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Ericsson Microwave Outlook

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Executive summary

Global demands on microwave backhaul capacity and network build-out are far-reaching as the world heads towards 5G. But these are being met with a host of advances in microwave technology, additional spectrum, an efficient combination with fiber, and the use of machine intelligence.

Contents

Exactly when and how to introduce 5G New Radio (NR) will be decided nationally for each operator, but what they will have in common is the importance of not only securing spectrum for access but also for backhaul. It's expected that there will be an increase in the variation of backhaul capacity needed for 5G NR, as operators choose to deploy with variable amounts of radio access spectrum and advanced radio features, to meet the specific needs at each location. Many have started shifting backhaul to future-proof frequency bands at new installations or when upgrading equipment.

E-band is not only becoming an essential backhaul band of high global alignment, but together with the 32GHz band, it will be an important prerequisite to facilitate the transition of some backhaul frequency bands to 5G NR access use. The 5G NR standardization will enable a new way to backhaul, known as Integrated Access and Backhaul (IAB), or self-backhauling. This is expected to be useful for dense millimeter-wave 5G NR deployments on street-level sites.

With the introduction of 5G, the interest in E-band is high, as it can provide up to 10Gbps for even the most extreme dense urban sites. But capacities are constantly growing in all parts of the network, from urban to rural areas. So the next major threshold to reach is 10Gbps everywhere. While the technology needed to enable this is already available, standardization and spectrum regulation changes will be fundamental to creating cost-efficient solutions.

With the advances in microwave technology using wider channels, higher modulations, E-band spectrum and multi-band solutions, microwave as a transport technology will also meet the future requirements set out by more advanced Radio Access Networks (RAN) and 5G. Operator trials, such as the A1 Hrvatska example in Croatia, are proof of the value of E-band and multi-band as tools to increase backhaul capacities over longer distances.

Artificial intelligence (AI) and machine intelligence (MI) have taken significant steps over the last decade, now offering techniques that leverage the expertise of microwave planners and engineers, allowing for management of larger, more complex and efficient microwave networks.

As we head towards 5G, microwave backhaul is well prepared to meet the challenges, as operators gain the suite of tools they need to enable networks to cope with increased capacity and rapid change.

The combination of fiber and microwave solutions remains a winning backhaul strategy for evolving 4G and developing 5G networks.

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Future capacity requirements

The first commercial deployment of 5G New Radio (NR) is imminent. Demands upon backhaul capacity are expected to keep growing as new services and higher capacity mobile broadband become available. These will be driven not only by 5G, but also by LTE Advanced.

The main capacity drivers in 5G NR will be the availability of larger amounts of access spectrum, the higher usage of advanced Radio Access Network (RAN) coordination services and the more advanced radio features like Multi-User Multiple Input Multiple Output (MU-MIMO). Variations in 5G backhaul capacity requirements are expected to increase, as operators choose to deploy with very different amounts of NR spectrum and advanced radio features, in order to meet consumer data demands in each location.

Typical backhaul capacity requirements in eMBB networks are shown in Figure 1, where Centralized RAN (CRAN) hub sites are excluded as they are normally located on central network sites that are connected directly to metro networks, and not through traditional backhaul networks.

Microwave as a technology is not only useable for traditional backhaul interfaces such as S1/X2 in LTE and NG in 5G. It can also be deployed for F1, the interface between centralized units and distributed units in Virtualized RAN (VRAN), and Common Public Radio Interface/evolved Common Public Radio Interface (CPRI/eCPRI) fronthaul interfaces. The architectural deployment view in Figure 2 shows dimensioning guidelines for the different interface types, and applicability of different microwave bands and technologies. Next generation Node B (gNB) in CRAN and Centralized Unit (CU) in VRAN are normally placed on centralized network locations, central offices or large aggregation sites where fiber infrastructure is available.

Figure 1: Backhaul capacity per site in Distributed RAN

	2018 Low – high cap sites	2022 Low – high cap sites	Towards 2025 Low – high cap sites
Urban	150Mbps – 1Gbps	450Mbps – 10Gbps	600Mbps – 20Gbps
Suburban	100Mbps – 350Mbps	200Mbps – 2Gbps	300Mbps – 5Gbps
Rural	50Mbps – 150Mbps	75Mbps – 350Mbps	100Mbps – 600Mbps

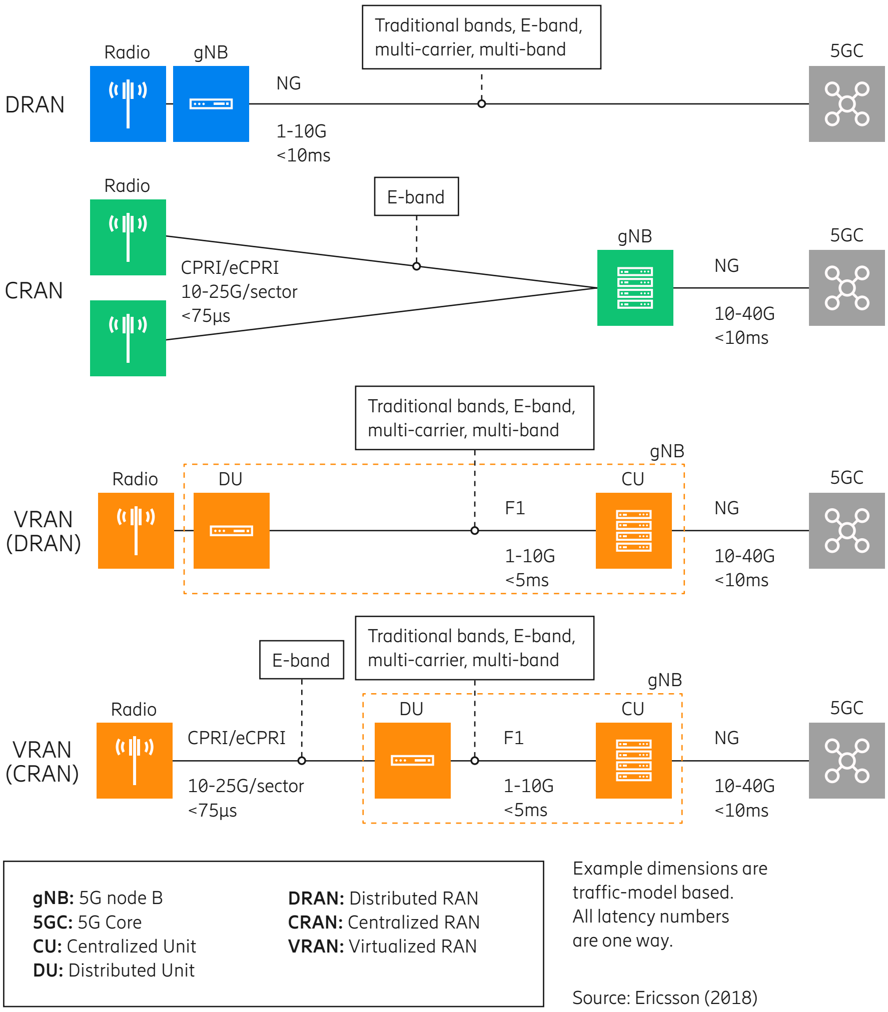
Source: Ericsson (2018)

As the characteristics of each interface are different, this must be taken into account when it comes to microwave deployment. Using eCPRI fronthaul as an example, high bandwidth and low latency are required, and this can be fulfilled by using E-band microwave.

Greater depth can be provided to the backhaul capacity table by examining geographical deployment, as there are major variations when moving from rural to dense urban environments. Urban and dense urban locations typically have short hop lengths with very high capacities, making E-band well suited. In suburban locations, the hop lengths increase, both for traditional eMBB and fixed wireless access (FWA), and capacities are lower. Here several microwave technologies can be used, depending on site requirements. For example, traditional bands, multi-carrier solutions and multi-band with E-band for both end-sites and aggregation sites. In rural environments, the hop lengths increase even further while end-site capacity decreases, making traditional microwave band solutions the preferred choice, for both short-haul and long-haul.

With advances in microwave technology using wider channels, higher modulations, E-band spectrum and multi-band solutions, microwave as a transport technology will also meet future requirements created by more advanced RAN networks and the evolution towards 5G.

