ERICSSON

ERICSSON MICROWAVE OUTLOOK

TRENDS AND NEEDS IN THE MICROWAVE INDUSTRY

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EXECUTIVE SUMMARY

With the buildout of LTE, the appetite for mobile broadband backhaul capacity has increased, as expected. This will continue to increase with the arrival of 5G. It is forecast that, by 2022, the typical backhaul capacity for a high-capacity radio site will be in the 1Gbps range, rising to 3–5Gbps by 2025. It is also predicted that 80 percent of sites in an advanced mobile broadband network will still be operating under 350Mbps in 2022, though by 2025 this will have increased to 600Mbps.

In the future, microwave share will continue to be high, supporting the requirements of LTE and 5G. Due to the increasing number and size of LTE deployments in India, microwave share is now forecast to be higher than previously estimated, exceeding 65 percent in 2022 (excluding China, Korea, Japan and Taiwan). The planned introduction of 5G in networks with as high as 80 percent microwave-based backhaul, shows that microwave is highly relevant for 5G. Globally, mobile network backhaul continues to evolve with a mix of fiber and microwave.

With the introduction of 5G in microwave bands, the availability and usage of microwave spectrum for fixed services will go through a major transformation in the next few years. E-band will grow in importance and in usage, and we will see an introduction of new bands around and beyond 100GHz.

Microwave – supporting 5G capacity and performance needs

The evolution of 5G new radio (NR) is rapidly progressing as more parts are being standardized by the 3rd Generation Partnership Project (3GPP) and other organizations, with a focus on both enhanced and new services. This requires a closer look at the demands that will be put on the transport networks to achieve the desired results. Transport networks need to support new types of radio networks and additional interfaces with different requirements on bandwidth and latency, but the diverse deployment possibilities in 5G RAN causes actual transport demands to vary more than in typical 4G networks.

With the evolution towards 5G gaining momentum, real network trials are on the horizon. Microwave technology is keeping pace in line with this, and today transport deployments of 10Gbps E-band links are an actuality. Over the next few years we will see the first 100Gbps links emerging from research labs using new frequency bands and MIMO technology, driven by rising traffic density and new, high-capacity radio interfaces in 5G.

Ahead of 5G's rollout, improvements in operational simplicity, efficiency and cost are necessary. Looking ahead, one way in which this can be done is to integrate transport further into the radio domain, as transport capabilities will impact the overall network performance for future 5G use cases.

FUTURE CAPACITY REQUIREMENTS

As predicted, recent years have seen mobile broadband backhaul capacity grow in line with the buildout of LTE. With 5G on the horizon, we can now expect that growth to continue. By 2022, the typical backhaul capacity for a high-capacity radio site will be in the 1Gbps range, rising to 3–5Gbps towards 2025.

Speed is coming to mobile. Operators are evolving their LTE networks to LTE-Advanced with Category (Cat) 4–16 implementations, combining lower and higher frequencies. This will lead to a wider coverage area, increased network capacity and faster data speeds. With Gigabit LTE, mobile broadband speeds can match those of fiber. We expect 5G New Radio (NR) to be deployed commercially in a few pioneering markets in 2018, with wider market uptake around 2020.

Mobile broadband introduction is represented in the upper table (Figure 1). The lower table shows the advanced mobile broadband phase. Most operators fall somewhere in between these two examples. In 2022, up to 80 percent of sites in an advanced mobile broadband network will still be operating under 350Mbps. By 2025 this will increase to 600Mbps. For mobile networks with fewer broadband services, the majority of radio sites will need up to 100Mbps in 2025, while the remainder will need 300–600Mbps backhaul capacity.

Microwave equipment is capable of Gigabit transport over considerable distances, and now customers are taking advantage of this. Comparing the 2014 and 2017 data on capacity deployment in mobile backhaul transport, (Figure 2), shows that change follows an expected trend. Operators that are introducing broadband are now in the 50–100Mbps range, versus the 10–20Mbps it was 2–3 years ago. We see a similar behavior in the other two segments. Operators are preparing their networks for the next level of mobile broadband services.

The biggest capacity change was anticipated in networks introducing mobile broadband, where expectations of capacity and LTE Cat 4-capable devices are now the norm. Among the more advanced mobile broadband networks preparing for newer customer device capabilities, such as Cat 16 devices, we see microwave capacities at speeds of well over 1Gbps.

As the evolution towards 5G continues, we can also see that microwave technology is keeping pace with needs. We are now seeing real transport deployments of 10Gbps E-band links.

Increased use of the E-band and wider channels in traditional microwave bands shows that the microwave transport technology meets the current capacity needs of radio sites.

Microwave as a technology is therefore well positioned to handle not only the upcoming support for faster LTE devices that are being introduced, but also the shift to 5G.

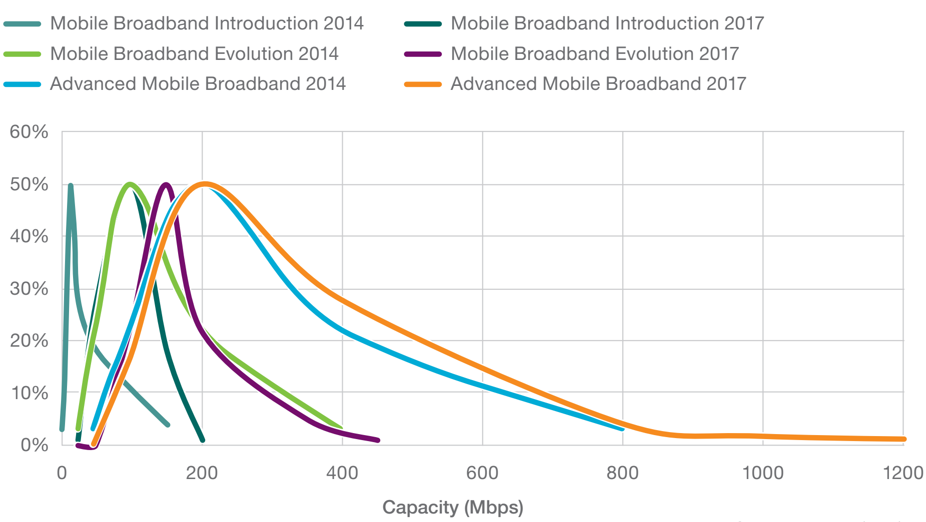
Figure 1: Backhaul capacity requirements per radio site for operators at two different stages of mobile broadband evolution

Mobile broadband introduction	2017	2022	Towards 2025
80 percent of sites	25Mbps	75Mbps	100Mbps
20 percent of sites	75Mbps	200Mbps	300Mbps
Few percent of sites	150Mbps	450Mbps	600Mbps

Advanced mobile broadband	2017	2022	Towards 2025
80 percent of sites	150Mbps	350Mbps	600Mbps
20 percent of sites	300Mbps	1-2Gbps	3-5Gbps
Few percent of sites	1Gbps	3-10Gbps	10-20Gbps

Source: Ericsson (2017)

Figure 2: Typical distribution of deployed microwave link capacities 2014 and today

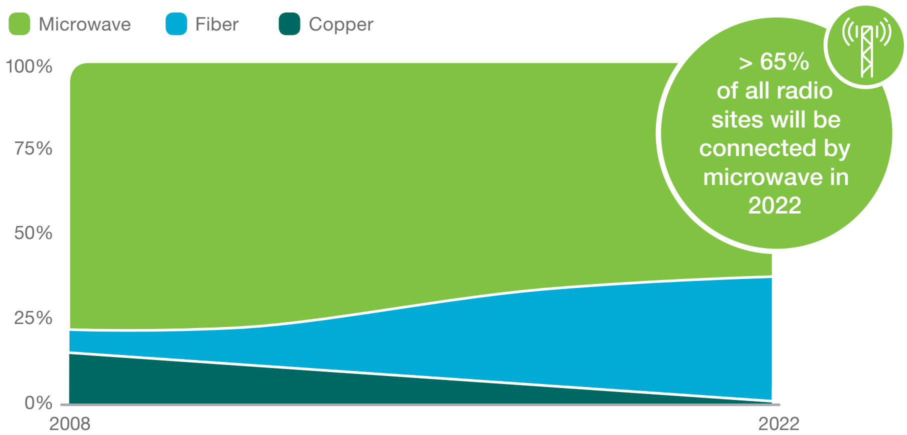


Source: Ericsson (2017)

MICROWAVE AND FIBER BACKHAUL

In India, LTE deployments are increasing. This means that microwave share will be higher than estimated in previous forecasts, exceeding 65 percent in 2022 (excluding China, Korea, Japan and Taiwan). Operators with 80 percent microwave are now planning for the introduction of 5G, while regional variations continue.

