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WORLDWIDE ANALYSIS AND PROPOSALS TO PROMOTE AND FACILITATE THE WIRELESS TRANSPORT NETWORK AS THE KEY ENABLER FOR FAST MOBILE BACKHAUL NETWORK MODERNIZATION

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Executive Summary

As countless studies have confirmed, the availability of services enabled by the fourth and fifth generation radio systems (4G/5G) lead to immense socio-economic benefits.

All sectors of the economy, from manufacturing to finance, agriculture etc., benefit or will benefit from the provision of services enabled by 4G/5G networks.

From: Policy options for broadband infrastructure strategies: A simulation model for affordable universal broadband in Africa [1]:

> *Broadband has long been recognized as critical for helping to deliver the Sustainable Development Goals (SDGs) and enable digitally-led development. Indeed, governments are increasingly treating broadband infrastructure on par with energy or water access, given its importance for economic development …. Even basic broadband transforms the opportunities available to citizens. …… empirical evidence for Internet deployment in Africa suggests the probability that an individual is employed substantially increases by approximately 7–13 % when broadband connectivity becomes available… . The results suggest that 'leapfrogging' to 4G is more cost efficient than 3G for providing universal broadband,*

One of the key points to fully enable these benefits will be the provision of these services to a large part of the population and this will only be possible thanks to a high penetration of the data transport network.

The key brick of a data transport network is optical fiber, which however, as widely demonstrated in the past and as recent studies have shown, needs to be complemented by radio systems, known as wireless backhauling systems (WBH).

It is widely recognized that the availability of WBH solutions makes the completion of the mobile transport network infrastructure simpler, cheaper and faster, an essential condition for benefiting fully and timely from the socio-economic benefits deriving from it.

In this document, we investigate the reasons that, in some parts of the world, prevent or make WBH solutions inadequate to support the new generation 4/5G networks, thus identifying the guidelines that should be followed to ensure that the WBH solution is a valid complement to the fiber in the mobile transport network, especially in suburban/rural areas.

In particular, we will show here:

- That the WBH solution can fulfill the requirements of 4/5G and beyond mobile transport network, when suitable frequency spectrum portions are made available
- The results of a study that correlates the level of modernization of the mobile transport network, using as KPI the penetration of the 4/5G market, and the level of the WBH's spectrum license fees, normalized to the local country ARPU.

Motivation

This document is primarily aimed at national administrations / regulators and in particular at people who deal with the management of the radio spectrum within them.

One of the key elements, unknown to many, which enables a smart implementation of a modern mobile transport network is the wireless solution, commonly called Wireless Back/Front-Haul (WBH).

WBH efficiently and effectively complements the optical fiber in the implementation of the mobile transport network, allowing to reach the necessary level of penetration, thus making the offered new services available to a wider audience of users.

The opportunity to adopt a WBH solution makes the completion of the mobile transport network infrastructure simpler, less expensive and faster, an essential condition for fully benefiting from the deriving socio-economic benefits.

Observing the limited use of WBH in some countries, we decided to investigate the reasons for this lack of use and, in parallel the state of the mobile transport network.

Substantially we discovered that WBH is underused where:

- The unavailability of suitable frequency spectrum resources, necessary for a WBH solution to adequately meet the new network requirements, mainly in terms of transported capacity, prevents any WBH deployment

and/or

- The cost of the license (WBH Spectrum fees) due for the use of the spectrum is too high, making the WBH a not viable solution or not appealing for MNOs that prefer to wait for investing.

This work aims to disseminate what are the necessary frequency spectrum resources to enable the WBH solutions to support the 5G and beyond network.

And regarding the cost of the licenses, it is here reported the results of a study which relates the level of the spectrum cost normalized by the country ARPU and the level of penetration of the 4/5G network, assumed it as a KPI of the transport network modernization. This study demonstrates that there is a strong correlation between the levels of network modernization and the level of the normalized frequency spectrum cost, reaching the conclusion that having a too high normalized spectrum cost is a barrier to WBH adoption.

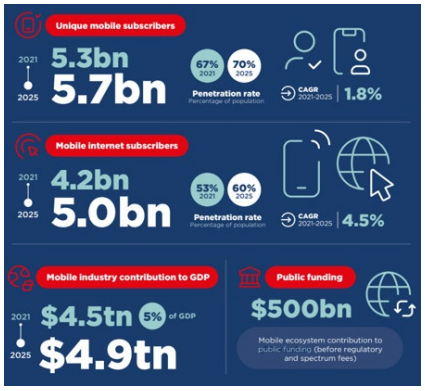
A reasonable level of normalized spectrum cost, making the WBH a viable option for MNOs to complement fiber, has been here identified/suggested.