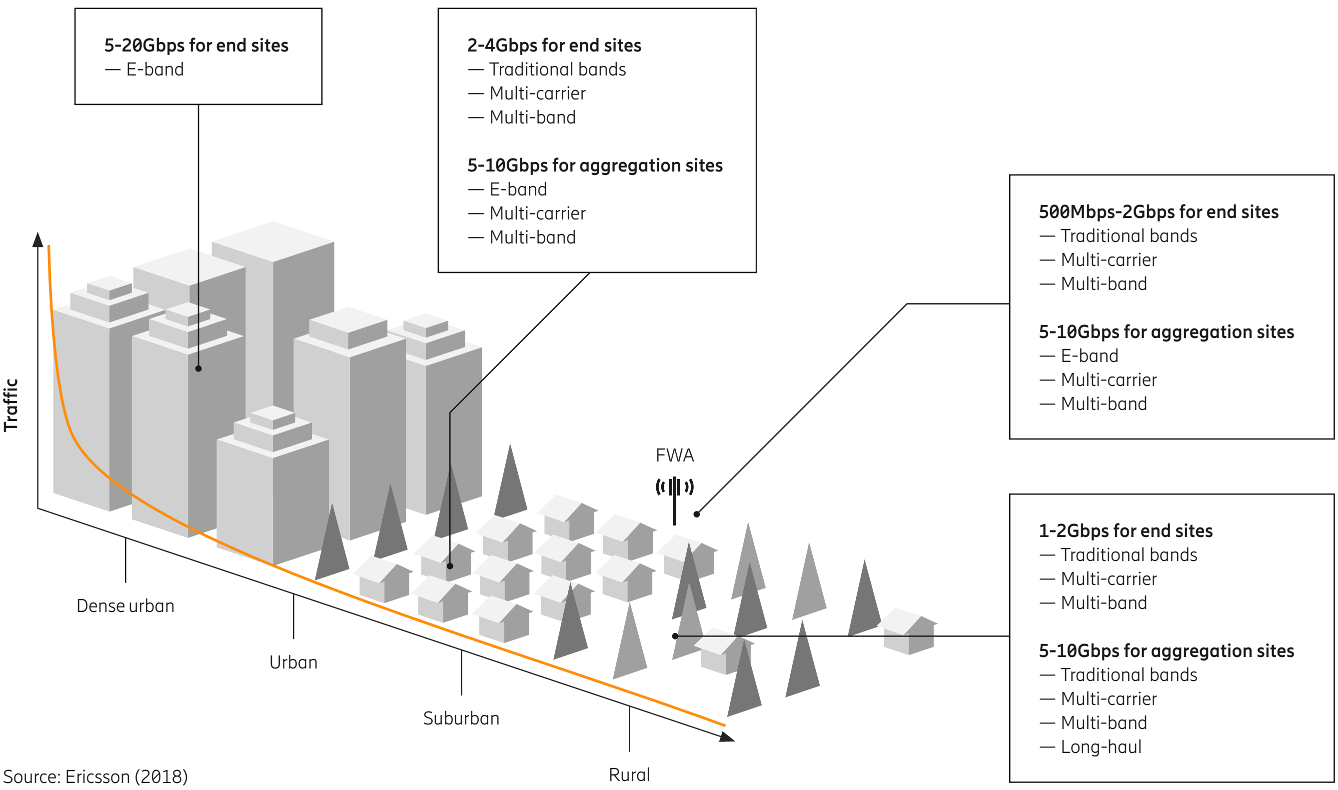
Figure 2: 5G transport dimensioning guidelines



Example dimensions are traffic-model based. All latency numbers are one way.

Source: Ericsson (2018)

Figure 3: 5G transport towards 2025



Source: Ericsson (2018)

Winning backhaul strategy

The combination of fiber and microwave solutions remains a winning backhaul strategy for evolving 4G and developing 5G networks.

Globally, 40 percent of backhaul connections are expected to be based on microwave by 2023, corresponding to 65 percent when excluding China, Taiwan, South Korea and Japan. The North East Asian market has grown disproportionately with large 4G/LTE deployments, and in combination with a high fiber penetration has influenced the global share as seen in Figure 4.

In the coming years, new sites will to a large extent come from 4G/LTE coverage expansions in regions that heavily rely on microwave. Initial 5G deployments will mainly be built on existing grids and in regions that rely of fiber. Together, the share of fiber and microwave is expected to remain stable the coming years.

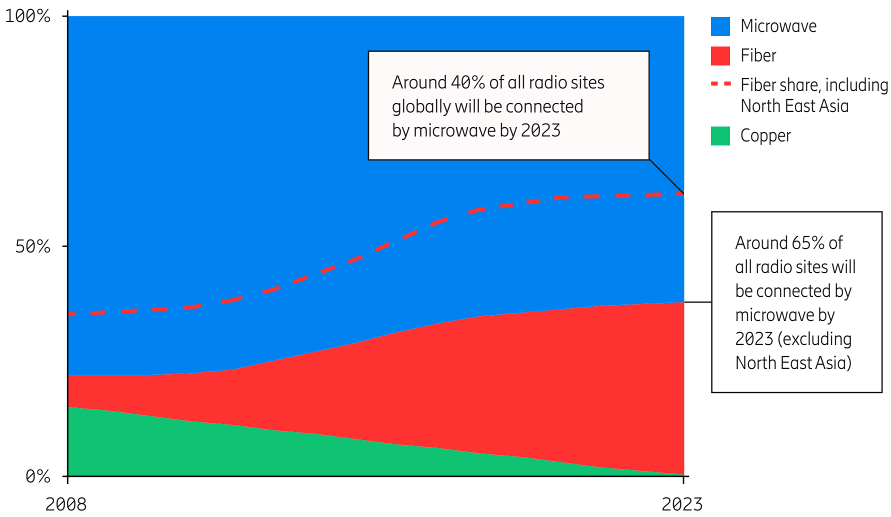
Total cost of ownership (TCO) is a key factor to consider when deploying a backhaul network.

In the example in Figure 5, a comparison is made of the cost of providing a connection of up to 10Gbps in Germany using self-built fiber, dark fiber and microwave solutions. Each of the solutions include initial and variable costs in a mix of urban and rural sites.

For microwave deployment, E-Band links are used up to 3,000m, and a multi-band solution combining E-Band with traditional bands is used between 3,000m and 5,000m.

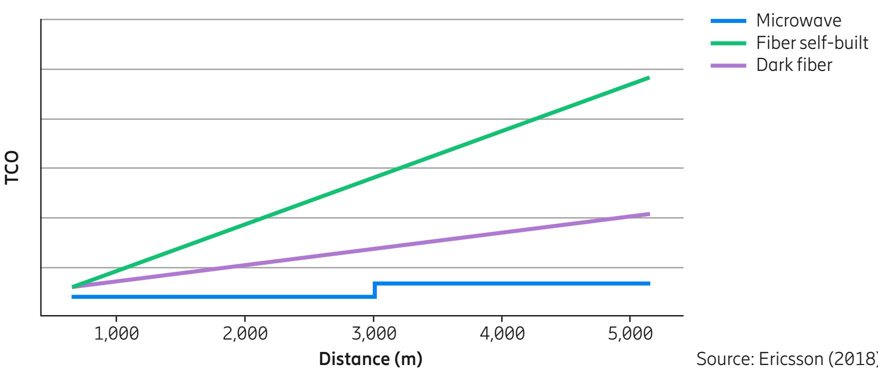
Self-built fiber is the most costly and capex-intensive solution, and so requires sharing investment costs with other services. Dark fiber, when available, is the most cost-efficient fiber solution as costs are shared cross multiple users. In this example, the microwave solution clearly has the lowest TCO, both in E-Band alone and when combining E-Band with traditional bands. However, costs will differ between markets due to variable fiber digging, lease and microwave spectrum costs.

Figure 4: Global backhaul media distribution



Source: Ericsson (2018)

Figure 5: Comparing backhaul solutions for a 10Gbps connection in Germany



Source: Ericsson (2018)

TCO is not the only parameter that requires consideration when selecting backhaul options. Potential capacity growth, sharing of services, microwave line-of-sight, short deployment time and spectrum availability should also be examined.

