Spectrum for Wireless Backhaul

GSMA Public Policy Position

February 2021

Executive Summary

The evolution of advanced 4G networks and the emergence of 5G pose significant challenges to mobile backhaul – the connection between base stations and the mobile core. While 4G and 5G access networks gain more attention, they are reliant on high-quality backhaul networks. Backhaul must evolve to support significantly higher data speeds, improved resiliency, a greater variety of network deployments and to extend coverage further into rural areas. Effective policy and regulation is central to success. In short, countries that want to become world leaders in 4G and 5G must enable world-leading backhaul networks.

While fibre remains the gold standard of backhaul due to its significant data capacity, wireless backhaul plays a vital role as fibre is not accessible or affordable at all sites. Terrestrial wireless backhaul is – and will continue to be for the foreseeable future – the most common backhaul method worldwide[1]. This is in large part due to the flexibility it offers. From high-frequency wireless backhaul bands (e.g. 70/80 GHz), which support the fastest 5G speeds, to lower microwave frequencies (e.g. 6 GHz) which support long link distances for rural base stations.

Terrestrial wireless backhaul continues to evolve with new very wide frequency bands, which will be essential for the fastest 5G speeds, and by supporting denser small cell networks in urban areas. Also, new technologies support significantly more data on a given amount of bandwidth; enable bands to be aggregated together to create wider bandwidths; and even allow access[2] spectrum to be used for backhaul in certain situations (i.e. so-called 'in-band backhaul').

The combination of new bands and technologies can have a major impact on the performance of mobile networks and what kind of services they can enable. But governments and national regulators must help make it come to fruition. They need to open up new terrestrial backhaul bands that are vital for 5G, while evaluating how existing bands can evolve to be suitable for the 5G era and beyond. This includes looking at widening channel sizes for key bands and, importantly, weighing up the pros and cons of other users gaining access to backhaul bands. For example, backhaul spectrum is at risk from calls for potential new unlicensed bands for Wi-Fi (e.g. 6 GHz) as well as new licensed 5G access bands (e.g. 26/28 GHz). They also need to evaluate how best to license backhaul bands, the conditions of use and how much to charge operators for access.

Regulatory approaches currently differ notably around the world. Most notably, the amount of spectrum that is available varies significantly which makes it challenging for operators to support the fastest data speeds and modern technologies. The cost operators must pay the government to access backhaul spectrum also varies - some markets are 22 times higher than the global median and 59 times higher than the lowest priced markets. This paper provides a short introduction to backhaul trends and regulatory approaches before outlining the GSMA's five policy recommendations:

1. **New backhaul bands are needed to support evolving network requirements and growing traffic**
2. **Current backhaul bands will still play an important role but need support to maintain relevance in the 5G era – especially through wider channel sizes**
3. **Regulators need to carefully consider the most effective backhaul licensing terms approaches, terms and conditions**
4. **High backhaul spectrum prices present a barrier to mobile network evolution, improved coverage and more spectrum efficient backhaul technologies**
5. **Regulators should, in consultation with the industry, ensure the timely availability of a sufficient amount of affordable backhaul spectrum under reasonable licensing approaches, terms and conditions**

1. See ABI Research report, 'Wireless Backhaul Evolution' (2021)
2. i.e. access spectrum is the bands that are used to connect user devices to base stations and have traditionally not been used for backhaul