Two best practices are reported as reference.

5G Impacts on Economy

The figures in this chapter, taken from a recent study by the GSMA [2], show the main expected results of what is referred to as the 5G mobile Economy.

The clear message here is that 5G is a pillar of digital transformation impacting communities and economies, bringing huge social and economic benefit to all the humanity activity sectors.



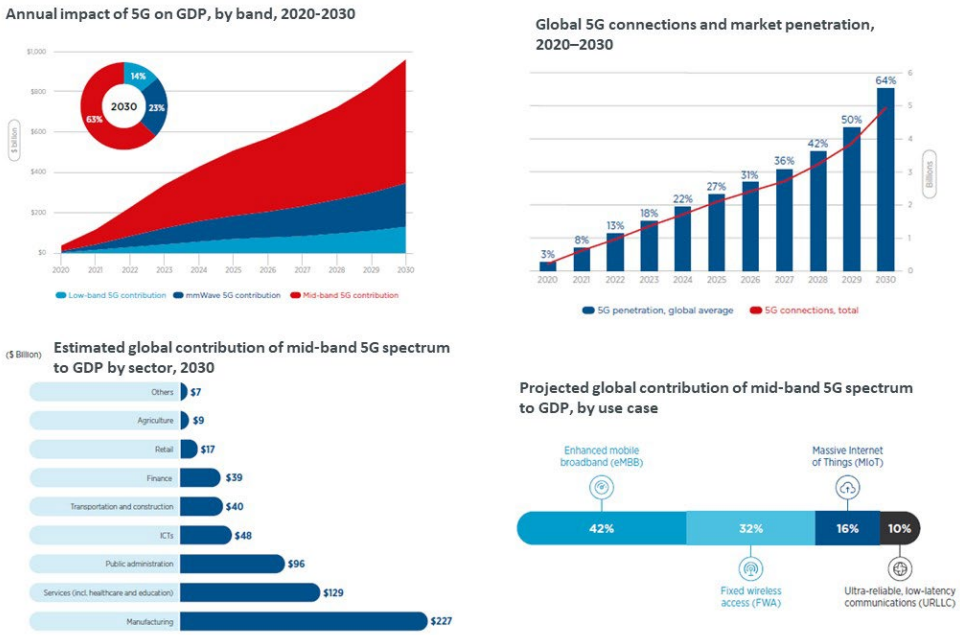
The Mobile Economy

In 2021, as 5G delivers transformational services, it generated 5% of global Gross Domestic Product (GDP), a contribution of $4.5Trillion of economic added value.

It is expected that in 2025 it will generate around $4.9Trilion and it will approach, in 2030, around 10Trilion $ of economic added in value Worldwide.

The mobile ecosystem supported ~ 26 million jobs (directly and indirectly) enabling a contribution to the funding of the public sector, with almost $500bn through taxes (excluding spectrum fees).

Going a bit more in details, the following set of pictures shows the projected global annual impact of 5G on GDP in the period 2020-2030, the expected market penetration in the same period, the impact among plenty of different sectors of the economy and the breakdown by use cases.

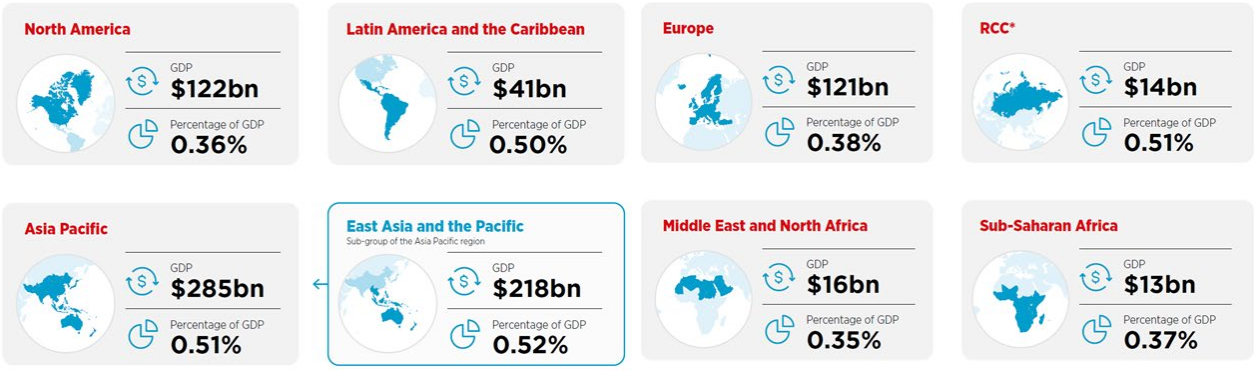


5G Impacts on Economy

The most impacted sectors are Manufacturing, services, public administrations and almost at the same level, ICTs, transportation and construction and Finance.