With the right prerequisites in terms of spectrum availability and spectrum price, a microwave solution is a very efficient component when deploying cost-effective, high-capacity backhaul for LTE and 5G networks.

Trends in spectrum

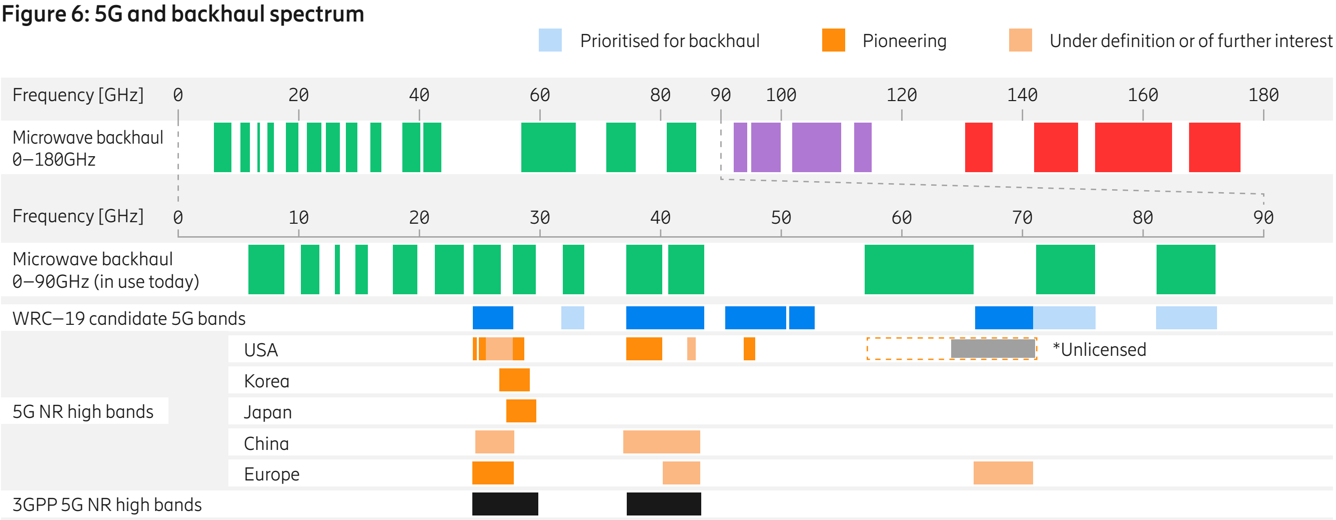
Both E-band and 32GHz band are now largely acknowledged as essential for backhaul, in contrast to access use. The strong prioritization of these bands is an important prerequisite to prepare transport networks for 5G, as well as facilitate the transition of the 26GHz band to 5G New Radio (NR) access use.

The next International Telecommunication Union (ITU) World Radiocommunication Conference (WRC-19) is scheduled to take place in November 2019. However, many countries see an urgency to start building 5G networks right away, to meet the ever increasing consumer data traffic demands and act as a foundation for future economic growth. Securing the right spectrum for 5G NR in low, mid and high frequency bands is important. An increasing number of countries are planning and awarding 5G spectrum, and the first commercial 5G NR services are being launched in the United States. The first 5G NR devices, such as pocket routers and smartphones, are expected in early 2019, with support for frequency bands such as 39GHz, 28GHz, 3.5GHz, 2.6GHz and 600MHz. The massive uptake of 5G subscriptions is expected to be fueled by next generation chipsets, due to be available from 2020. In general, all 3GPP bands in use for current mobile generations are also being considered for 5G services.

The early 5G launches in the United States are in high band, while in Europe and Asia the initial focus is generally in mid band with high band as a second stage. Microwave backhaul is in extensive use in many frequency bands above 6GHz and will also remain an essential media for transport of 5G. The E-band and 32GHz band will grow in importance for backhaul, while a few other bands will eventually be transitioned to 5G NR access use (Figure 6). In Korea, the 28GHz band (26.5–28.9GHz) for 5G NR was auctioned in June 2018, with 800MHz allocated to each operator. The initial deployments of millimeter wave (mmWave) 5G NR in the United States are in the 28GHz band (27.5–28.35GHz) and 39GHz band (38.6–40GHz). The first mmWave spectrum auction took place in November 2018 and included available spectrum in the 28GHz band. This is followed by the planned auctions of the 24GHz band (24.25–24.45GHz and 24.75–25.25GHz) in the first half of 2019, and of the 39GHz band (37.6–40GHz) and 47GHz band (47.2-48.2 GHz) in the second half of 2019.

In the US, the suitability for 5G NR use in the 26GHz band (25.25–27.5GHz) and 42–42.5GHz is also being investigated.

Figure 6: 5G and backhaul spectrum



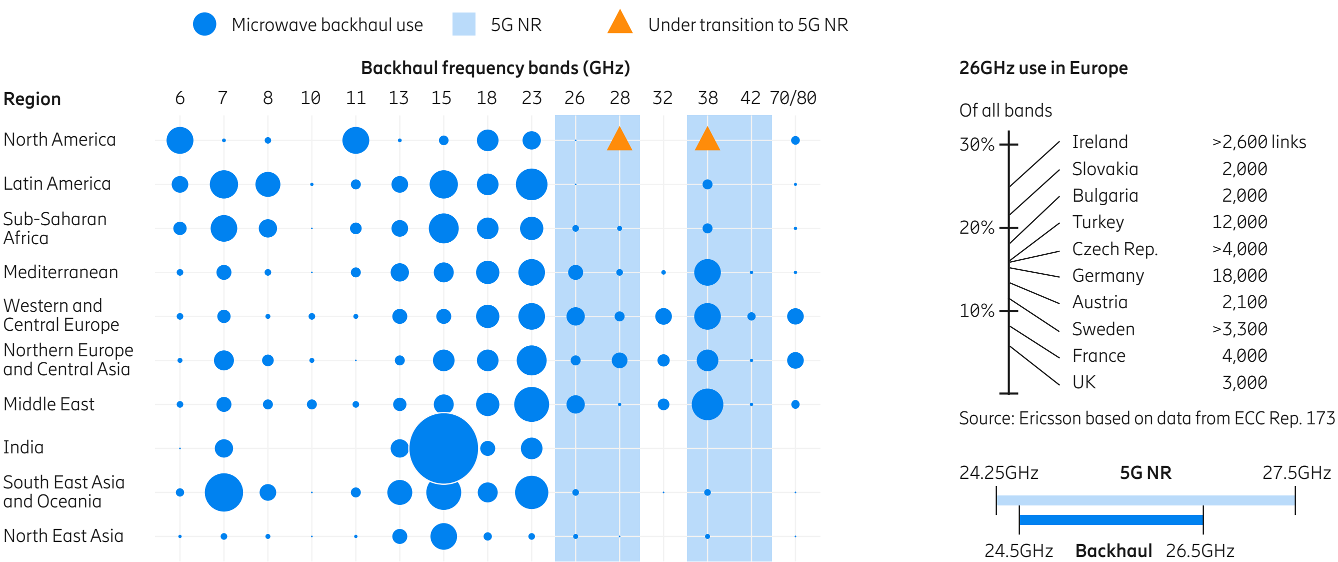
Source: Ericsson (2018)

In Europe, the 26GHz band (24.25–27.5GHz) is the pioneering mmWave 5G NR band. However, it is expected that some countries will release 26.5–27.5GHz first, partly due to the current high usage of microwave backhaul in the 24.5–26.5GHz range (Figure 7). For example, in October 2018 Italy auctioned 26.5–27.5GHz for 5G NR, with 200MHz for each of the operators. The 38GHz band (37-39.5GHz) is heavily used for microwave backhaul in Europe (Figure 7) – which is why Europe is interested in the 42GHz band (40.5–43.5GHz) as a second stage for mmWave 5G NR, and eventually also the 66–71GHz band. Japan is expected to release spectrum in the 27–29.5GHz range for 5G NR in early 2019. China has indicated early interest in the 26GHz band for 5G NR, as well as in the 37–42.5GHz range. 3GPP has specified 5G NR bands in the range 24.25–29.5GHz and 37–40GHz, and work has started on specifications for the 42GHz band.