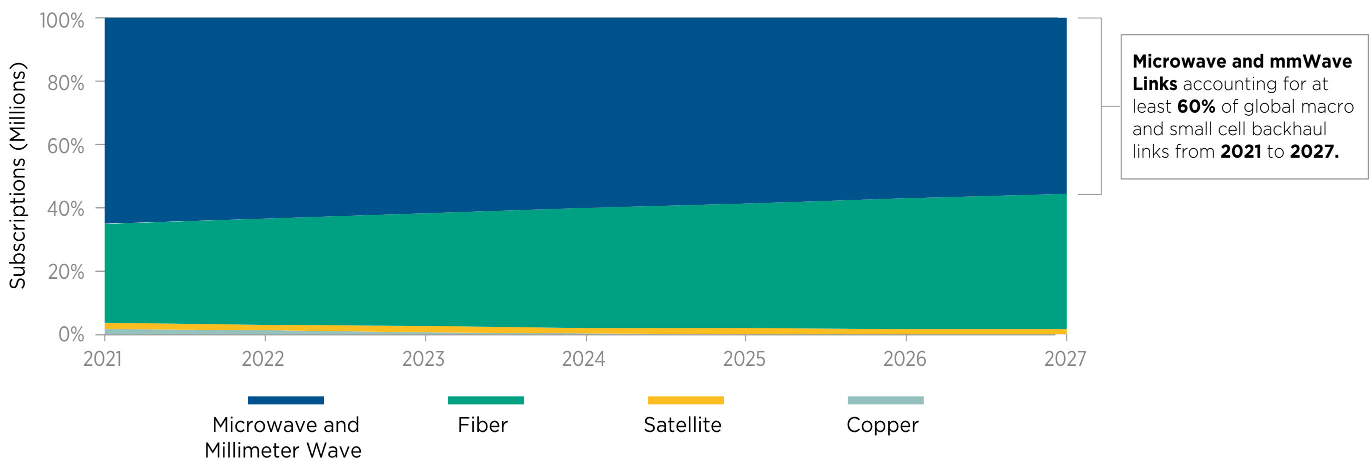
Background

Backhaul connects mobile operators' base stations to the network core. It is technically distinct from fronthaul[3] and midhaul[4] which connect different components that have traditionally sat within base stations. However, this paper considers the needs of fronthaul and midhaul as part of the wider spectrum requirements of backhaul – the three together are sometimes referred to as crosshaul.

The huge growth in mobile data traffic, and the evolution of networks to 4G and 5G, means backhaul network capacity must continually, and substantially, increase. Global mobile data traffic reached around 33 exabytes[5] (EB) per month by the end of 2019, and is projected to increase over five-fold to reach 164 EB per month in 2025[6]. 5G is forecast to account for 45 per cent of global mobile data traffic by 2025.

There have traditionally been four main types of mobile backhaul: fibre, copper (e.g. DSL), terrestrial wireless backhaul and satellite. However, the evolution of mobile networks and the continued rise in data usage mean that fibre and terrestrial wireless backhaul dominate the market today and will for the foreseeable future - they will connect 97 per cent of all base stations by 2027[7]. Satellite backhaul continues to play a minor role in rural areas where operators today have no other options and constitutes around 2 per cent of backhaul connections worldwide.

FIGURE 1



The architecture of backhaul networks is evolving in advanced mobile markets. For example, star-based backhaul network topologies where small cells connect to a growing number of fibre points of presence (PoPs) are becoming more common. However, although fibre is the optimum backhaul method due to its increased capacity, terrestrial wireless backhaul links will play a vital role as fibre will not be accessible or affordable at all sites. In fact, terrestrial wireless backhaul links[8] are expected to represent at least 60 per cent of the global market from 2021 to 2027.

Terrestrial backhaul bands can be divided into ranges with different properties. Lower bands travel longer distances (known as hops) but typically support less data as they have narrower bandwidths. The ranges can be defined as:

- Low (below 11 GHz and able to support 10-50 km hops)
- Medium (11-23 GHz and able to support 8-20 km hops)
- High (above 23 GHz and able to support hops below 8 km)

3. Fronthaul is the connection between a base station's baseband unit and the radio units
4. Midhaul is the new connection that was created in 5G networks by splitting the baseband unit into a remote unit (RU) and a separate central unit (CU).
5. One exabyte is one billion gigabytes
6. Ericsson Mobility Report June 2020
7. See ABI Research report, 'Wireless Backhaul Evolution' (2021)
8. This includes microwave and mmW frequency bands which range from 6 GHz to 175 GHz

The significant increases in backhaul capacity required to support advanced 4G and 5G require new high frequency bands. The V-band (60 GHz), E-band (70/80 GHz are increasingly being used for 5G backhaul worldwide and developed markets are expected to start embracing the W-Band (92-114 GHz) and D-Bands (130-175 GHz) after 2025. These bands can support channel sizes of up to 2 GHz, unlike traditional microwave bands (e.g. 6-42 GHz) which can only support channels of 7-224 MHz. However, traditional backhaul bands still play an important role, especially in rural areas, as they can affordably cover longer distances.

Wireless backhaul networks are also increasingly adopting a range of new technologies to help increase capacity and support more flexible deployments. These include:

- **Cross-Polarisation Interference Cancellation** (XPIC) transmits signals on horizontal and verticals planes using the same radio channel to double spectrum efficiency by cancelling the self-generated interference;
- **Band and Carrier Aggregation** (BCA) bonds multiple discrete radio channels[9] to support greater capacity and extend the life of traditional narrower microwave channels;
- **Integrated Access Backhaul** (IAB) allows access bands (i.e. the connection between user terminals and base stations) to be used for backhaul as well; and
- **Line of Sight MIMO** allows several independent radio transmissions over the same channel.