Of particular interest is the GDP contribution generated by 5G (mid-band only) at the regional level in 2023, summarised in the following picture.

Regional overview in 2023: GDP contribution generated by 5G



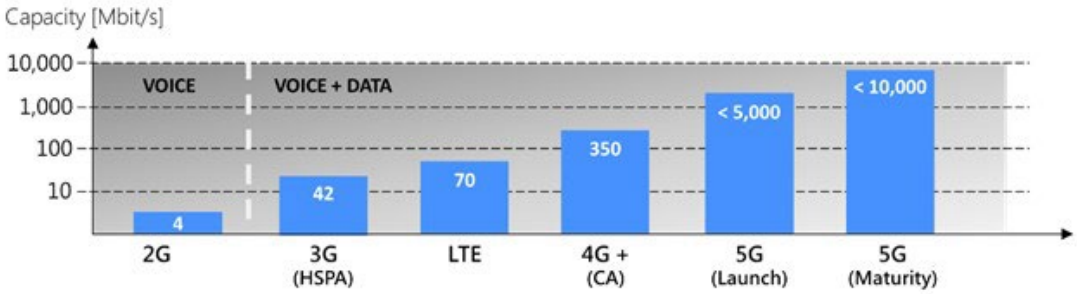
All these benefits will not happen for free but will require investments especially in the mobile transport network infrastructures.

Wireless Backhaul

The WBH is an important technology in the process of modernizing the transport data networks and in particular for the mobile transport network towards 4G, 5G and beyond.

4G and 5G networks require more and more capacity, as shown in the following figure and this implies that the mobile transport networks will have to be suitably dimensioned to support this massive demand as well. More details about Backhaul capacity can be found here [3][4].

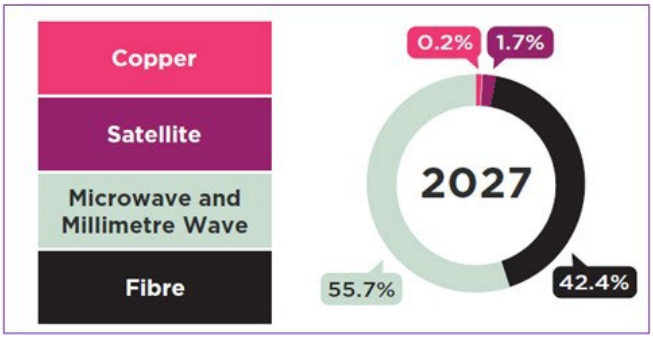
Backhaul capacity growth along RAN technology generations



The role that a radio solution plays in the implementation of mobile transport networks is surprising to non-experts in the sector who are inclined to think that optical fiber is essentially the only building block needed.

As we can see from the following figure of the GSMA [4], and as confirmed by other independent studies, the use of radio solutions is and will be fundamental for mobile transport networks implementation. It has been predicted that by 2027, more than 55% of mobile transport networks connections will be by radio using microwave and millimeter frequencies, substantially a stable percentage with respect to today's situation.

Breakdown of Mobile Transport Network connections by Technologies

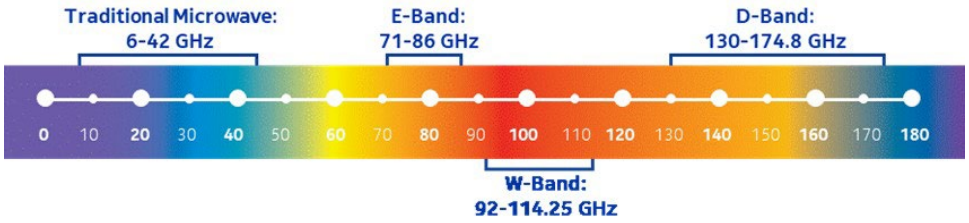


This data explains very well the vital role of Wireless Backhaul in covering all those cases cannot be implemented using fiber because not available, not convenient or for any other reasons.

To cope with that, the Wireless backhaul need a significant and affordable amount of spectrum, that must be made available. And this will only be possible with the right regulatory decisions.

The picture here after shows the frequency spectrum, that is the main asset for a radio solution, currently used or foreseen to be used by WBH. It includes the traditional frequency bands, usually identified as "Traditional" Microwave, ranging from 6 to 42 GHz, the E-Band covering the portion 71-76 GHz and 81-86 GHz. The last two portions are the new bands WBH are looking for a future application like 5G and beyond, the W-Band covering the portion 92-114.25GHz [6] and D-Band 130-174.8GHz [6].