For backhaul, the use of E-band has grown rapidly over the last couple of years (Figure 7). For example in Poland, about 20 percent of all hops are now in E-band, and in the Czech Republic, it is about 15 percent. Also, the use of 32GHz band has increased in the last few years, for example in Middle East. The E-band (71–76GHz paired with 81–86GHz) is becoming an essential backhaul band of high global alignment. This will facilitate the transition of backhaul from bands now being designated for 5G NR use. In preparation for 5G, transport networks will be upgraded to support higher capacities. Fiber penetration will increase, and the E-band is the widely recognized frequency choice for 5G transport in urban and suburban areas. In preparation for WRC-19, E-band is also being studied for 5G NR access. However, it has only limited support and is preferred for backhauling use.

The 32GHz band (31.8–33.4GHz) is also being studied ahead of the WRC-19 for 5G NR access, but is seen as less suitable. It is now being positioned as an additional microwave backhaul replacement for the transition of the 26GHz and 28GHz bands to 5G NR access use. The band is already used for backhauling in Europe, the Middle East, and Indonesia, and is also planned to be released in Canada. It is a strong candidate to become a global backhaul band.

Figure 7: 5G in former backhaul spectrum – large regional and national differences



Close to 5 million microwave backhaul hops in global use

Source: Ericsson (2018)

Source: Ericsson (2018)

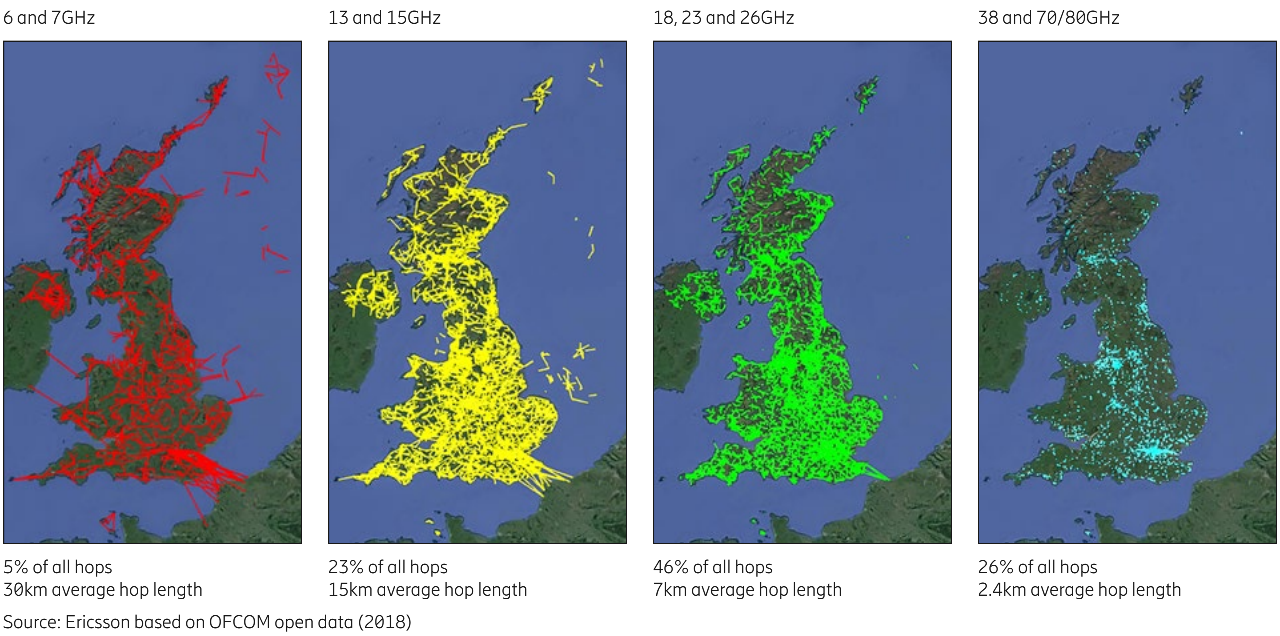
When and how to introduce 5G NR is a national decision, but operators have already now begun to prefer the use of other future-proof frequency bands, at installations of new microwave backhaul equipment. The preparation for mid-band 5G NR is also starting in Europe, with upgrades of transport networks and microwave backhaul. Accordingly, a rapid decline is expected in the use of 26GHz for backhaul, which will simplify and bring forward the transition of the band to 5G NR access use. The strong prioritization of the E-band for backhaul is thus an important prerequisite to prepare transport networks to 5G, as well as facilitate the transition of the 26GHz.

In the longer term, additional spectrum will be needed for backhaul to support throughputs of up to 100Gbps. In preparation for future demands, the specifications of the W-band (92–115GHz) and D-band (130–175GHz) have been finalized in Europe; the Electronic Communications Committee (ECC) has issued recommendations 18(02) and 18(01), and activities have also started in the United States (Figure 6).

Looking at microwave networks from above is not only a magnificent view, it also gives insight into future opportunities for a more efficient use of spectrum (Figure 8). The emerging multi-band booster concept represents a paradigm shift toward a much more efficient use of diverse backhaul spectrum assets. This will unleash the use of E-band to provide transport for 5G in much wider geographical areas currently served using 15, 18 and 23GHz bands for backhaul.

Frequency bands below 10GHz are essential for long-range backhaul. However, these are sparsely deployed, accordingly there is locally unused spectrum (Figure 8). Interest is growing in this spectrum-sharing opportunity, and the possibility to introduce unlicensed and licensed access in parts of the 6GHz band. This opportunity is being studied in both the United States and Europe, with the requirement that it must not cause harmful interference to backhaul use. In addition, 3GPP is also investigating the use of the 6GHz band for 5G NR. It should be noted that there are large variations in the use of 6GHz for backhaul, in different locations, countries and regions. For example, in the United Kingdom about 2 percent of all links are in the 6GHz band, in France about 8 percent and United States about 30 percent.

Figure 8: Example of backhaul spectrum use – United Kingdom



Source: Ericsson based on OFCOM open data (2018)

Integrated Access and Backhaul in 5G NR

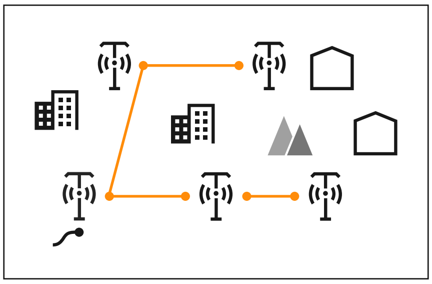
5G New Radio (NR) will bring a new backhaul option known as Integrated Access and Backhaul (IAB), of high interest for the deployment of dense millimeter wave (mmWave), street-level radio nodes.

Historically, self-backhauling has had limited traction, since it consumes spectrum resources that are valuable for radio access. However, with mmWave 5G NR, large bandwidth and native beamforming create an opportunity to use IAB links. This will enable fast, flexible and very dense deployment of mmWave radio access sites at street level, without the need for a denser transport network (see Figure 9).

A study item on IAB is being concluded in 3GPP, followed by a work item in Release 16 that will be finalized at the end of 2019. The backhaul and access may be on the same or different frequency bands, known as in-band and out-of-band. In-band IAB is of higher interest since it could provide backhaul without any additional equipment. However, it is also more challenging and requires tight interworking between access and backhaul to avoid interference, both within the radio nodes as well as across the radio network. The IAB relays enhance access coverage and capacity, as users' devices connected to a nearby relay will experience far less path loss compared to a distant IAB donor (see Figure 10). The IAB link from the donor limits the total throughput of the connected relay nodes. The relay nodes will use a more symmetric downlink (DL) – uplink (UL) Time Division Duplex (TDD) ratio, when compared to typical DL-heavy radio nodes, as much user data is transiting the relay from receive to transmit side. The latency will also increase per IAB hop. The IAB network should be carefully planned to meet the targeted end-user experience at busy hours. Topologies with a limited number of aggregated relay nodes and few hops are expected to be most common.

