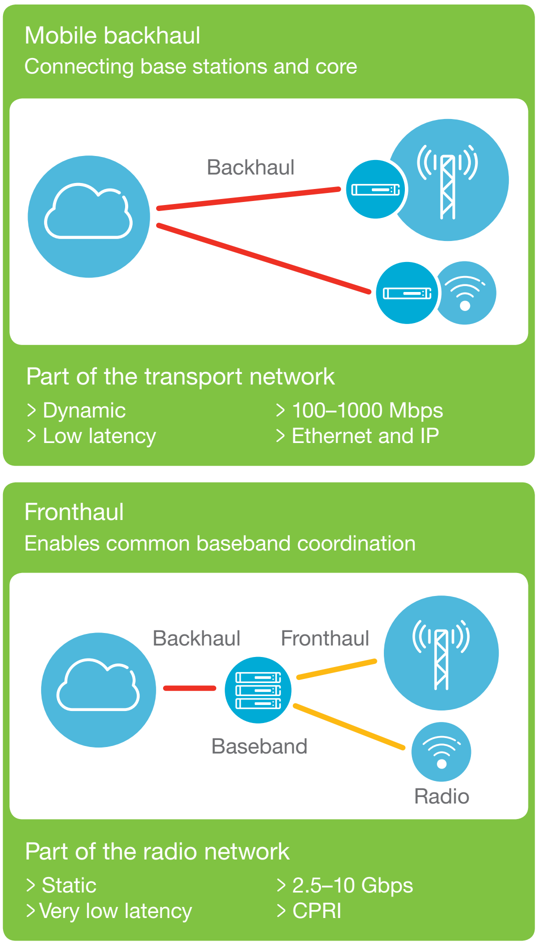
WIRELESS FRONTHAUL

E-band spectrum enables wireless fronthaul, which gives operators flexibility in deployments, overcomes right-of-way issues and provides quick deployments.

The way radio networks are built is changing. The LTE architecture will evolve from the current distributed deployment of integrated base stations to a mixture of distributed and centralized deployments of base band capacity.

Figure 17 illustrates the difference between backhaul and fronthaul connections. Backhaul connects a base station, for example a baseband unit, to the core network. Fronthaul is a point-to-point connection between the radio remote unit and the baseband unit. The interface is called Common Public Radio Interface (CPRI) and is a standardized internal interface of radio base stations where parts are vendor specific.

Figure 17: Mobile backhaul vs. fronthaul



Source: Ericsson (2015)

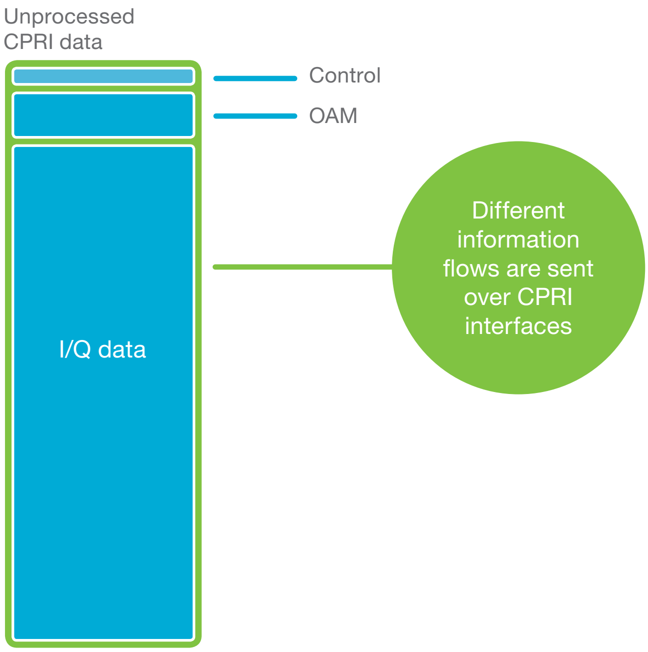
What is unique to fronthaul compared to backhaul is the need for very high capacities from 2.5 Gbps and beyond, such as in combination with very low latencies (around 100 µs). Backhaul capacity needs are generally within 100–1000 Mbps and latency design requirements between the core and base station are 15–30 ms. Moreover, since IP is used in backhaul, it can handle congestion. In comparison, fronthaul is a static connection with no mechanism to handle congestion points.

It is essential that the radio network has full control and visibility of the fronthaul since the performance requirements are very high. That is, the fronthaul should in a sense be a part of the radio network.

Fronthaul over E-band

Figure 18 shows that there are different information flows sent over CPRI interfaces, such as user plane data (I/Q data), control and management plane and synchronization plane. In addition to the CPRI content, a line code called 8B/10B is added. CPRI interfaces can be of different line rates such as 2.5 Gbps (option 3), 5 Gbps (option 5) and 10 Gbps (option 7). For example, a 2.5 Gbps CPRI connection can serve a 2x2 20 MHz LTE FDD sector.