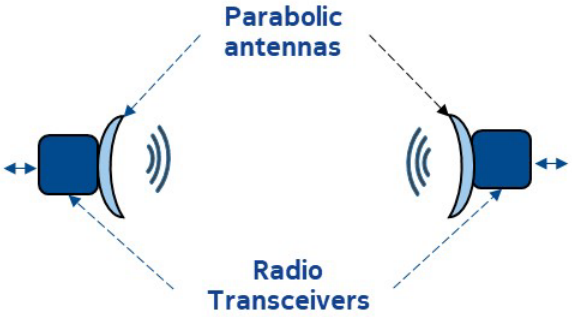
Frequency Spectrum for WBH



Wireless Backhaul – What WBH is in a snapshot

Wireless Backhaul is today mainly implemented using a point-to-point connection between two parabolic antennas. The main asset WBH needs is the availability of different frequency bands to be used to address different connection scenarios.

Point-to-point Wireless Backhaul



For a Point-to-point interconnection, the main parameters to be considered are:

- The distance
- The throughput and latency
- The country regulation (availability of a given spectrum resources)

- The propagation in the region, mainly due to rain.

The main usage of Point-to-Point wireless system is usually identified into three main cases:

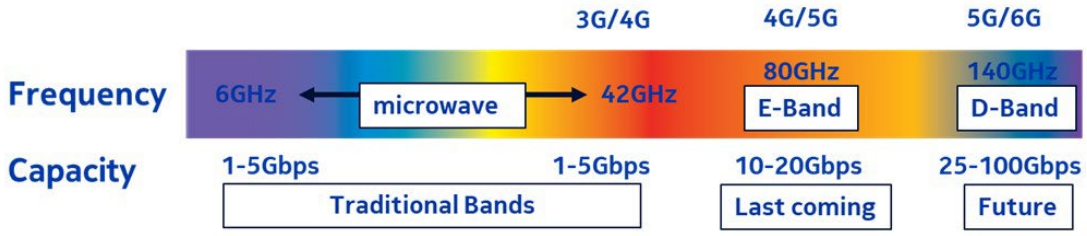
- Radio Access Network (RAN) – Wireless backhauls and Fronthaul for public and private Mobile network
- Enterprise – For mission critical networks, Government, Transport and Mining
- Long Distance – Considers the High-capacity backbones, rural sites and difficult fiber connectivity

The shift from the traditional frequency bands toward higher frequency bands has been dictated by the need to transport more capacity, as required by the network evolution. This is possible because the basic channel size of higher frequency bands is larger, allowing to transport more capacity.

The trend to go up in frequency is still ongoing, and to support 5G advanced and beyond requirements the D-Band (130-174.8GHz) has been already considered by many studies and trials links for the WBH [8].

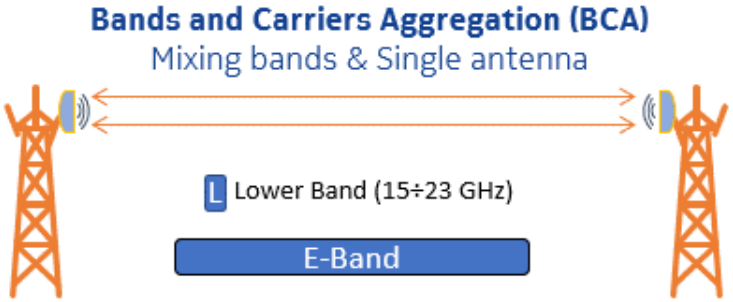
The picture here below represents well this trend, where the last coming frequency band, the E-Band, was introduced to transport capacity in the order of multigigabit/s some years ago.

Relation among Frequency Spectrum, capacity, and system evolution



Evolution of WBH toward more capacity, includes the introduction of technique like the Cross polar canceller, alias XPIC, that allow to use the same channel two times, doubling the spectral efficiency and recently the Band and Carriers aggregation (BCA) [8], allowing to extend the reach of high-capacity link, exploiting the complementary performances of traditional bands link and E-Band link.