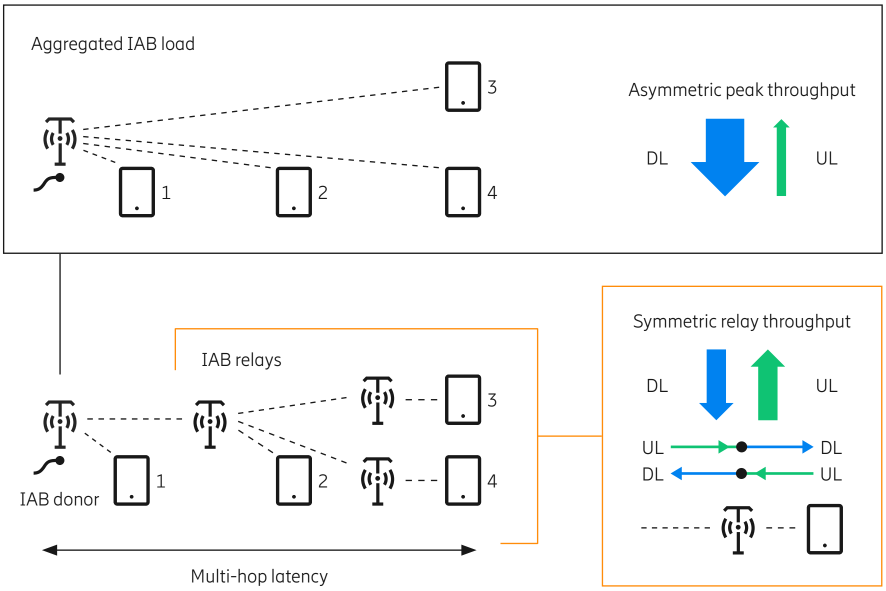
Microwave backhaul and IAB are complementary alternatives to fiber with different advantages and uses. IAB is part of the 5G NR Radio Access Network, with several advantages: automatically established backhaul; no additional equipment needed, when the backhaul direction is within the access sector; and backhaul for limited line-of-sight path, but at a reduced distance. Microwave backhaul also has advantages: high capacity without using valuable access spectrum; a latency less than one-tenth of a single IAB hop; and a hop distance of more than five times that of IAB, with optional higher-gain antennas. Microwave backhaul has been the dominant backhaul media for over two decades, and will remain a very attractive alternative to fiber for traditional macro radio node deployments. IAB is expected to become an equally attractive alternative to fiber for the emerging dense street-level, mmWave 5G NR deployments.

Figure 9: IAB deployment scenario



Source: Ericsson (2018)

Figure 10: IAB characteristics to consider



Source: Ericsson (2018)

How can 10Gbps be reached everywhere?

With the introduction of 5G, the interest in E-band is high, as it can provide up to 10Gbps for even the most extreme dense urban sites. But capacities are constantly growing in all parts of the network, from urban to rural areas. So the next logical question to ask is: How can 10Gbps be reached everywhere?

The 2017 edition of this report discussed how to break the futuristic 100Gbps barrier. In this edition we will study how to reach 10Gbps, not just for shorter distances but everywhere.

The foundation for achieving 10Gbps is starting with sufficient spectrum. Then depending on hop length, climate, availability targets and channel availability, different configurations and frequency bands can be identified. Antenna configuration, capex and opex costs must also be considered.

In Figure 11, three different configurations have been identified for achieving 10Gbps in typical urban, suburban and rural deployment scenarios. Both a mild climate (Stockholm in Sweden, with 27mm/h of rain exceeded for 0.01 percent of the time according to Rec. ITU-R P.530) and a more severe climate (New Delhi in India, with 58mm/h of rain) have been considered. The results correspond well to typical hop lengths deployed in these regions. To enable use of multi-band antennas, each scenario uses the same antenna size in all bands.

In all configurations, a modulation enabling at least 0.5Gbps per channel has been used to reach availability targets, namely 64QAM/112MHz in traditional bands and half BPSK/2000MHz in E-band. The availability target is set to the very strict 99.999 percent in the lowest band (for priority traffic) and 99.9 percent in the highest band (for capacity).

Figure 11: How to reach 10Gbps in urban, suburban and rural deployment scenarios

Frequency band	Antenna: 0.3m Typical deployment: Urban Typical range: <2km, mild climate <1km, severe climate	Antenna: 0.6m Typical deployment: Suburban Typical range: <8km, mild climate <4km, severe climate	Antenna: 0.9m Typical deployment: Rural Typical range: <15km, mild climate <10km, severe climate
Traditional low 6–13GHz			**2Gbps / 99.999%** 1x 224MHz or 2x 112MHz or 4x 56MHz
Traditional mid 15–23GHz		**1Gbps / 99.999%** 1x 112MHz or 2x 56MHz or 4x 28MHz	**4Gbps / 99.99%** 2x 224MHz or 4x 112MHz
Traditional high 26–42GHz			**4Gbps / 99.9%** 2x 224MHz or 4x 112MHz
E–band 70/80GHz	**10Gbps / 99.999%** 1x 2000MHz or 2x 1000MHz	**10Gbps / 99.9%** 1x 2000MHz or 2x 1000MHz	
Capacity total	10Gbps	11Gbps	10Gbps

Source: Ericsson (2018)

Urban deployment
In short-range urban hops, pure E-band and 0.3m antennas can be used. A 2000MHz channel, or 2x 1000MHz, is needed. In a mild climate this gives a range of typically 2km. In more severe climates the distance is typically 1km. For dense urban scenarios where visual appearance is critical, and the required range is shorter, smaller antennas like 0.1m and 0.2m can be used.

Suburban deployment
To stretch range in suburban hops, the E-band needs to be complemented by a 112MHz channel in a traditional mid band as well as using 0.6m antennas. Dual-band antennas combining these frequencies in a single antenna are available in the market today. The range is typically 8km in a mild climate and 4km in a more severe climate. This configuration is often referred to as "multi-band booster".

Rural deployment
In rural scenarios, range needs to be extended even further. E-band is then no longer a practical option. The traditional bands need to be exploited to achieve extended reach. Depending on spectrum availability, channels in two or three bands will be needed. This is combined with the use of 0.9m antennas. A typical range will then be 15km in a mild climate and 10km in a more severe climate. The range can be extended beyond 15km by using antennas larger than 0.9m and/or by considering reduced availability targets. Tri-band antennas are not available in the market today, so for the foreseeable future two or three antennas will be needed for this configuration.

Hardware optimization
All these configurations can be realized with existing single carrier radios. A maximum of four channels in traditional bands are used. A graphical representation of the channels discussed in Figure 11 can be found in Figure 12. The channel widths are drawn to scale to provide an insight into the amount of spectrum needed.

To minimize the amount of hardware and hence capex and opex, the first choice is always to use channels that are as wide as possible. In an increasing number of markets, the important 112MHz channels are available. However, in most markets today a maximum channel width is often 28 or 56MHz, and the only option is to use multiple carriers.

Since changing regulations is a slow process, there is also a market for dual carrier radios (in one or two polarizations) and carrier aggregation radios (in one polarization). But such radios inherently have a higher cost, so this option should only be used when wider channels are not available and when it is highly likely that the second carrier will be enabled from initial installation or in the near future.