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



Source: Ericsson (2017)

Global picture

Global mobile network backhaul continues to evolve with a mix of fiber and microwave. There are two major trends influencing backhaul deployments around the world, as operators are in very different phases in the evolution of mobile broadband. The advanced mobile broadband operators are starting to plan for the introduction of 5G, while most operators are in a phase of expanding LTE networks.

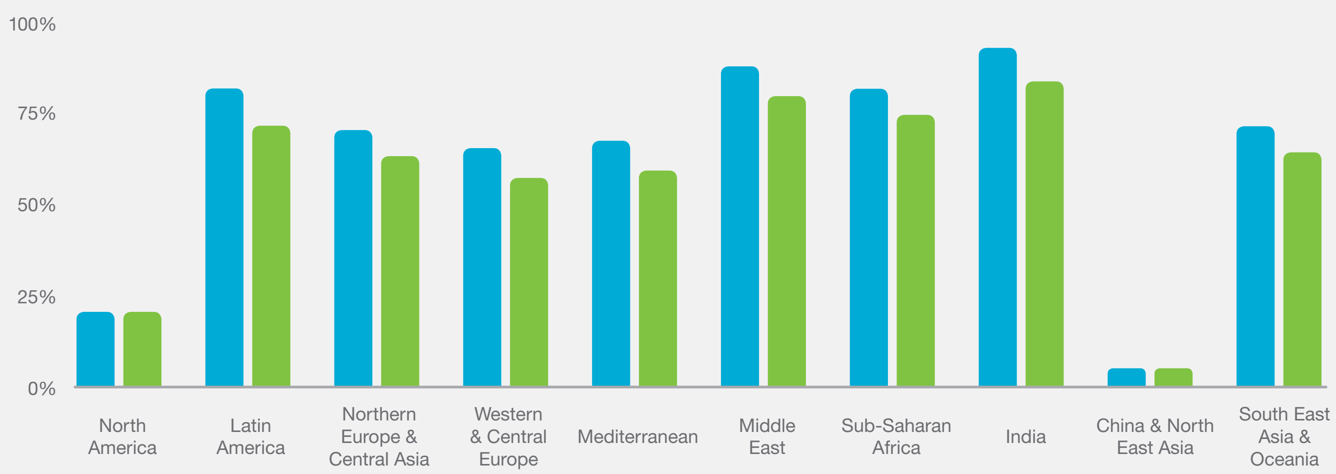
According to the Ericsson Mobility Report Q4 2017, 3.3 billion mobile broadband subscribers will be added in the next five years, and a clear majority of these will come from LTE and 3G/HSPA in microwave-centric markets. The addition of an Indian greenfield LTE/4G operator and the densification needed to support proper MBB services will increase the number of sites, stabilizing microwave share on a global basis.

The large-scale 5G volume deployments are initially expected in areas with high fiber penetration, such as China, Korea, Japan and US. There are also operators in Western Europe that have a combination of microwave and fiber, and are looking at introducing 5G. Larger volume rollouts of 5G networks are planned for a later point in the next few years.

Regional variations

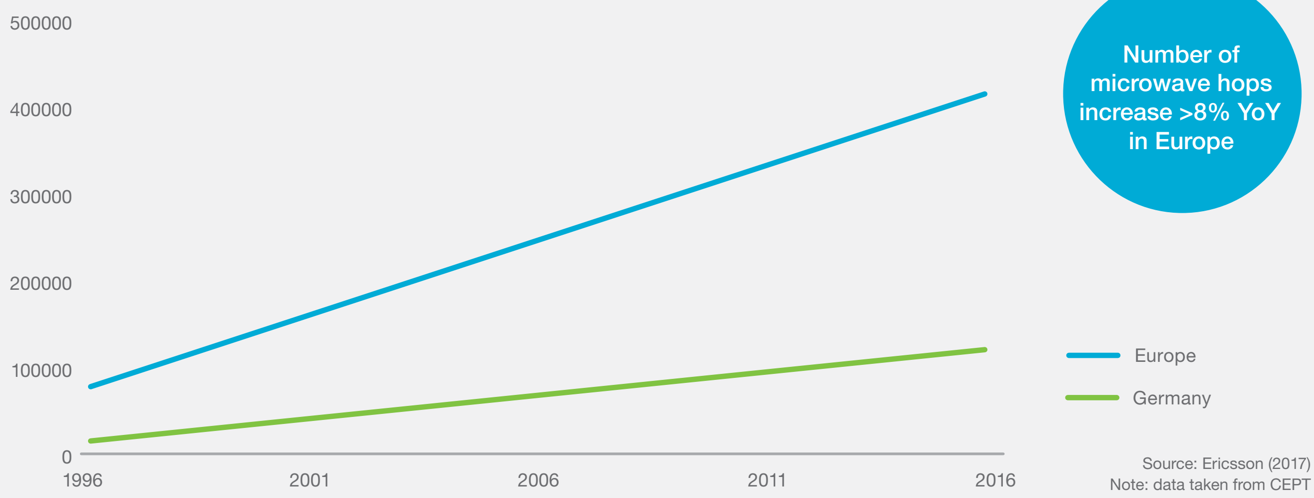
Regional differences are expected to continue over the next five years. For operators evolving their LTE Networks, the focus will be on improving total cost of ownership and time-to-market in order to outperform competitors.

Figure 4: Microwave backhaul share in different regions



Source: Ericsson (2017)

Figure 5: Number of microwave hops in Europe according to CEPT statistics



Source: Ericsson (2017)
Note: data taken from CEPT

In mature mobile broadband regions such as Western Europe, there are examples of large operators using up to 80 percent microwave that now plan for 5G introduction using existing microwave networks. Microwave technology has evolved to manage the demand of mobile networks, and can do so from any macro site. Core and inter-city aggregation networks are typically deployed with fiber backhaul, while spurs are implemented using microwave. It has also been observed that usage of lower spectrum for longer-distance hops is decreasing in favor of higher-frequency bands for short-distance and high-capacity hops.

Fiber vs Microwave considerations

- Governmental subsidies
- Type of operator – incumbent vs competing mobile
- Broadband maturity
- Fiber capex
- Dark fiber opex cost
- Microwave spectrum cost
- Wide channels available for microwave
- Aggregated capacity need

When introducing 5G, the demand for aggregated transport capacity will increase within the network and the depth of the microwave network will decrease. Microwave will mainly be used as last-mile access in the urban and dense urban areas, whereas a combination of last mile and aggregation links will be appropriate for suburban and rural areas.
It will be necessary to both upgrade existing sites and deploy new ones, because mobile access will primarily use higher-frequency bands to support 5G. The increased traffic will drive a need for fiber within the dense urban areas in order to expand the aggregation network, complemented with high-capacity microwave solutions such as 10Gbps E-Band to connect existing and new sites.

Networks today with 80% microwave backhaul plan for 5G

In the emerging areas such as Asia, including India, Middle East, Africa and Latin America, there is often a lack of countrywide fixed infrastructure. In many cases, mobile services are the first countrywide telecom facilities available, and the revenue per subscriber is relatively low. The total cost of ownership and time-to-market becomes critical to secure the overall operator business case. As fiber investments typically have a depreciation of around 25 years, and 5–8 years for microwave, it becomes important to invest in fiber within the right areas, such as core and aggregation networks, which historically have been deployed with long-haul microwave. These long-haul microwave networks are currently being modernized to manage lack of fiber and are often used as backup solutions when fiber has been put in place. In these markets, it is also important to secure sufficient microwave spectrum at a reasonable cost, to ensure that it becomes economically viable to deploy the LTE networks.

European hops

Based on data gathered by the European Conference of Postal and Telecommunications Administrations (CEPT) from several frequency authorities, the amount of microwave hops has risen linearly over the last 20 years, with around 8 percent growth year-on-year. A similar trend can be seen when looking at a large advanced country such as Germany. Over the past 20 years, microwave technology has been continuously evolving to meet requirements. In 1996, microwave hops typically supported 34Mbps, whereas today products have the ability to support up to 1Gbps in traditional bands, and up to 10Gbps with E-Band.

TRENDS IN SPECTRUM

Greater capacity requirements are driving the introduction of 5G in microwave bands, meaning the availability and usage of microwave spectrum for fixed services will go through a major transformation in the next 5 to 10 years. E-band will grow in importance and in usage, and we will see an introduction of the new W- and D-bands.