Wireless backhaul spectrum management

New terrestrial wireless backhaul bands are agreed globally at the ITU's World Radiocommunication Conference that is held every three to four years. Wireless backhaul is a type of 'fixed link' which traditionally uses bands that are allocated to the 'Fixed Service' as defined in the ITU's Radio Regulations. However, as 5G access bands support increasingly wide frequency bands, and use narrower beams, there is interest in using some for both backhaul and access to improve cost and spectrum efficiencies - this is sometimes referred to as 'in-band' backhaul

Governments and regulators make terrestrial wireless backhaul spectrum available through a variety of licensing regimes. These provide different access rights and guarantees – ranging from exclusive access to a portion of spectrum, to unlicensed access which provides no service guarantees. The type of access and the mechanisms to control, and mitigate, interference have a significant impact on quality of service and thus levels of operator investment. Backhaul links are typically designed to guarantee high availability as outages can affect so many end-users.

Types of backhaul licensing include:

- **Per link licence:** Exclusive rights to spectrum for a single link between two geographically defined locations;
- **Block licence:** Exclusive rights to a block of spectrum in a defined area;
- **Light licence:** Non-exclusive licences where licensees manage interference together, typically using a database to understand current usage; and
- **Unlicensed:** Unlicensed bands include 2.4 GHz, 5 GHz and, in numerous countries, the 60 GHz 'V-band', but there are no guarantees of interference protection.

Wireless backhaul licences provide access for a fixed duration. In a recent study[10], 60 per cent of countries offered long licences (i.e. 10 years or more) with renewal options to protect and incentivise long-term backhaul network investments. Shorter licences (e.g. 1 year) with fewer safeguards for continued access are also relatively common (18 per cent).

The licences can have conditions which present limitations on operator deployments. For example, licences may have restrictions on secondary polarisation[11] so operators aren't able to double their link capacity – or they may have to pay an additional fee for such permission.

The price that operators pay for wireless backhaul licences varies significantly around the world. A recent study found that the highest spectrum prices in some markets were 22 times higher than the global median and 59 times higher than the lowest priced markets. This places a significant financial burden on operators in these markets making it more difficult to afford to quickly rollout faster broadband services with better coverage.

Over the 5G era, mobile operators will need to continually upgrade their backhaul networks to support growing adoption of the technology and increased usage. Technology upgrades alone will not be able to scale capacity to meet expected demand. This means it will be necessary for regulators to make available additional backhaul bands – especially in higher frequency ranges such as E-band and eventually D-band and W-bands. The cost that regulators charge for wireless backhaul licences is expected to have a significant impact on operators' abilities to invest in 5G upgrades including backhaul.

Recent research has shown that the highest spectrum fees across all backhaul bands for a network in a developed market could result in an average per year aggregate network total cost of ownership (TCO) of $1.68 billion which is 266 per cent higher than the minimum spectrum fee scenario. Similarly, the annual TCO of a network in a developing market was $427 million and would be 59 per cent higher than the minimal spectrum fee scenario.

9. This can be within one band or across multiple different frequency bands
10. See ABI Research report, 'Wireless Backhaul Evolution' (2021)
11. As discussed previously, wireless backhaul can make use of the vertical as well as horizontal polarisation over a single frequency channel thus doubling channel capacity
12. See ABI Research report 'Wireless Backhaul Evolution' (2021)

Positions

1. **New backhaul bands are needed to support evolving network requirements and growing traffic**
   The significant increases in backhaul capacity required to support advanced 4G, and especially 5G, make wider channel bandwidth solutions vital. While fibre has an important role to play, it is essential that regulators plan to make available newer higher frequency bands which can support wider channels and have a greater total amount of spectrum available. In the near-term the E-band (70/80 GHz) will be most important, especially to support initial 5G growth, but the W-band (92-114 GHz) and D-band (130-175 GHz) will also be vital to help power 5G networks in subsequent years. V-band (66-71 GHz) is also likely to be used for backhaul and portions will be used for 5G access as well.