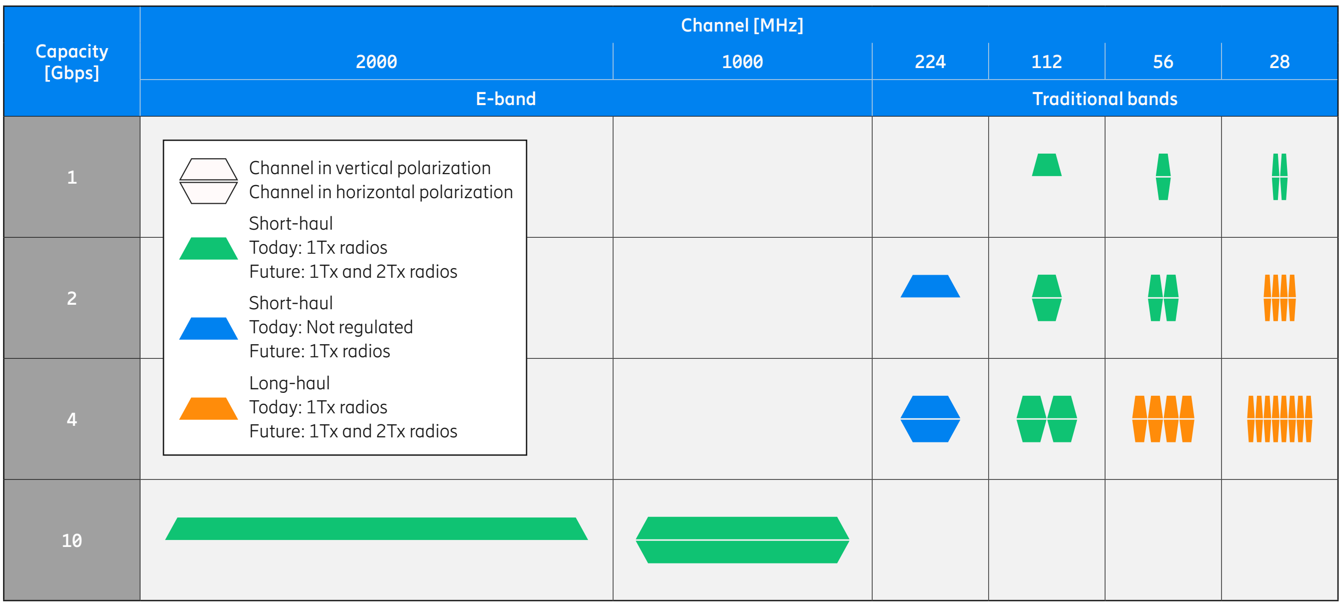
Standardization and spectrum regulation
For urban and suburban scenarios, the main enabler today is the E-band. In the future the wide channels in E-band will be complemented by W-band and D-band.

In traditional bands, 112MHz channels are today only regulated in bands 18–42GHz. It is important that regulatory bodies also start allowing 112MHz channels in 6–15GHz. In addition, there is a need for 224MHz channels in 6–42GHz bands.

It is also crucial to review spectrum fees in traditional bands. The spectrum fee for wide channels in traditional bands can currently be very expensive. With the introduction of even wider channels this could become a major hurdle if the fee calculation model is not changed.

The technology is available to enable 10Gbps everywhere already today, but standardization and spectrum regulation changes are fundamental to create cost-efficient solutions.

Figure 12: Capacity vs. channel width and number of channels, in E-band and traditional bands



Source: Ericsson (2018)

E-band through the eyes of an operator

Ahead of 5G, networks delivering high capacities over longer distances in rural areas will continue to rely on microwave backhaul. A Croatian operator put E-band capacity over longer distances to the test.

Croatia is now a popular holiday destination and each summer, thousands of tourists flock to the Adriatic coastline and its remote archipelagos.

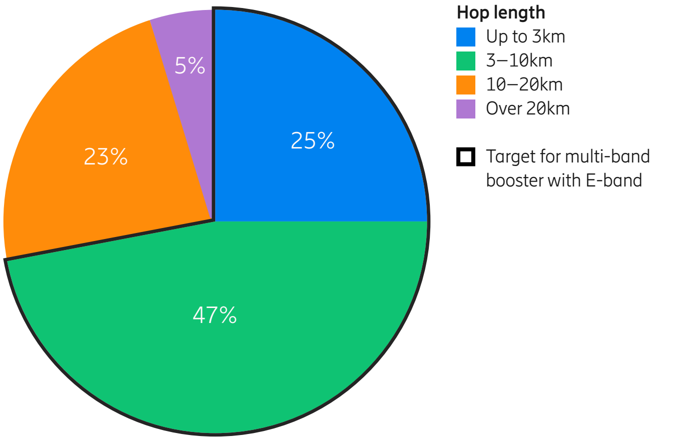
This annual tourist wave sees an increase in mobile traffic volumes, which the backhaul network needs to be able to handle cost-effectively. Operator A1 Hrvatska, part of A1 Telekom Austria Group, has been looking at increasing backhaul capacities across its microwave network using E-band and multi-band.

For link distances of up to 10km and beyond, A1 Hrvatska previously used a bonded multi-channel XPIC configuration. This provided 2.4Gbps capacity, but had multiple disadvantages – including high TCO, complex installation and low scalability due to the limited amount of available spectrum.

Using the E-band link in addition to the existing low-band link solves many of these issues, since E-band provides up to 10Gbps capacity over a single radio frequency with very low licencing fees. A1 Hrvatska has now started to roll out multi-band configurations after careful consideration of how to meet the availability targets for different traffic limits, using E-band together with a lower-frequency band.

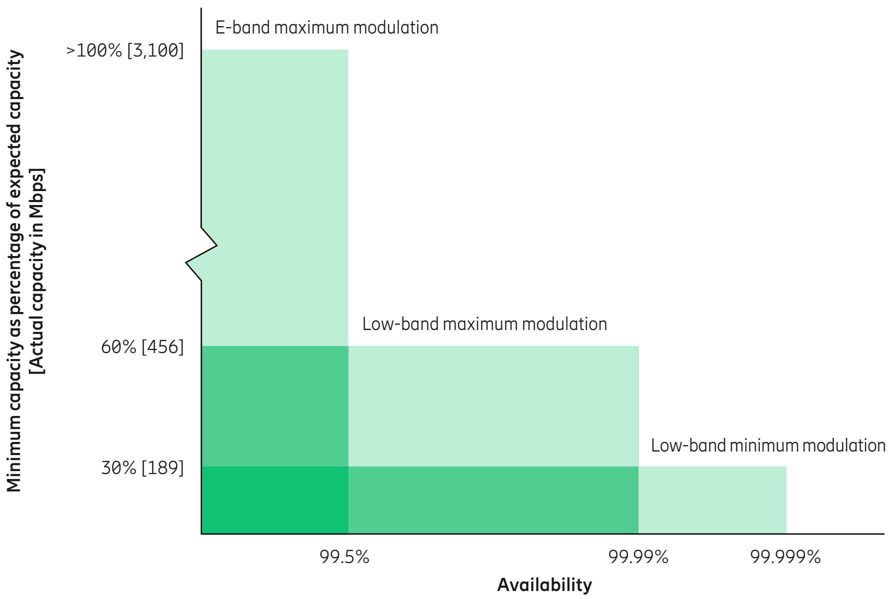
Target capacity rates for these multi-band links were set at 189, 456 and 3100Mbps with availability at 99.999, 99.99 and 99.5 percent respectively. With the low band dimensioned for the two first data rates and the two highest availability figures (according to Figure 14).

Figure 13: Remote hop lengths handled across A1 Hrvatska network



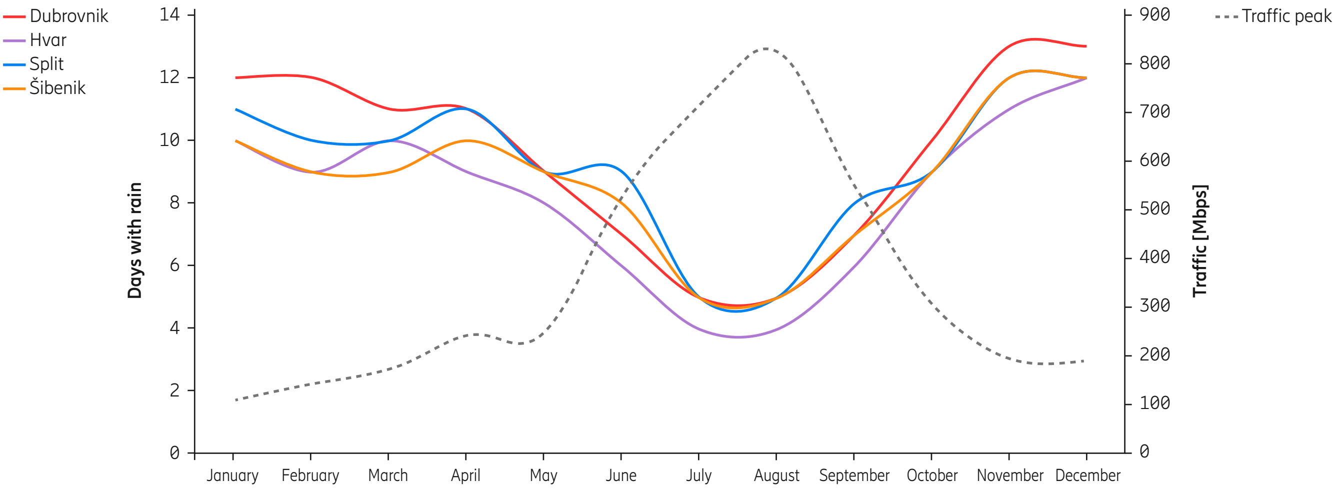
Source: Ericsson and A1 Hrvatska (2018)

Figure 14: A1 Hrvatska capacity planning for E-band and multi-band



Source: Ericsson and A1 Hrvatska (2018)

Figure 15: Yearly A1 Hrvatska network traffic analysis



Source: Ericsson and A1 Hrvatska (2018)

Link distances of 3–10km were specifically targeted for multi-band (according to Figure 13), with multiple links considered for the trial phase. Availability calculations showed that a combination of E-band and traditional 18 and 23GHz bands could be used widely within Croatia while still meeting availability and capacity targets. However, for the early phase of roll-out, seasonal traffic trends and low precipitation zones were taken into consideration, as seen in Figure 15.