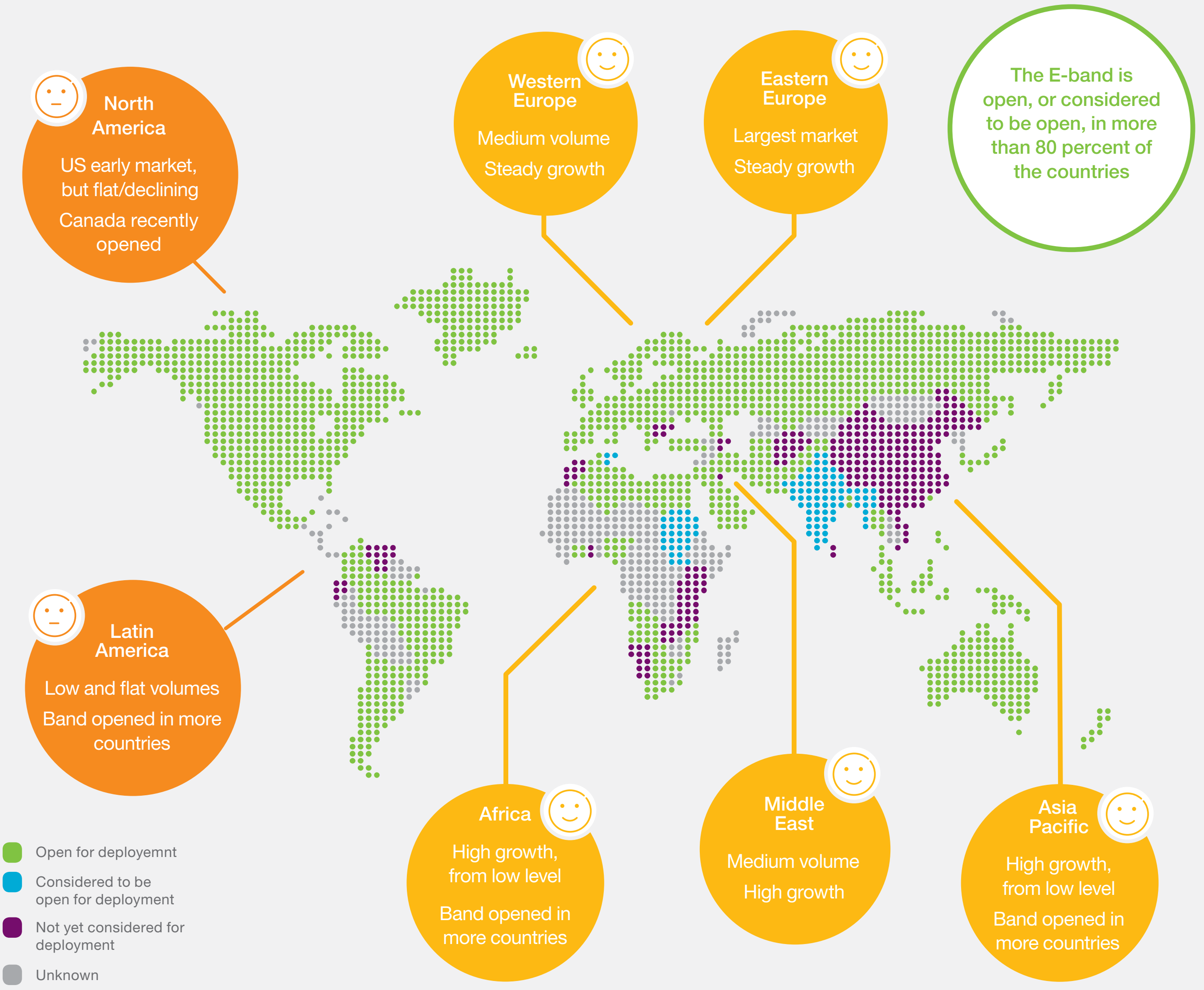
E-band was established in the US over 10 years ago. It was then that the Federal Communications Commission (FCC) introduced the first standard and initial products began to appear.

It took more than five years for more products to be released and for further countries to open the band. Since then, E-band has grown steadily. In more than 80 percent of countries with a known regulatory status, it is open for deployment or considered to be open for deployment (Figure 6).

With E-band now open in more than 85 countries, growth has accelerated in 2017 and a significant further growth is expected in the next 5 years. The main drivers for E-band are high capacities and low spectrum fees.

Eastern Europe is still the largest E-band market, mainly driven by low spectrum fees and simplified licensing. In Poland, the replacement of existing links with E-band

Figure 6: Regulatory and market status of the E-band



Source: Ericsson (2017)

continues (as reported in Ericsson Microwave Outlook 2016). But it is not only Eastern Europe that drives the E-band market, Western Europe and the Middle East are also seeing strong growth.

India has the world's largest installed base of microwave in traditional bands. The opening of E-band in India has been postponed a few times. But once it is open, India is likely to become the world's largest E-band market, assuming it will have a low-spectrum fee approach, like most countries. The main drivers for E-band in India are: traditional spectrum fees; a lack of broad channels (max 28MHz) in traditional bands hampering capacity growth; and many short hops.

Multi-band booster and dual-band antennas

Another driver for E-band is the introduction of the multi-band booster. In general this is a concept where two bands with different properties are used together to get the best out of both bands. By combining a lower-frequency band that has good propagation properties with a higher-frequency band that has broader channels and more capacity, it is possible to achieve high capacities over longer distances with increased availability.

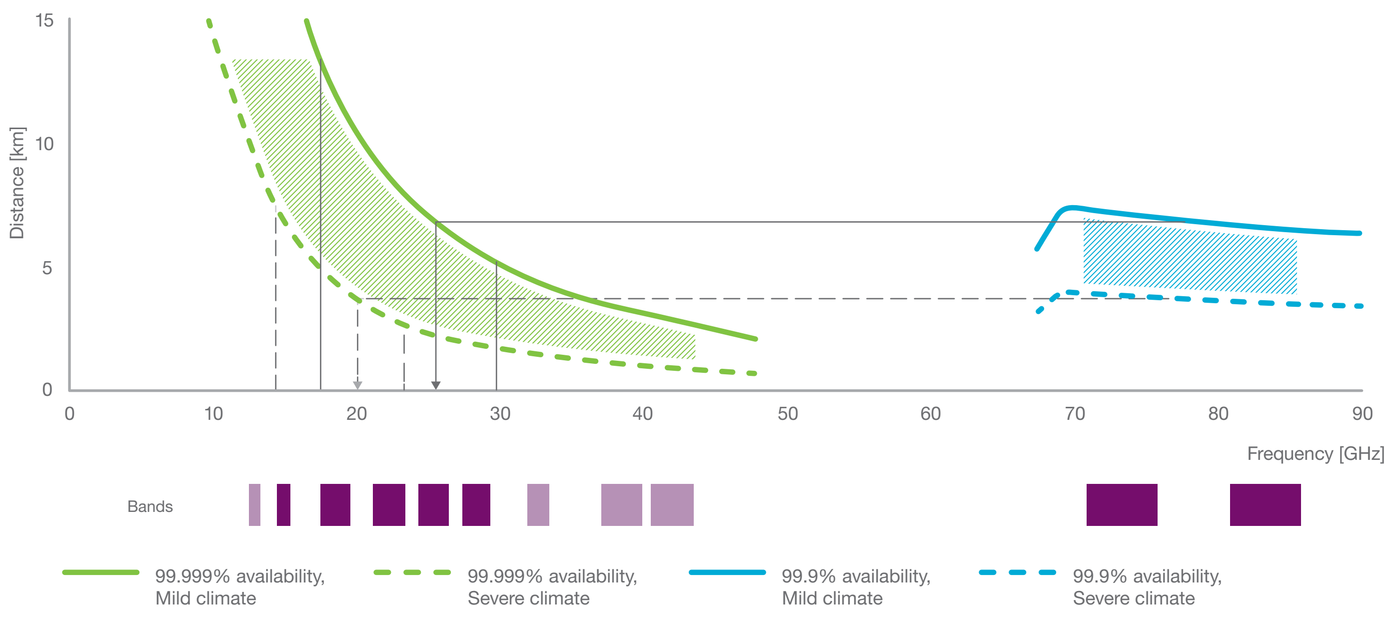
This concept is extremely flexible and can be used for many different frequency combinations. The current market focus is, however, to combine a traditional-frequency band with E-band.