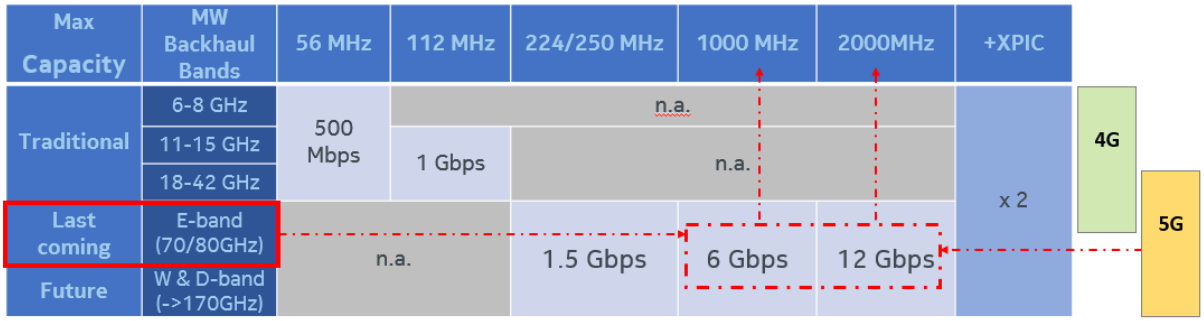
Band and Carriers Aggregation



Overview of current wireless backhaul needs vs 4G & 5G and beyond

Scope of the following picture is to summarize which frequency bands and channel size need to be available for implementing a WBH solution tailored for 4G and 5G and beyond network.

4G and 5G requirements vs Spectrum bands and channel size



Substantially we can see that channel size up to 112MHz (and rarely up to 224MHz today) are available in the traditional band, allowing to transport capacity, with a single channel up to 1Gbps and up to 2Gbpsusing XPIC.

The introduction of E-Band, characterized by having a channel size of 250MHz and multiple up to 2GHz, has enabled the possibility to transport up to 12/13Gbps with a single channel that becomes 25Gbps when XPIC is considered.

Considering that the requirement for the 4G network is for up to some Gbps and for the 5G network up to 10Gbps and more, and considering that the frequency spectrum is a scarce resource, we can conclude that:

- **E-Band is the key band and the baseline for any backhaul network post 4G** because having wide channels makes it possible to transport capacities in the order of Gbps
- **Bands and Carrier Aggregation (BCA**) that include **E-Band combined with one traditional band** (same antenna) mainly, is mandatory to have when large distances are concerned
- Techniques allowing to reuse of the same channel, like XPIC and LoS MIMO that is doubling the capacity need to be incentivized (more spectral efficiency)

4/5G and beyond system requires, just today, wireless backhaul solutions based on large channels in E-band and traditional bands. In particular:

- Availability of larger channels, 56-224MHz, in Traditional bands
- Availability of E-band spectrum, today
- W-band and D-band in the near future
- The E-band, D-band, and W-band with channel sizes of up to 2 GHz

Market Penetration vs Normalized Fees

In this chapter we present a study that takes into consideration the market penetration of 2&3G and 4&5G technologies country by country. The market penetration is defined as the percentage of the share of the total market population. The data used here is referred to 2021 and was taken from GSMA Intelligence [10].

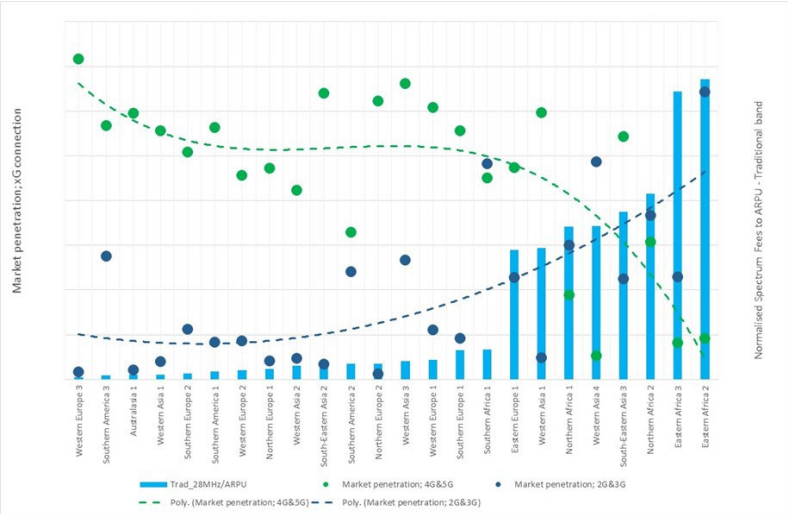
Considering that the advent of new technologies, 4/5G, should in principle make the old technologies, 2/3G, somehow obsolete, and considering that switching off the old technologies makes it possible to free up some frequencies that can be reused to facilitate the installation of the new technologies, it seemed reasonable to define the level of modernization of a network, considering two KPIs,

- The level of market penetration of 4/5G
- The level of 2/3G switch off.

Substantially, we are saying that the level of modernization of a network is r proportional to the 4G/5G penetration and the 2G/3G switch off level.