As a result, multi-band deployment focused on southern parts of the country, where A1 Hrvatska initially installed a multi-band combination of E-band and 23GHz over a distance of 6.1km. Seeing positive results, the operator made additional implementations, with a 12km link being the longest distance covered using a combination of E-band and 18GHz frequency band.

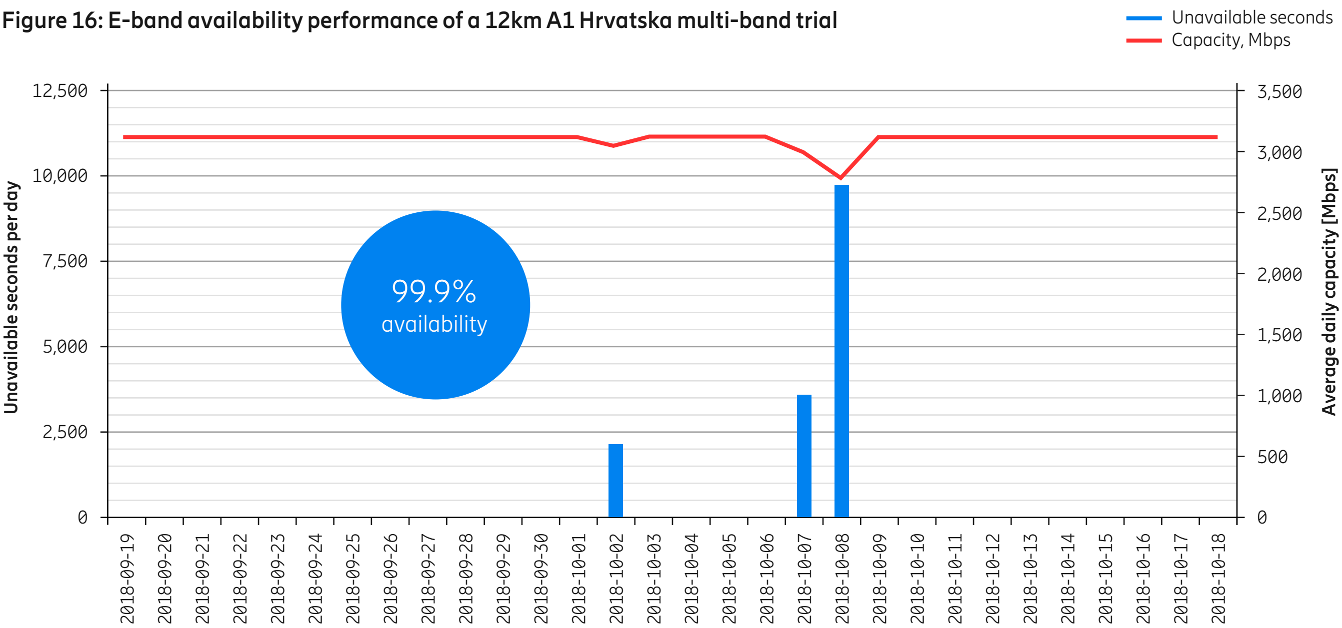
Another 7.7km-long link was installed in the most northern area of Croatia as part of the trial, using E-band in combination with 23GHz.

Analysis of link performance showed positive results with some challenges only for the longest 12km link in meeting the availability criteria as seen in Figure 16. All other multi-band links achieved the performance targets, with the E-band layer ensuring high capacity during the majority of operational time, and the lower band ensuring enough capacity available for service-critical traffic at any given time.

After a successful trial, A1 Hrvatska is now planning for more multi-band deployments for link distances of up to 10km.

The article was written in cooperation with A1 Hrvatska, formerly Vipnet, an operator that is part of the A1 Telekom Austria Group and based in Croatia. A1 Hrvatska provides their customers with a converged offering that includes a combination of mobile and fixed services as well as television. They also offer complete business, security and cloud-based solutions.

Figure 16: E-band availability performance of a 12km A1 Hrvatska multi-band trial

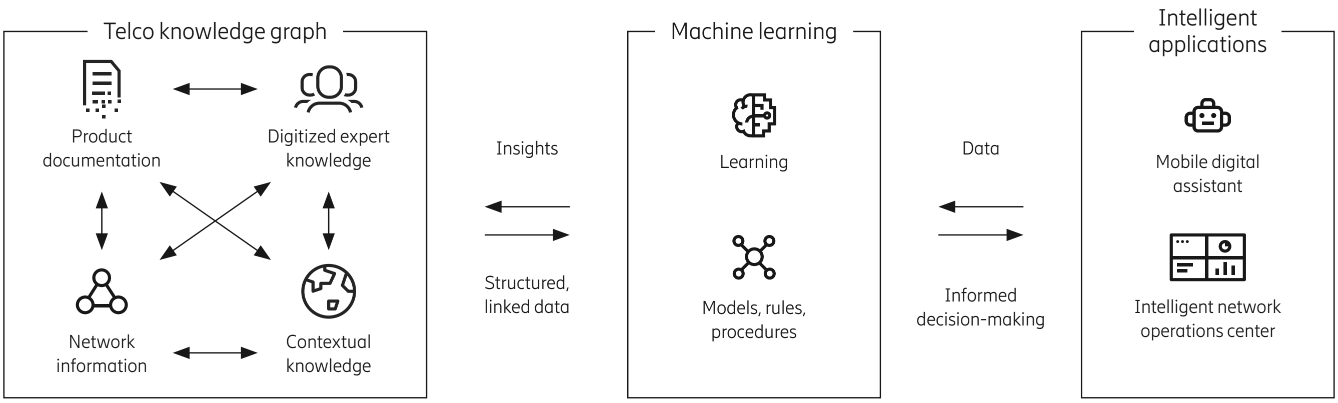


Source: Ericsson and A1 Hrvatska (2018)

How machine intelligence is helping to manage networks

Artificial intelligence (AI) has evolved from systems mimicking human behavior to systems leveraging human expertise. Tools and techniques are finding their way into all parts of society, with applications even helping to manage microwave networks.

Figure 17: The role of structured knowledge in enabling machine intelligence and intelligent applications



Source: Ericsson Mobility Report (2018)

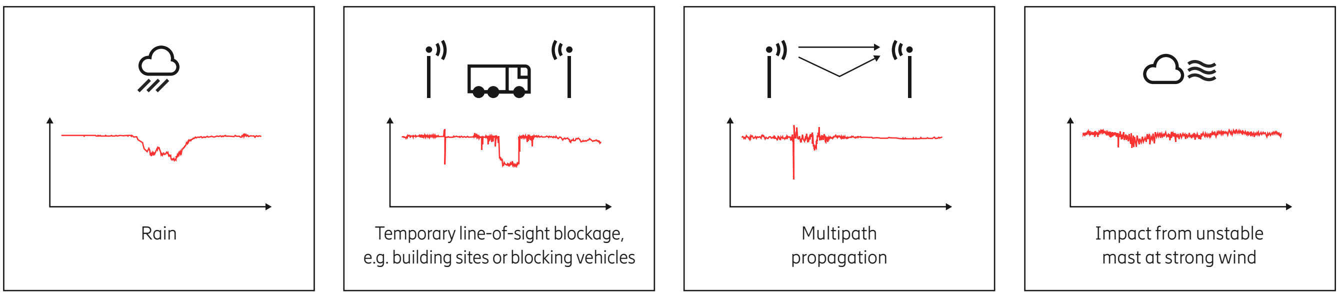
Based on structured digitized data, such as product documentation, network information, expert knowledge and contextual knowledge, machine learning software can build models, rules and procedures (Figure 17). Adding AI techniques such as reasoning and planning to machine learning enables the creation of intelligent applications we refer to as machine intelligence (MI).