Multi-band booster – enabling high capacity over longer distances

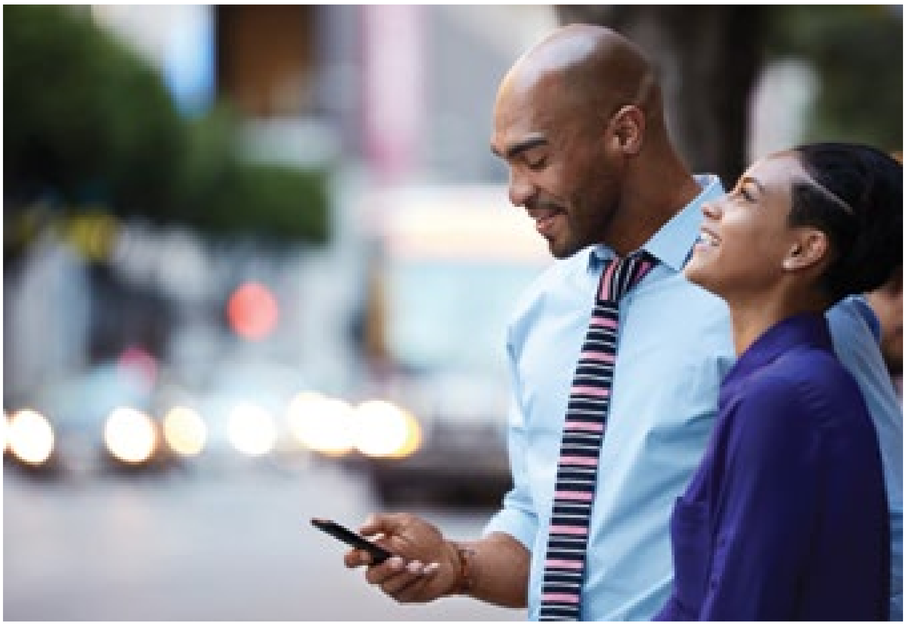
The hop lengths for bands 13–42GHz and 70/80GHz have been plotted for two different climates (Figure 7). "Mild climate" corresponds to major parts of Europe and "severe climate" corresponds to countries with more severe weather conditions, such as India. An availability of 99.999 percent in the traditional bands (with an outage of just 5 minutes per year), and 99.9 percent in 70/80GHz (with an outage of 9 hours per year), has been assumed. From the graph, it can be seen that for mild climate, the same hop length can be achieved at 70/80GHz as for ≈26GHz. For severe climate, the same hop length can be achieved at 70/80GHz as for ≈20GHz. By applying some flexibility both up and down on the availability target for the traditional band, it can be seen that the most relevant bands to combine with 70/80GHz are 18–28GHz in mild climate, and 15–23GHz in severe climate. For 32–42GHz, the availability has dropped so much that it would be more effective to install a pure 70/80GHz link instead of a multi-band booster link.

Already today, multi-band booster can be installed using two antennas – one in each band. However, to reduce load and rental cost of tower space, there is a clear need for dual-band antennas. The global high-volume bands 15, 18 and 23GHz are the most relevant for dual-band antennas, for combined use with 70/80GHz. In certain markets, 26 and 28GHz will also be relevant.

Figure 7: Recommended multi-band booster configurations for traditional bands in combination with E-band



Source: Ericsson (2017)

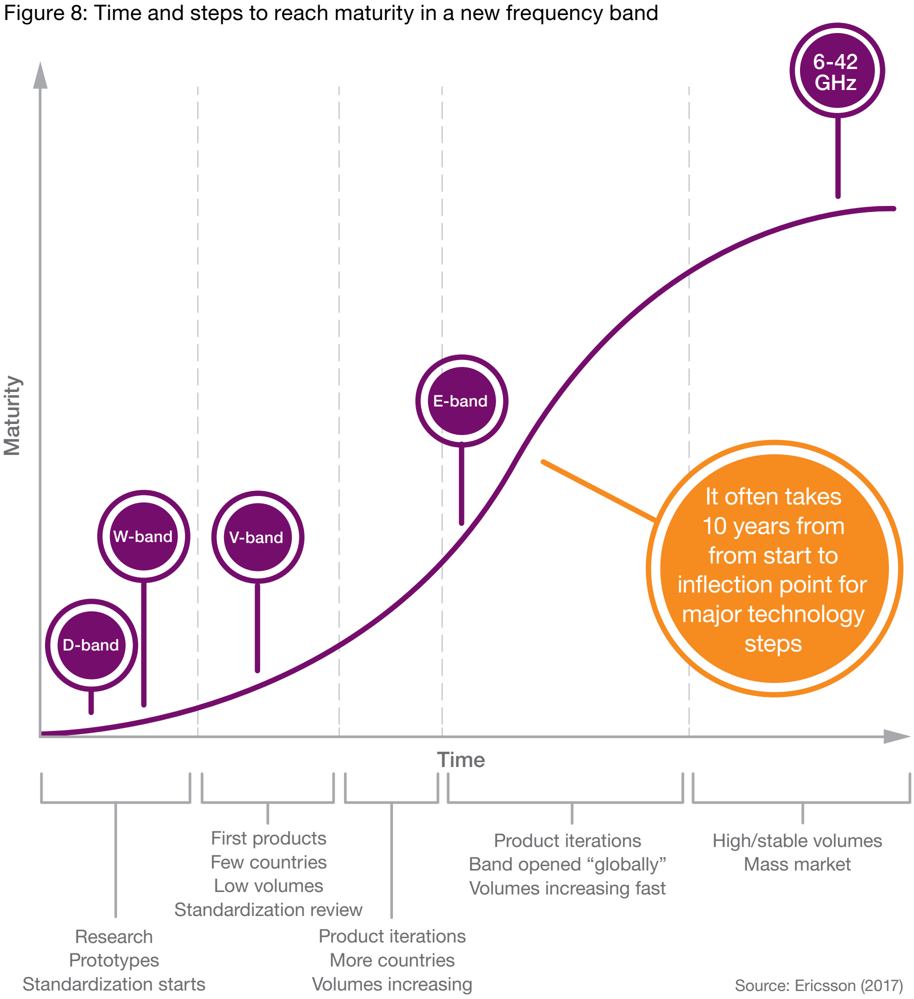


W- and D-band

E-band satisfies the high-capacity demands of today's networks, and will be suitable during the coming years when 5G is rolled out. However, in the long term more spectrum will be needed. Standardization of the W-band (92–114.25GHz) and D-band (130–174.8GHz) is ongoing. The bands are not made up of a continuous block of spectrum, but rather a number of blocks. The total amount of spectrum in W- and D-band is almost 50GHz, i.e. five times more than in E-band. This is an important asset for the future. In addition to standardization, research and prototyping are also ongoing. For a new band based on new technology, the road to maturity can be very long as the standardization, products, components and market normally need to go through a number of stages (Figure 8). For E-band, it has taken 10 or more years to get to the point where it is today. Something similar could be expected for D-band. The timeline for W-band might be shorter as it is closer to E-band. No significant usage is expected in these bands until 2025. The traditional bands, V-band and E-band, can handle the needs until then.

W- and D-band give five times more spectrum than E-band

Figure 8: Time and steps to reach maturity in a new frequency band



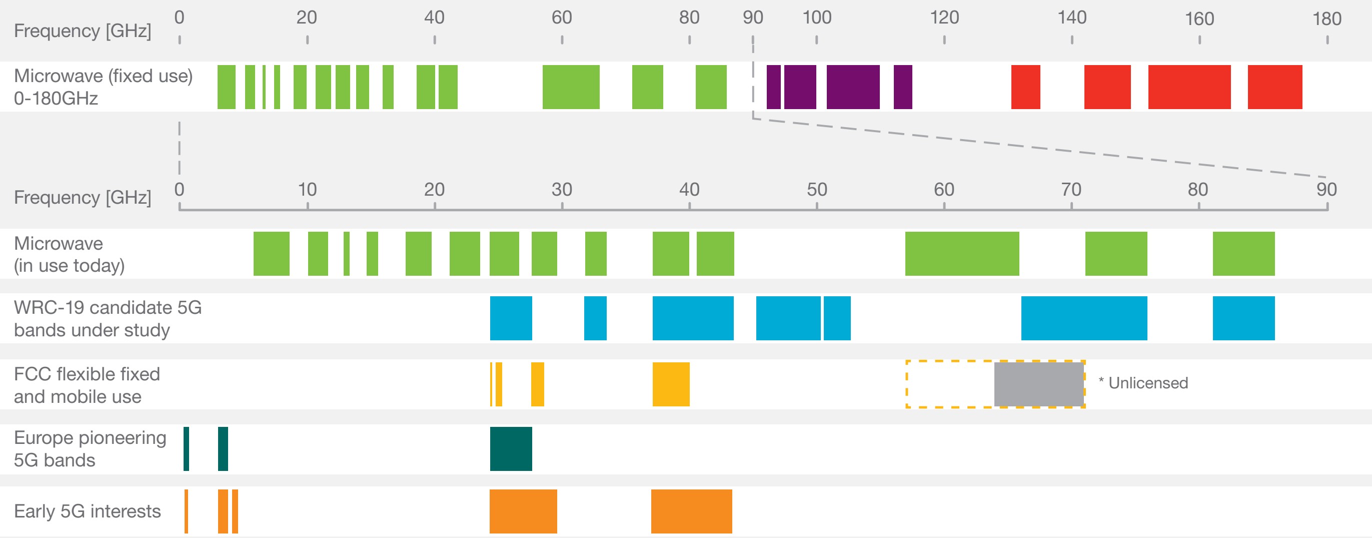
Source: Ericsson (2017)

Spectrum trends up to 2025

Spectrum below 3GHz will provide coverage in 5G. The 3–5GHz spectrum will enable high bandwidth balanced with good coverage. These bands are not used by microwave today to any major extent (apart from some 4 and 5GHz long-haul links).