Based on data available on the web, we considered, as a single reference value for the traditional bands, the cost of an annual license (Fees) for a 28MHz channel at 18GHz for all countries where this data was available. We have then defined a normalized level of fees (NF), dividing the value of the fees by the monthly ARPU of the relevant country considered. In this way we have obtained a parameter that is independent of the local currency and independent of the exchange rate, with the further advantage of representing well, from the point of view of an MNO, an index of expenditure for a product (spectrum), correlated in some way to the expected income/benefit.

Market penetration vs Normalized Fees for different countries worldwide



Therefore, considering the list of these NFs we have drawn a graph that correlates the NF and the penetration of the 2&3G and 4&5G market. The countries were sorted by increasing level of traditional bands NF.

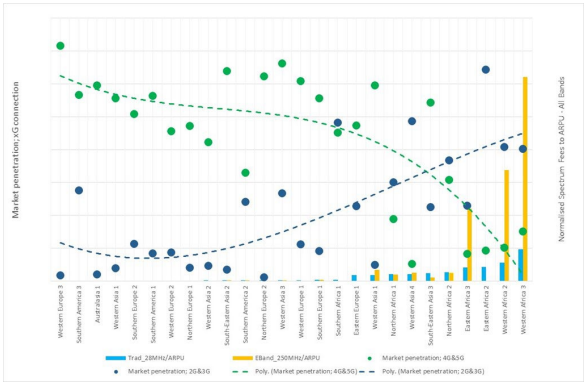
The blue bar reports the NF for traditional bands, the dark blue dots indicate the level of 2/3G market penetration while the green dots the 4/5G market penetration. The two additional dashed lines represent the two market penetration cases interpolated with a polynomial.

We can observe that all the cases on the left, representing countries with a low level of NF, have a high level of network modernization, with high levels of 4/5G penetration and now low levels of 2/3G market penetration.

To complete the analysis, we also considered a reference value of NF for the E-Band case, considering its annual fees for a 250MHz channel. The graph below reports the same data above adding the E-Band NF with the yellow bar.

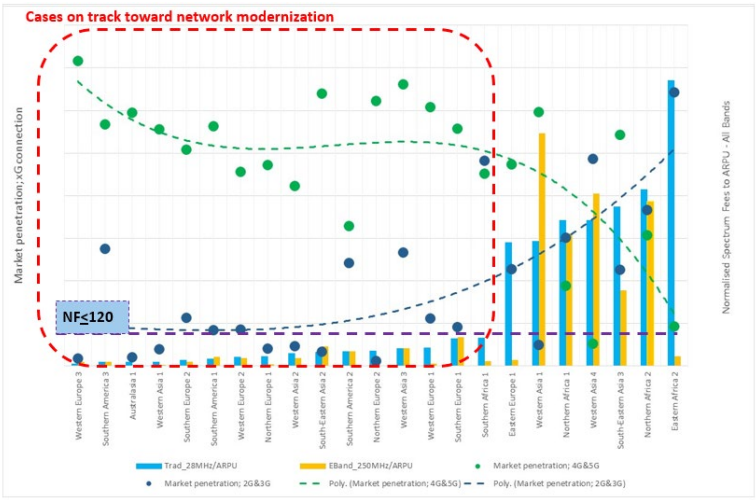
Looking at it, excluding rare cases, the countries sorted based on traditional NF remain substantially unchanged when considering E-Band cases as well.

Market penetration vs Normalized Fees including E-Band



To make the graph more readable, we removed the three cases on the right which are clearly out of scale due to an excessively high value of E-Band NF.

Market penetration vs Normalized Fees with suggested NF level

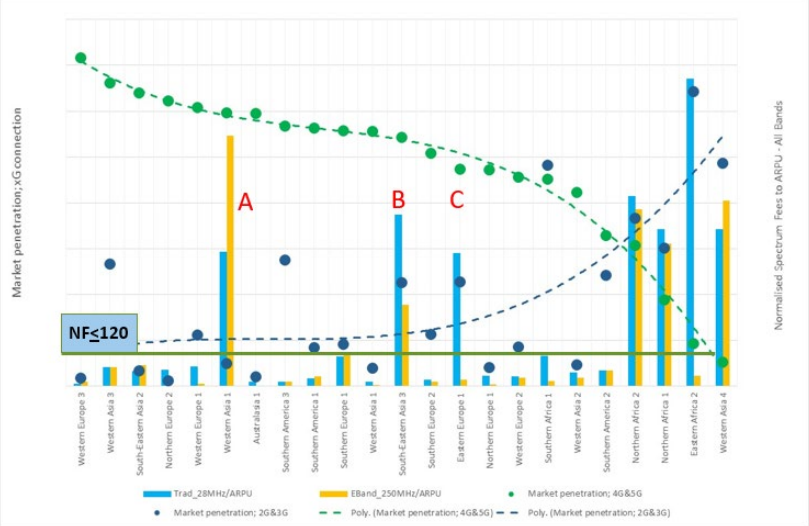


The new graph confirms the very good tendency in many of the case on track to modernize the network, those included in the red box, to apply the following rules, that we recommend:

- **Normalised Fees levels below 120 (NF<120)**
- **Similar fee level for the two reference cases**: **E-Band/250MHz & Traditional bands/28MHz.**

To investigate further, we thought, using the same data, to sort the countries not according to the NFs, but by decreasing values of the level of penetration of the 4/5G market.