Currently, challenges in the microwave networks are met by domain experts at the network operations center (NOC). They are required to make fast and intelligent decisions based on alarm, configuration and performance data in networks that may cover thousands of sites over vast geographical areas.

MI applications need to support the technicians in this decision-making process. They can be used as stand-alone applications or as enhancements of SDN solutions, as discussed in the 2017 Ericsson Microwave Outlook Report. We examined an MI tool that identifies signal fading events in real-time. The process can distinguish between normal events caused by rain and multi-path propagation, and abnormal events caused by a line-of-sight blockage or unstable antennas. The input dataset is signal strength versus time, as illustrated in Figure 18, and the machine learning software is based on a convolutional neural network architecture.

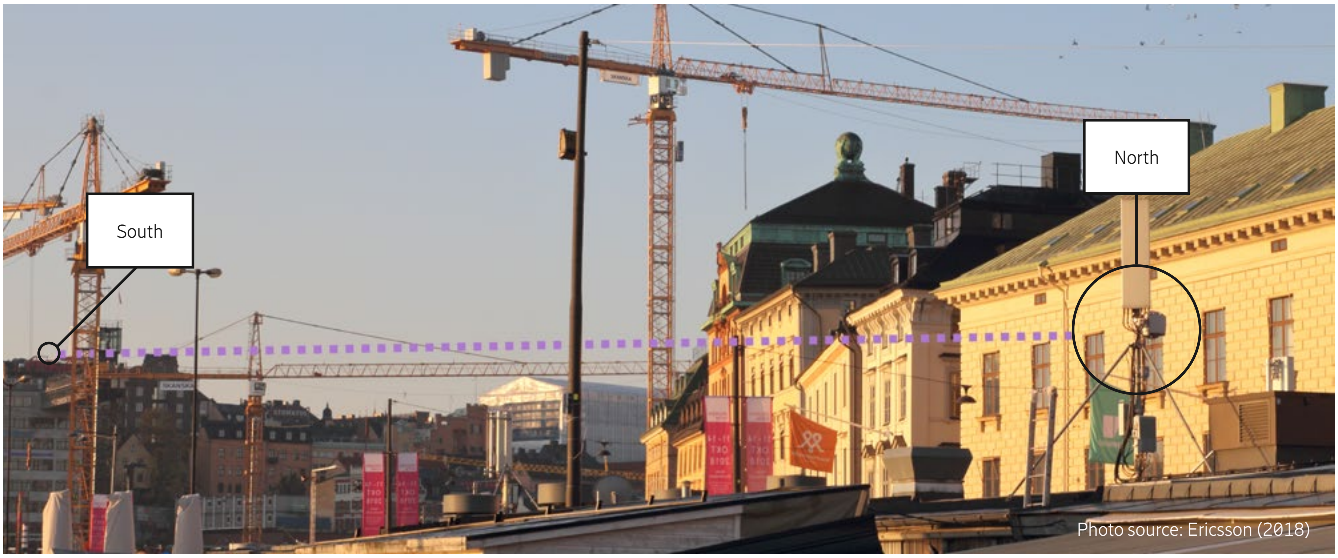
> MI is used to leverage the skills of microwave planners and engineers.

Figure 18: Signal fade events in microwave networks



Source: Ericsson (2018)

Figure 19: Microwave link in construction site in Stockholm, Sweden



> An intelligent NOC supports engineers with MI for root cause analysis, datamining, interpretation of patterns in large datasets and proposed network optimizations.

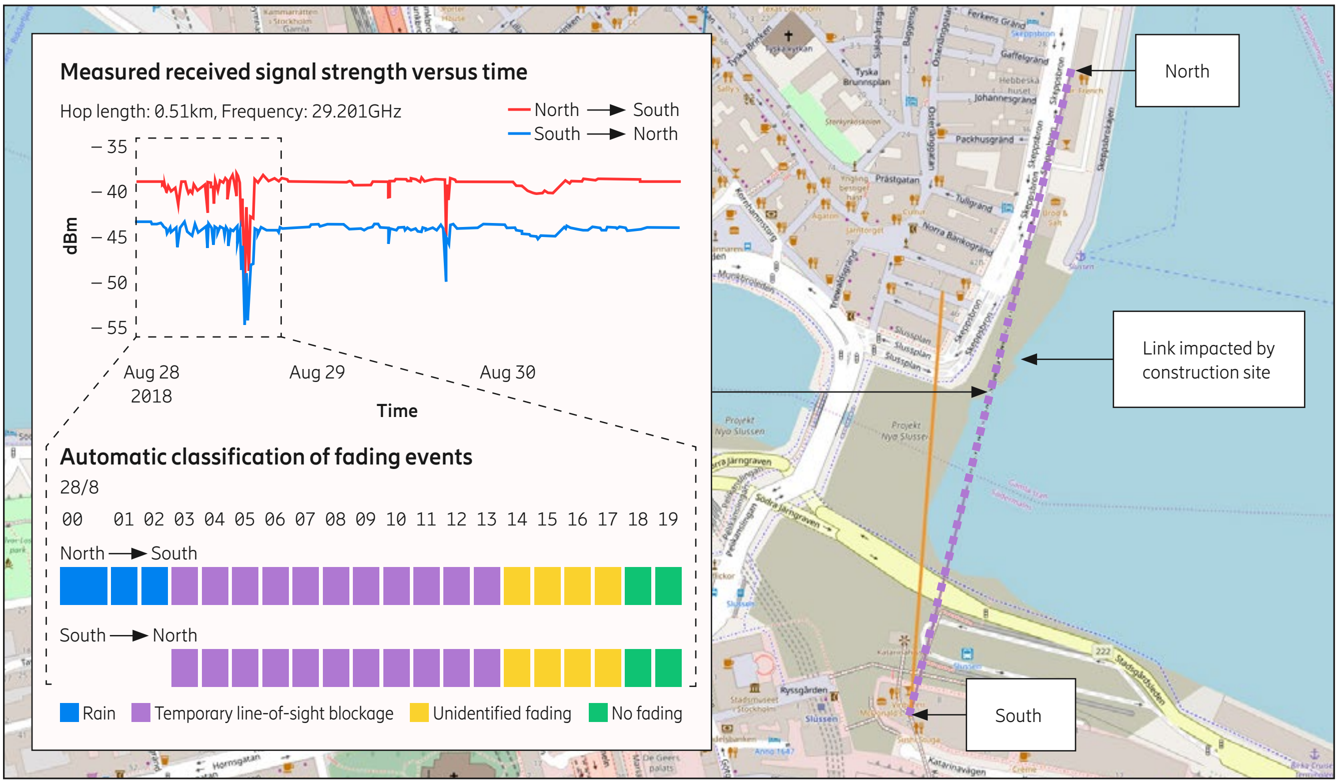
Figures 19 and 20 show a live example that demonstrates the technique. The microwave link is located in Stockholm, next to a large construction site, and is part of a nationwide network. The inset shows received signal strength in both directions over three days, and identified events during the first 19 hours of August 28. The hours marked in purple indicate hours in which the signal faded due to the use of construction cranes at the site. The offset in received signal strength between the two directions is due to different output power signal settings.

The tool can be used to reduce load at the NOC (e.g. by de-prioritizing alarms prompted by natural causes such as rain) and provide root cause insights (e.g. "This link has a lot of events indicating it is mounted on an unstable mast – consider stabilizing it to improve performance") to the technicians in the NOC.

MI has taken significant steps over the last decade. It offers techniques that leverage the expertise of microwave planners and engineers, allowing for management of larger, more complex and efficient microwave networks.

> MI is allowing systems to expand in size and complexity while improving productivity.

Figure 20: Automatic detection of temporary line-of-sight blocking from construction site



Source: Ericsson (2018)

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