The extreme bandwidths in 5G will be enabled for hotspots and industry applications in spectrum above 20GHz. The bands that will be used for this are

Figure 9: 5G and backhaul spectrum



Source: Ericsson (2017)

currently under review in a study by the International Telecommunication Union (ITU) and will be decided in 2019. However, it is clear that the main focus will be on bands 24–42GHz. The US/FCC currently has a 24, 28 and 38GHz focus and in Europe there is a focus on 26GHz. 3GPP is specifying 5G bands in 24.25–29.5GHz and 37–43.5GHz in Release 15. It excludes 32GHz and E-band, which are both part of the ITU study and, in a recent report, the FCC stresses the importance of E-band for 5G backhaul. The decision on which bands to use and where, will be unique to each nation. But long-term parts of the 24–42GHz spectrum will be used more by 5G and less by microwave fixed services. In some of these bands, e.g. 26 and 38GHz in Europe, there are many existing microwave links in several countries.

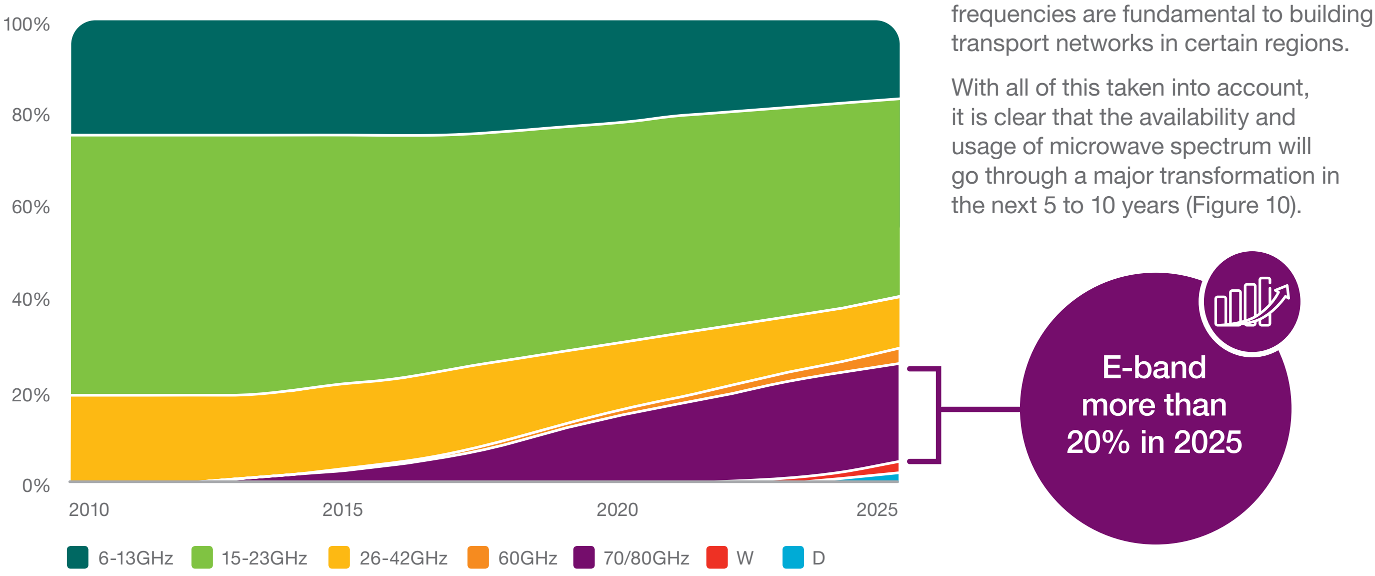
It will take time to move these links to other bands such as E-band.

The 15–23GHz spectrum will remain as the global high-volume microwave bands. E-band will become a global high-volume band, both on its own and in a multi-band booster combination with 15–23GHz.

For long hops and as an economical replacement to fiber, 6–13GHz will also remain important. Due to their good propagation properties in geographical areas with high rain rates, these low frequencies are fundamental to building transport networks in certain regions.

With all of this taken into account, it is clear that the availability and usage of microwave spectrum will go through a major transformation in the next 5 to 10 years (Figure 10).

Figure 10: New deployment share per frequency range



Source: Ericsson (2017)

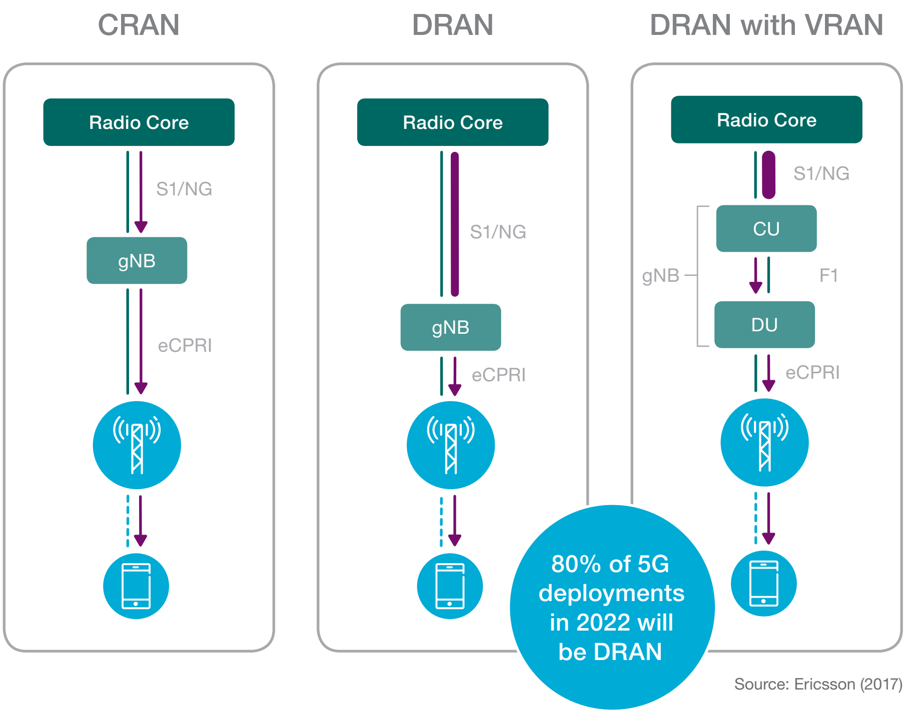
5G NR EVOLUTION

The evolution of 5G new radio (NR) is rapidly moving forward, as more parts are being standardized by the 3rd Generation Partnership Project (3GPP) and other organizations. Agreed proposals within spectrum allocation and interface types, as well RAN network deployment strategies, are outlining the requirements on the transport networks for the future.

The evolution of 5G NR is continuing with a focus on both enhanced and new services. Evolved mobile broadband will see a significant increase in bandwidth, up to 10Gbps at peak-rates, to allow for new services such as streaming high definition (HD) and ultra-high definition (UHD) video, virtual reality (VR) and augmented reality (AR). The higher bandwidth also increases the possibility of using Fixed Wireless Access (FWA) as an alternative to fixed broadband services. The flexibility of the 5G RAN network also allows for services that focus on other characteristics, such as low latency, critical to IoT and MTC, or high connection user density, for IoT.

With standardization and the global rollout of 5G test networks, the first commercial networks are nearing, necessitating a closer look at the demands that will be put on the transport network to obtain the desired characteristics.

Figure 11: 5G RAN networks



Source: Ericsson (2017)

5G NR RAN networks

There are two major types of RAN networks for 5G, and their use depends on several factors, such as service requirements, physical geography and access to transport. They are distributed RAN (DRAN), and centralized RAN (CRAN). Of these two, DRAN will be the most common.

CRAN's main use case is in dense and ultra-dense urban environments where co-location of baseband processing increases coordination gains, but it also puts high demands on the transport network. Virtualized RAN (VRAN), increases the flexibility of the network by virtualizing parts of the baseband process, making it easier to scale capacity, deploy new services and adopt the network. The increased flexibility of this split-architecture will lead to a more diverse range of deployments for the operators, with the possibility of tailoring the networks to meet customer needs – from dense urban, high enhanced Mobile Broadband (eMBB) bandwidth applications to automated factory machine control. VRAN can be applied on both DRAN and CRAN networks.