   The E-band, D-band and W-bands can handle 15-50 times more traffic than typical popular mid-microwave backhaul bands (e.g. 14 GHz-25 GHz). This is possible because they can support channel sizes of up to 2 GHz, as opposed to between 7-224 MHz, in traditional bands. Therefore regulators should plan to support very wide channels in order to extract the maximum capabilities from the bands.

   These bands are expected to be used mostly in urban and suburban environments as they travel relatively short distances (e.g. 2-3 km) due to their limited propagation and susceptibility to bad weather. However, it is expected that aggregation technologies should allow them to be paired with lower frequency backhaul bands to offset each other's weaknesses. The lower band provides a reliable and resilient core connection, even in bad weather, while the higher frequency band can provide significant additional capacity on a best effort basis. For example, lower bands (such as 15, 18 or 23 GHz) combined with E-band links could support 7-10 km links with capacities that exceed 10 Gbps.

   National regulators should consult with industry to understand their future backhaul requirements in new bands and relevant issues. Use cases as well as the capabilities, readiness and cost of solutions all need to be considered. This should also encompass the most appropriate licensing regime. That's important because these bands can be used with a wide variety of regimes including less conventional approaches such as block licensing (see position 4).

2. **Current backhaul bands will still play an important role but need support to maintain relevance in the 5G era – especially through wider channel sizes**
   Traditional microwave backhaul bands continue to have an important role to play especially as they can cover longer distances with fewer hops than newer higher frequency bands (e.g. E-band). They are vital in many suburban and rural areas, where less capacity is typically needed, as well as to provide added resiliency when combined with higher frequency backhaul bands (see position 1).

   These bands cannot be replaced with higher frequency bands without incurring costs[13] that may ultimately render sites in some areas economically unviable. Regulators need to ensure they are making sufficient spectrum available in these bands, and in sufficiently wide channel sizes, to address various backhaul scenarios. They also need to carefully consider interest in these bands from alternative use cases – including 5G access and unlicensed Wi-Fi.

   The amount of spectrum available in traditional microwave backhaul bands varies significantly between countries. Regulators should make available sufficient amounts of spectrum and support wider channel sizes in order to best support evolving mobile services and uptake. Operators in numerous markets report a lack of available backhaul spectrum in traditional microwave bands. They also highlight that narrow channel sizes present a bottleneck so an effort should be made to increase these up to 56 MHz-250 MHz bandwidths (as opposed to 6-56 MHz).

   Plans to make more spectrum available and wider channel sizes should be announced well in advance through a spectrum roadmap and consultation process. A balance must also be struck between supporting wider channel sizes and having a sufficient number of channels in the band to support demand from the mobile operator community. Regulators should also ensure operators are able to easily and affordably extract the maximum capacity from these backhaul bands by supporting technology neutrality and not penalising operators for adopting more spectrum efficient technologies (see position 5).

13. Higher frequency bands require more hops resulting in higher equipment and site costs (e.g. rent, power etc)

Regulators will also need to consider new interest in traditional microwave backhaul bands for alternative use cases. This includes the 26 GHz, 28 GHz and 40 GHz bands which will be important for 5G access and interest in the 6 GHz band both licensed 5G and as a new unlicensed band (e.g. for Wi-Fi) . It is essential that regulators carefully consider backhaul requirements and impacts when weighing up these decisions and should consult the industry. Safeguarding core bands in low, medium and high backhaul ranges is required. For example, the 6 GHz band remains important for backhaul, especially in rural areas and for non-line of sight use in urban areas. Mobile operators in many countries will want to deploy more links in this band where there are no viable alternatives[14]. Therefore there will be a need for compromises to ensure services can coexist without impacting backhaul link quality and availability.

3. **Regulators need to carefully consider the most effective backhaul licensing terms approaches, terms and conditions**
There are a variety of approaches for licensing backhaul bands, especially with the emergence of higher frequency bands and dense small cell networks. Regulators should carefully consider how they can encourage spectrum efficiency and facilitate rapid deployments. Making sure the process can be efficiently managed by all parties is also key. Supporting longer licence durations and encouraging spectrum trading can also encourage more extensive network investment and more efficient spectrum use.

Regulators typically issue per link licences on a first-come-first-served basis in most traditional microwave backhaul bands. This continues to be a fair and effective means of awarding licences for point-to-point and point-to-multipoint licences, especially for macrocell deployments. However, this can become an administrative burden for regulators and operators as deployments densify (e.g. high small cell uptake).