Market penetration vs Normalized Fees sorted by 4/5G penetration



The results obtained show that except for three exceptions, A-B-C, it is confirmed the strong correlation between fair/low normalised fees (NF<120) and a high level of 4/5G penetration.

According to the info we have, in all the three cases, the local governments are pursuing a fiber incentive policy, disregarding the WBH option.

Case A: Government's heavy investment in favouring fibre facing now a difficult and onerous step to complete the 4/5G penetration

Case B-C: Despite the governments' heavy investment in favouring fibre, 4/5G penetration is not excellent and 2/3G is holding out.

Best Practices

Two best practices are here provided as possible guidance

These two cases recently changed the fees policy in such a way as to encourage, enable and favor the use of the WBH, by opening a fast and sustainable transport network modernization

They represent a good example of managing the spectrum for WBH, adapting it to the new challenges due to 5G introduction (allowing wider channel and E-Band) and incentivizing the spectral efficiency as well (e.g.: incentivizing the XPIC)

The reader interested in going further into detail concerning how spectrum policing can facilitate the use of WBH solution can find some studies and material here [10] .

KSA - E-Band opening incentivized 5G Roll-out

Here it is reported how the frequency policing has been changed in KSA to facilitate network modernization.

In the picture it is reported the old formula that was used to define the fees level in the past.

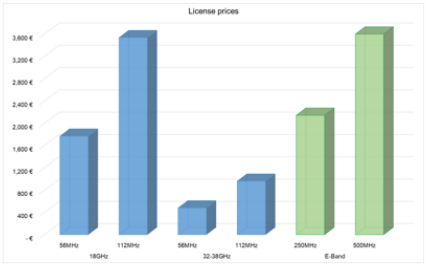
The old formula was clearly not tailored for a Point-to-point link ending up with very high Fees level.

KSA: Old formula for Fees and some cases

Spectrum Fee= 0.1xB x H x M x P x W x L x G Saudi Riyals

Parameter	*Definition*
B	The bandwidth factor
H	The antenna height factor
M	The mobile or non-directional antenna factor
P	The power factor
W	Spectrum demand density factor
L	The high-usage-cities factor
G	Geographical coverage factor

1SAR=0.25€



After a massive E-Band and BCA deployment in 2019-2021 granted to improve 5G coverage by 74%, it was recognized the WBH decisive role in the modernization of their network and decided to revise their fees policing to incentivize its use.

The new formula is now considering:

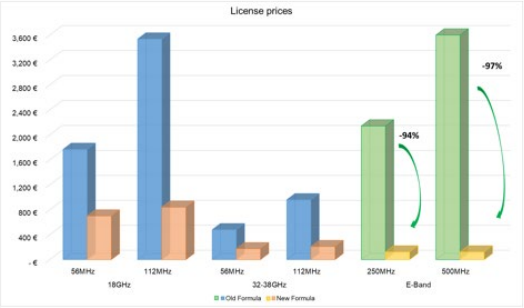
- Band Factor F decreasing when Frequency band Increase
- A factor (E) that should be set from 0 to 1 according to the special technique to increase efficiency of use of the spectrum
- About 60% decrease for 56MHz CS and >75% for 112MHz CS

- More than 90% cost reduction on E-Band.

KSA: New formula for Fees and Comparison between old and new Fees

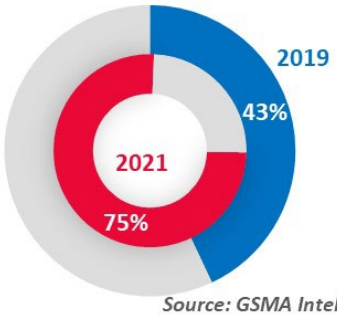
Spectrum Fee= C x B x F x S x E Saudi Riyals

- (C): A fixed value that represents the minimum costs of frequency spectrum management and is equal to (200).
- (B): The bandwidth factor; the value of this factor is equal to the sum of the transmitter frequency bandwidth in MHz.
- (F): The frequency band factor.
- (S): The Frequency spectrum service factor.
- (E): The Frequency spectrum efficiency factor; the value of this factor in normal cases is (1). CITC has the right to set other values for this factor in some cases according to what CITC perceives to be encouraging for the optimal use of the frequency spectrum.