5G NR RAN interfaces

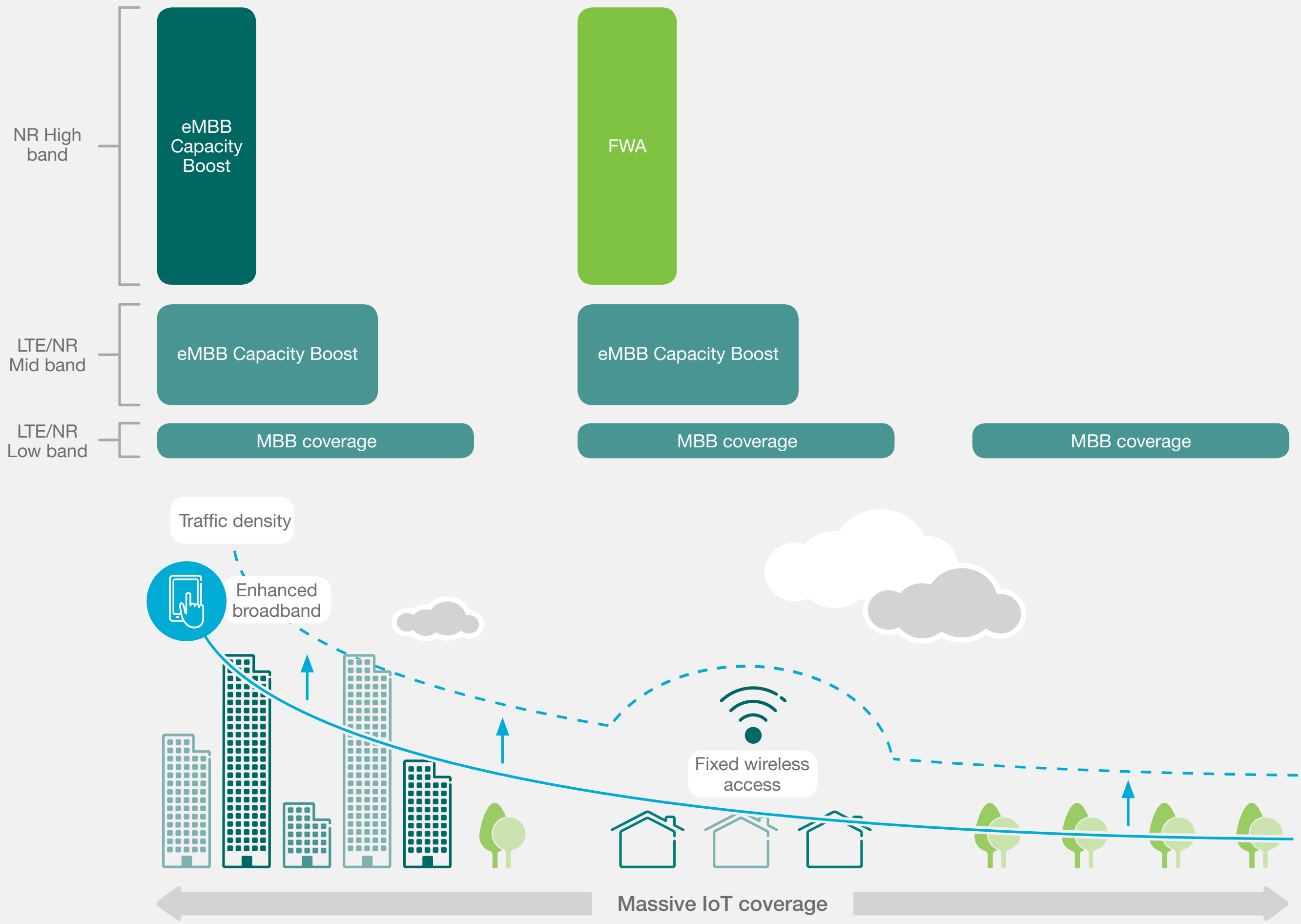
For the new 5G RAN architecture, including the split architecture, new interfaces have been standardized. The Common Public Radio Interface (CPRI) has been replaced by new fronthaul interface eCPRI – a packetized interface for improving bandwidth efficiency and ease of deployment. The new IP-based interface between the centralized unit (CU) and distributed unit (DU) processing nodes in VRAN, (Figure 11), is similar to the traditional S1 backhaul interface but demands lower latency for optimal performance. S1/NG backhaul will retain most of the characteristics of current S1 backhaul, but with increased bandwidth.

5G NR RAN performance

5G NR increases accessible User Equipment (UE) bandwidth and lowers latency, by improving spectrum efficiency and using additional spectrum. Band availability will depend on market factors; three main categories have been identified where the amount of spectrum bandwidth available is different for each of them.

Low-band is used for coverage, typically in rural areas, but also for deep indoor coverage in urban areas. Mid-band offers relatively good coverage in combination with high bandwidth. High-band will be focused on high bandwidth coverage, typically as a capacity boost in dense urban environments. For suburban areas, high-band will also be used for fixed wireless access, covering a number of households in a limited geographical area with high bandwidth eMBB services.

Figure 12: The use of the 5G spectrum



Source: Ericsson (2017)

Band	Bandwidth
Low-band <3GHz	up to 50MHz
Mid-band 3–5GHz	up to 150MHz
High-band >6GHz	up to 800MHz

5G NR RAN transport requirements

Larger spectrum, coordination services and low latency services, made possible by VRAN deployments and eCPRI fronthaul, lead to new demands on the transport network. Higher capacities will be required for the majority of 5G fronthaul and backhaul networks, driven by the increased user data rates. In VRAN, lower latencies are also needed. The diverse deployment possibilities in 5G RAN makes actual transport requirements vary more than in typical 4G networks. As an example, rural DRAN deployments will have moderately increased backhaul demand compared to the 4G networks currently deployed. Whereas networks in urban environments, with VRAN and advanced coordination services, will require major changes in the transport network due to the amount of data that needs to be transferred.

There are different guidelines for transport interfaces in typical DRAN and VRAN networks. In CRAN, and networks utilizing advanced coordination services, the 5G NR numbers can be significantly higher.

5G moving forward

Deployment of the first 5G NR test networks and standards that are currently being finalized will give valuable insight into how the real 5G NR networks will look, but preparing the transport network is already an essential step operators need to take.

Figure 13: Transport requirements

LTE	Bandwidth	Latency
CPRI	1-10Gbps/sector	75µs
S1/NG	1-2Gbps/site	30/5ms
5G NR	**Bandwidth**	**Latency**
eCPRI	10-25Gbps	75µs
F1	1-10Gbps	5ms
S1/NG	1-10Gbps	30/5ms

Actual numbers will depend on site size, access spectrum and network type

Source: Ericsson (2017)

BREAKING THE 1, 10 AND 100GBPS BARRIERS

Throughputs of 1 and 10Gbps in microwave backhaul are now a reality. In the next few years, the first 100Gbps links will emerge from research labs.

Beginning at 1Gbps

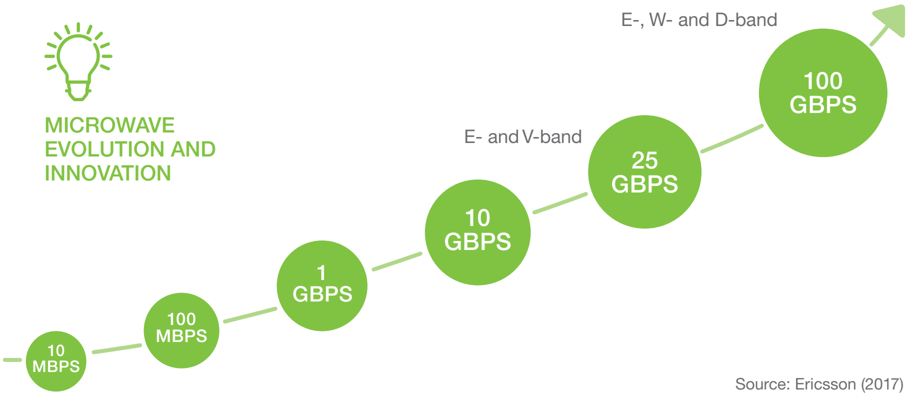
In the early years of mobile networks, a backhaul link typically supported a few Mbps, using a couple of MHz of channel bandwidth. Capacity evolved gradually over the following years to meet the demand of the new generations of networks. This was due to improved spectrum and throughput efficiency, as well as the addition of spectrum.