Figure 18: CPRI content



Source: Ericsson (2015)

When aggregating several sectors, the capacities will increase even further in a linear way. This means aggregating three sectors of 2.5 Gbps CPRI requires a partially utilized 10 Gbps CPRI connection. Carrier aggregation in a multi-sector site would therefore easily need 10 Gbps and beyond. Fiber has been seen as the only viable fronthaul media, but it is sometimes not an option due to right-of-way issues, high cost and the need to minimize time-to-market. Wireless fronthaul is therefore a great complement and E-band is the most suitable spectrum for high capacity links (2.5–10 Gbps) with very low latency. Wireless fronthaul can fit both macro and small cell use cases (Figure 19). Yet the most straightforward use cases are, due to capacity, single sector deployments. This could be, for example, adding small cells or improving the macro coverage by including an additional sector on a nearby rooftop to an existing macro base station.

E-band enables wireless fronthaul

This is also a good fit for the expected hop lengths that can be done with E-band. The operator interest shows that there is a need for wireless solutions to complement fiber for fronthaul connections, however a standard Ethernet-based E-band radio cannot support CPRI. E-band radio needs a CPRI interface and either acts as a pure layer one connection or supporting CPRI protocol.

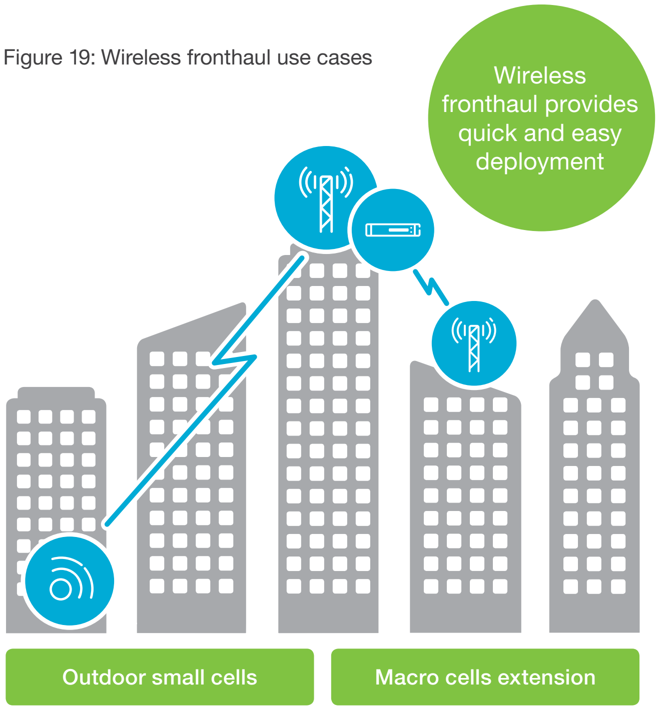
Dimensioning of a CPRI link is slightly different compared to a backhaul link, due to the specific properties of the CPRI. The link should therefore be dimensioned for 10^{-12} bit error rate (BER) levels and a high availability target.

CPRI compression

Due to very high CPRI rates, CPRI compression is discussed when using wireless fronthaul to reduce the data that needs to be sent over the air. This is only natural, since the microwave and millimeter wave spectrum are scarce resources. Digitally performing loss-less compression of a fully loaded CPRI containing peaking sector(s), won't be beneficial after the removal of the 8B/10B code, which in itself gives 20 percent reduction. But if the CPRI is not fully used, there is an opportunity to perform digital compression.

However, it is not easy to estimate nor guarantee that it will always fit into a wireless channel and still have a loss-less compression. The most appropriate way is to let the RAN vendor do the optimization and compression of CPRI. The RAN vendor has full knowledge of CPRI and can make the right judgments without sacrificing performance on the RAN air interface. When a RAN vendor optimizes their CPRI protocol, a 2.5 Gbps E-band CPRI solution will be more future-proof and will therefore be able to handle a single sector site using carrier aggregation. To compress even further is theoretically possible, but is not loss-less and will therefore impact the performance of the RAN air interface which is not recommended.

Figure 19: Wireless fronthaul use cases



Source: Ericsson (2015)

CPRI compression should be done in RAN and not in the radio link

Next steps towards 2020

With the introduction of 5G, there will be a major focus on reducing latencies and handling substantially increased bandwidths. To minimize the latency over the air interface, it is important for the real-time critical parts of the radio functionality to reside close to the antenna. At the same time, the rapid development of data centers and Network Function Virtualization (NFV) offers many attractive reasons to centralize other parts of the functionality. There will most likely be another type of internal interface between the central part and the part close to the antenna. This interface will not be a CPRI as it is known today.

Wireless fronthaul will support capacities beyond 2.5 Gbps. Due to the optimization of CPRI the need for higher capacities is not that urgent.

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