This is the evolution of the 5G network situation in Saudi in the period 2019-2021

5G Coverage as a percentage of total Population 2019-2021



Source: GSMA Intelligence

Italy – New License Scheme Incentivize Frequency reuse

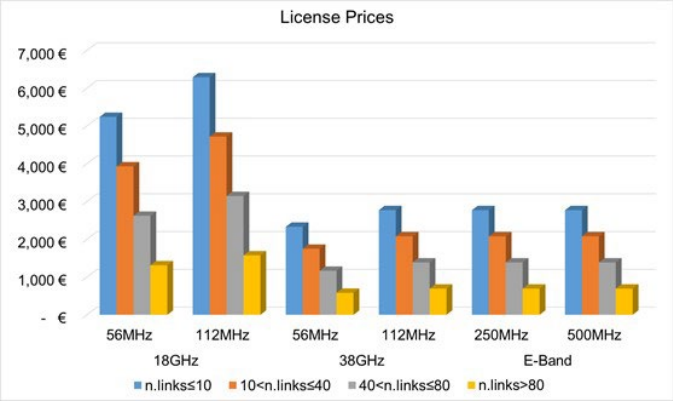
Some years ago, the Italian administration revised its license cost for Fixed service.

The old Fees level were based on the following assumptions:

- Discount based on the number of links deployed
- In the case of XPIC the fees were due twice
- Flat fees level for any frequency above 30GHz and for any channel size greater than 56MHz. This implied that flat fees were applied for channel size greater than 56 MHz channel above 30GHz. E.g.: One 112MHz channel @38GHz was charged as one 250 MHZ or greater up to 2000GHz channel @E-Band.

The following picture provide a view of the old absolute fee level for some cases.

Italy: Old License price



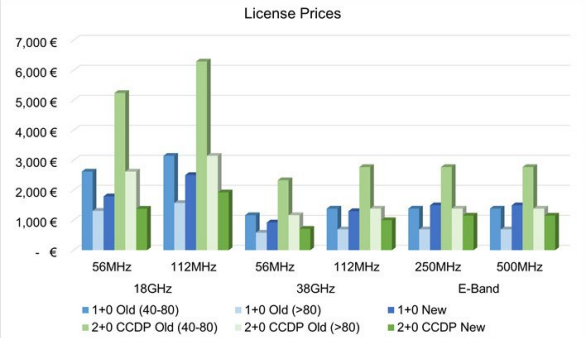
After a revision, a new Fee level has been defined with a clear scope to consider the peculiarities of the higher bands, mainly E-Band, and to favoring the efficient use of the spectrum.

The main new points are:

- No longer discount based on number of links deployed. Incentive to reuse as much as possible the spectrum.
- Fees are considering the XPIC as the “standard” condition to be adopted. If XPIC is not used, a +30% is due.
- Tailored E-Band fees level considering, from now on, the proper channel size as a factor.
- Fees are mainly based on connectivity and not linearly scale with channel size (e.g.: from 56MHz to 112MHz fees are increased by 22%)

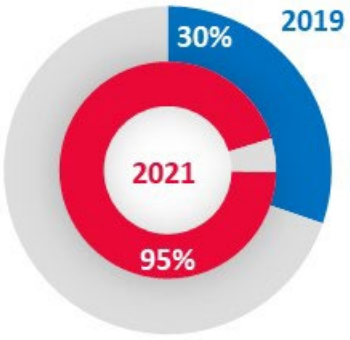
The following picture provide a comparison between the and new situation for some cases.

Italy: Comparison between old and new FEES level regime.



This is the evolution of the 5G network situation in Italy in the period 2019-2021.

5G Coverage as percentage of total Italian Population



Source: GSMA Intelligence

Conclusion/Takes aways

Quickly modernizing the mobile transport network aiming for 5G deployment and preparing the future 6G, brings substantial socio-economic benefits to the whole population.

One of the key elements that allow this to happen is the effective availability of the WBH solution for complementing fiber infrastructure.

The studies here presented shows that the effective availability of WBH solution is strictly correlated to the availability of the suited frequency spectrum and to a fair level of the fees to be paid for it.

In the end, it is proposed a reference level for the ARPU normalized fees to be considered for the cases of 28MHz channel in traditional bands and 250MHz channel in E-Band. For different channel sizes, fees should be based on connectivity and not be linearly scaled with channel size.

Reference

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