Microwave backhaul continues to evolve towards 100Gbps

Today, 1Gbps-capable microwave radios are the norm, propelled by the needs of mobile broadband, the availability of channel bandwidths above 50MHz, the use of high-modulation schemes, and XPIC.

The spectrum efficiency for a state-of-the-art single-carrier radio is in the order of ~13bps/Hz. However, increased spectrum efficiency is not free. Every bit per transmitted symbol requires a doubled signal-to-noise ratio. Thus, to enable a high-order modulation, a radio link will require a very good system gain.

Figure 14: Microwave backhaul capacity evolution



Source: Ericsson (2017)

This is achieved through a combination of efficient coding, error correction and linearization of the transmitter and receiver, along with high-gain antennas. As these solutions increase cost and energy use, a compromise is the introduction of adaptive modulation. The radio link normally operates on its highest modulation; but this is automatically reduced during short high-fade events, such as intense rain storms, in order to compensate for the increased path attenuation. Consequently, the link capacity will be diminished at these occasions, but the reduced modulation scheme will ensure the system gain increases and the link is still able to continue serving high-priority traffic. Adaptive modulation enables very high capacity most of the time.

Some efficiency may be gained by header compression, i.e. by processing the signal before transmission, removing redundant information in packet headers for example. However, efficiency is dependent on the type of data in the network. It could result in an efficiency gain of up to 20–30 percent when working with smaller packages, but is less efficient with larger packages.

When combining data over multiple carriers, radio link bonding is a key technology. An efficient bonding technique ensures that a single data stream is seamlessly transmitted across different radio channels, with negligible overhead.

SPECTRUM EFFICIENCY

- High modulation schemes
- Superior system gain
- Adaptive modulation
- XPIC and MIMO

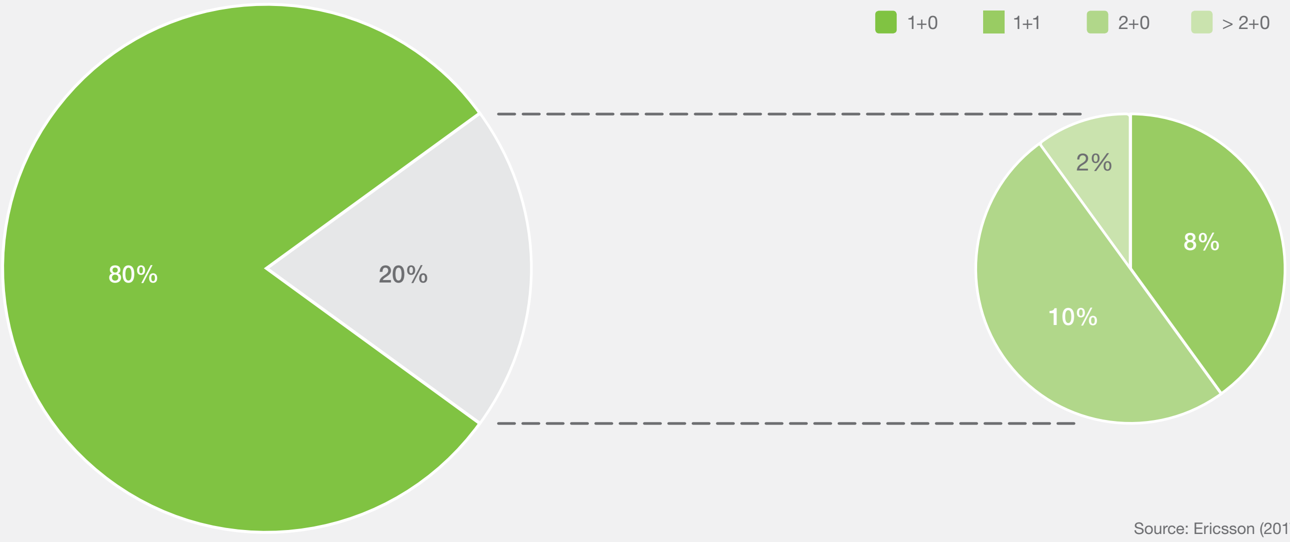
SPECTRUM

- Today V-, and E-band
- Beyond 2020 W- and D-band
- Multi-band booster

THROUGHPUT EFFICIENCY

- Radio link bonding
- Multi-layer header compression

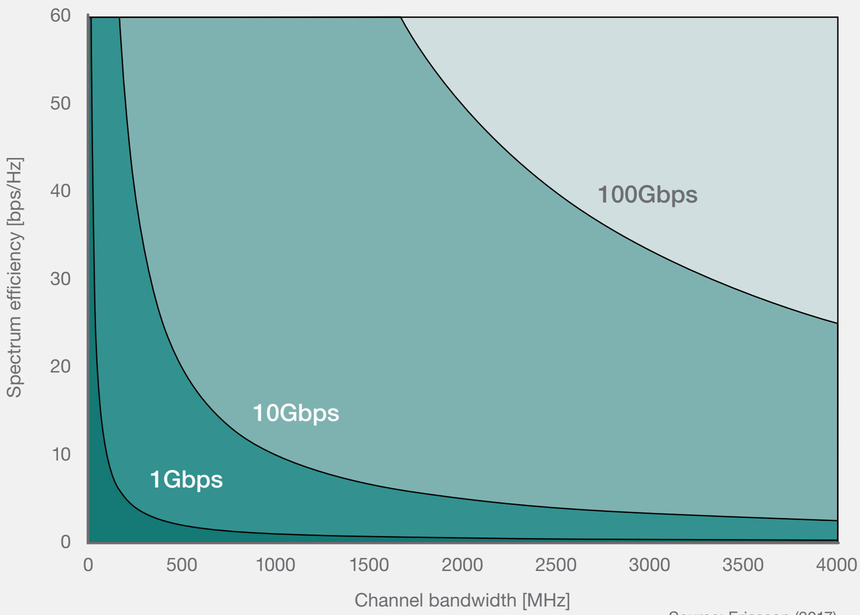
Figure 15: Global distribution of radio link configurations. 80 percent are configured as single-carrier links (1+0), 20 percent are configured as multiple radio links



Source: Ericsson (2017)

A global view of multicarrier configurations can be seen above (Figure 15). About 80 percent are configured as single carriers (1+0), the remainder as multi-carrier links with backup links as protection. About 8 percent are set up with one active radio and the protection link in hot standby mode (1+1); 10 percent are configured with dual-carrier radio link bonding (2+0), where the capacity of the backup link is used to increase the link's peak capacity. Only 2 percent are configured for three or more carriers (>2+0). Due to the need for increased transport capacity, the number of links aggregated over two or more carriers is rising globally.

Figure 16: Required spectrum efficiency in bps/Hz versus channel bandwidth for 1Gbps, 10Gbps and 100Gbps radio links.



Source: Ericsson (2017)

The required spectrum efficiency versus channel bandwidth for 1, 10 and 100Gbps throughput can be seen in the graph (Figure 16). With today's E-band links it is possible to reach 1 and 10Gbps using a single carrier radio.

Onwards and upwards from 10Gbps

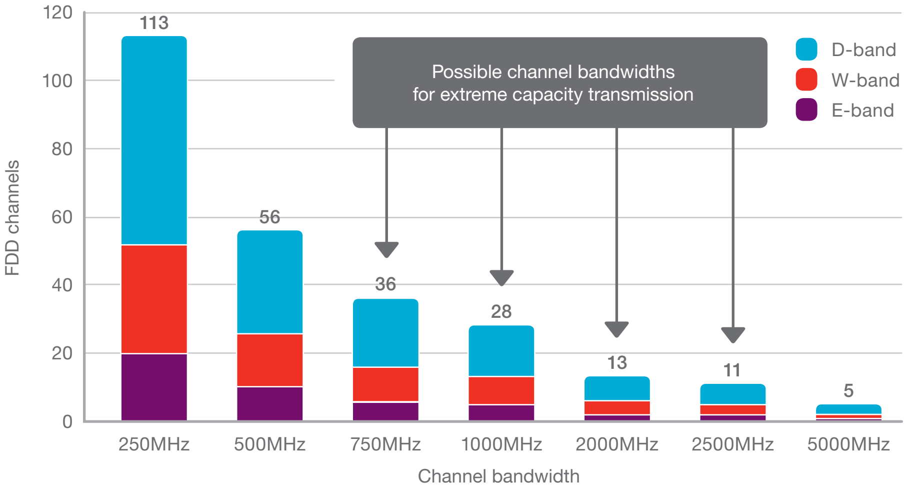
The 10Gbps mark was passed in early 2016, driven by rising data usage for mobile broadband and ongoing trials of 5G networks.

A single-carrier radio in a 2GHz channel calls for a spectral efficiency of 5bps/Hz to reach 10Gbps. Using channels with bandwidths of 1GHz and below will require more than 10bps/Hz. This is only practical in multi-carrier configurations such as XPIC or MIMO.

Higher-frequency bands, such as the E-band, can experience limitations due to the impact of rain, but are deployed in 3–5km hops with high availability. With the introduction of multi-band solutions, two frequency bands with different properties are combined. Combining the lower frequency band enabling high availability, and the higher frequency band enabling high capacity, achieves Gbps throughput up to 10km with acceptable availability. The lower frequency bands guarantee that the high-priority traffic is transmitted with telecom-grade availability.

Mass deployment of 10Gbps radio links will require more wideband channels. The E-band supports just six 750MHz channels or two 2GHz channels. The introduction of spectrum in the W- and D-band will improve this situation. Propagation-wise the W-, and D-band will enable radio links with hop lengths and availability similar to E-band.

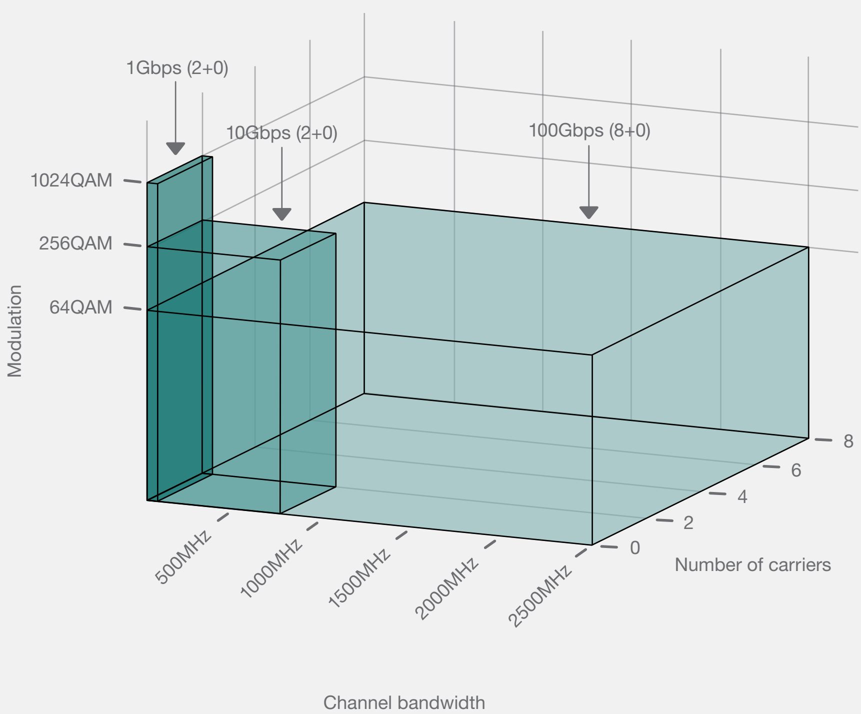
Figure 17: Number of available channels versus channel bandwidth in the E-, W-, and D-band



Source: Ericsson (2017)

Combining the E-, W- and D-band will provide a large number of wideband channels (Figure 17).

Figure 18: 1, 10 , and 100Gbps configurations in multicarrier links



Source: Ericsson (2017)

To enable a fair distribution of extreme capacity channels between different users, channel bandwidths between 750MHz and 2.5GHz will most likely be used. Bandwidths beyond 2.5GHz will not be available at scale.

100Gbps and beyond

Driven by rising traffic density and new, high-capacity radio interfaces, microwave backhaul continues to evolve towards 100Gbps in 5G.

Limiting the maximum channel bandwidth to 2.5GHz calls for a spectral efficiency of 40bps/Hz. This will only be possible using multicarrier solutions.

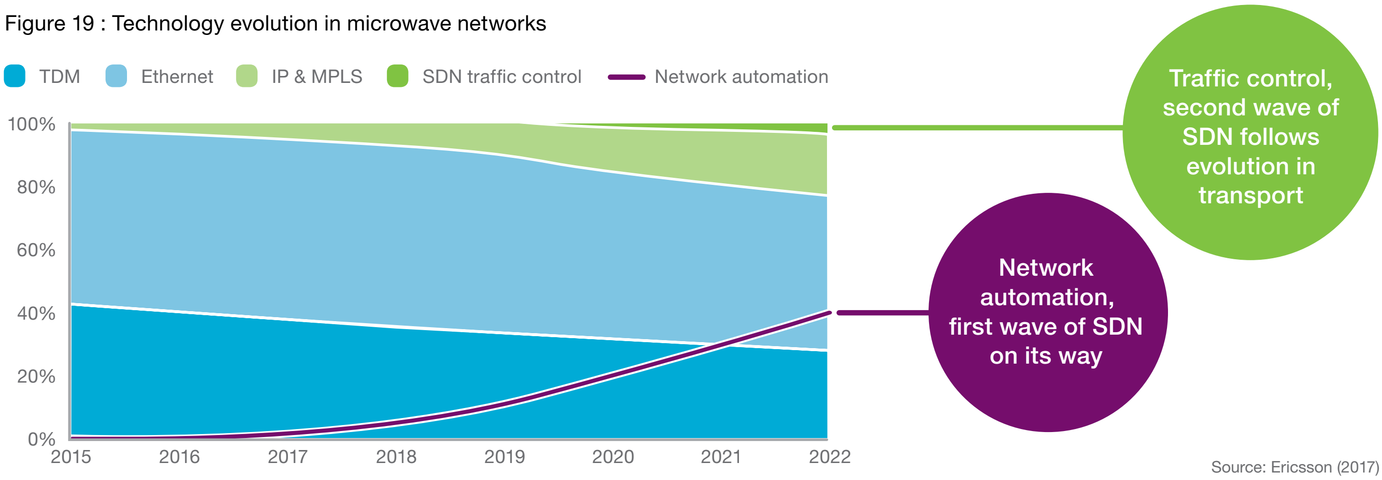
When combining XPIC with single polarization MIMO, a large number of additional carriers is enabled on the same frequency channel.

In the future, a 100Gbps configuration could consist of eight carriers in a two-by-two antenna configuration using XPIC. Using a single 2.5 GHz channel and modulation as low as 64QAM, it will be possible to reach beyond 100Gbps. The microwave solution is very well prepared to support the future evolution of LTE and of 5G.

SDN MOVING FORWARD

The first wave of software-defined networking (SDN) for microwave has hit the industry. The initial focus is on automation and centralization of network and service configurations.

Figure 19 : Technology evolution in microwave networks



Source: Ericsson (2017)

The evolution to 5G calls for improvements in operational simplicity, efficiency and cost. Network architectures need to be transformed, to increase flexibility in deployment and the dynamic response of networks. This can be provided by SDN, thanks to its ability to automate static configuration of the transport connectivity, as well as more dynamic provisioning of the service layer in multi-technology and multi-vendor networks.

The pace of automation is expected to increase and we are now seeing the first wave of SDN-based network automation within the microwave industry.

The microwave SDN use cases described in the previous edition of this report, have been confirmed by the European Telecommunications Standards Institute in report ETSI GR mWT 16. We expect selected use cases to be deployed commercially. Others will be prototyped in order for us to better understand their value, compared to policy-based node local control and traditional network management.

Both open and standardized node interfaces are now becoming available, while legacy interfaces in existing network deployments can be handled either by mediation layers or by transformation in domain-specific hierarchical SDN controllers. Unifying node interfaces will provide clear benefits for both the development of SDN applications and for the integration of nodes into SDN controllers, especially in multi-technology or vendor environments. The NETCONF protocol and YANG models are the preference for SDN network automation.

Initially, the larger operators will deploy network automation in regions of increased network complexity, where they can benefit from the automation of conventional network management.

5G networks require increased automation

As the area matures, it is expected that more operators will follow. It is also estimated that a substantial part of networks globally will benefit from network automation by 2022.

SDN traffic control involves decoupling network control from data forwarding in the nodes. The purpose is to make it directly programmable from a centralized controller with a global view of the network. This process makes it possible to configure and optimize network resources dynamically from end to end.

This second wave will be driven by the need to simplify the handling of more complex 5G architectures by optimizing transport network resources dynamically.

It can be introduced in microwave networks when more advanced packet functionality is embedded in the microwave nodes, and traffic control functionality becomes applicable for transport networks in general. Limited deployments of SDN traffic control for microwave are expected to be seen in combination with 5G rollouts around 2020, and will increase in line with the pace of evolution in transport technology. SDN deployments will also be further empowered in the future by machine learning and artificial intelligence.

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