Light licensing can be a complementary option for small cells as it reduces much of the burden by letting users register with a database and often coordinate their usage amongst themselves. It should be noted that as backhaul links are between fixed points, coordination is far easier compared with access spectrum and the same frequency can be much more densely re-used in a given area.

Regulators are also encouraged to adopt block licensing in backhaul bands where there is a greater amount of spectrum (e.g. 70/80 GHz, 32 GHz etc). The relative lack of spectrum scarcity in these bands means operators can be granted exclusive access to a block of spectrum on a nationwide or regional basis[15]. This supports the growth of dense small cell networks, daisy chained networks[16] and especially point-to-multipoint backhaul links[17]. These situations do not lend themselves to traditional 'per link' licensing as the administrative burden can be significant, deployments can be slowed and licence costs can be prohibitive.

Unlicensed spectrum has not been successful for backhaul to date so cannot currently be widely encouraged as an effective approach. Operators have not used the 2.4 GHz and 5 GHz unlicensed bands significantly due to quality-of-service concerns arising from potential interference.

Regulators are also encouraged to consider licence terms and conditions that encourage efficient usage and heavy investment in mobile broadband networks. Longer licence durations give operators greater assurances of their continued access to spectrum and thus justify increased investments. Licences of at least five years and preferably over ten years provide such access guarantees. Many regulators have adopted this approach in recent years and the number of single-year licences continues to decline[18]. Permitting operators to trade their licences also increases spectrum efficiency as it helps avoid spectrum lying idle. Thus trading can help overcome concerns about longer licences or inefficient use by operators.

14. If operators do need to move to different backhaul bands and/or band plans, then there will be a financial impact that must be considered and potentially compensated for as part of any plan.
15. This is similar to the licensing approach for access spectrum (i.e. connecting devices to base stations)
16. A series of daisy chained connections can help route traffic around urban clutter (e.g. buildings) that may otherwise block backhaul links. It also supports small cell networks where a series of lamp post based base stations can connect directly to each other rather than directly to a single site
17. Where a hub base station/site connects to several other base stations/sites using a single radio transceiver. This contrasts with simple point-to-point links where a radio on one base station/site only connects to one other
18. ABI report 'Mobile backhaul options' 2018

4. **High backhaul spectrum prices present a barrier to mobile network evolution, improved coverage and more spectrum efficient backhaul technologies**
   A central challenge facing backhaul evolution for many mobile operators is the high spectrum costs associated with wider channels and the use of more efficient technologies. High prices can discourage investment in backhaul spectrum, and harm network investment more widely, which in turn reduces the speed of networks and coverage levels. It is essential that regulators are realistic when setting pricing formulas for backhaul spectrum and to ensure fees do not scale linearly with channel sizes or penalise new technologies that use spectrum more efficiently.

   The formulas used to calculate spectrum prices are often little different from those designed for legacy voice and data networks that had 3.5 MHz, 7 MHz or 14 MHz channels. This means costs can scale significantly when applied to newer backhaul bands which can support 2 GHz channels. It is essential that regulators ensure formulas contain components that mitigate such price jumps. This helps avoid excessively high prices while also recognising the limited propagation benefits, lower overall demand and higher re-usability of spectrum in these higher bands.

   Some approaches to pricing can also discourage the use of more spectrum efficient technologies that deliver significant network capacity improvements. For example, cross-polarisation interference cancellation allows operators to double capacity over a single radio channel. However, numerous regulators charge operators double per link for using this technology despite it having little practical impact on other potential usage in the vicinity. Line of sight MIMO is another technology that improves spectrum efficiency by allowing several transmissions over the same radio channel by using multiple antennas in very close proximity to each other on a single site. Some regulators charge these as separate links thus discouraging the use of a technology which also does not limit third party usage in the vicinity.

5. **Regulators should, in consultation with the industry, ensure the timely availability of a sufficient amount of affordable backhaul spectrum under reasonable licensing approaches, terms and conditions.**
   Regulatory decisions play a key role in determining the cost, performance and coverage of mobile broadband services. Therefore, effective backhaul regulation and policy making is a critical component of national-level ICT strategy. It is essential that regulators carefully consider mobile operators' network rollout plans and the challenges they face. High-quality 4G and 5G services will only be as ubiquitous and affordable as the currently available backhaul. As part of a successful backhaul strategy, regulators should:
   - Support widespread, competitive fibre rollouts and ensure the timely availability of a sufficient amount of affordable backhaul spectrum under reasonable licensing approaches, terms and conditions. This includes rapidly issuing new licences and permits to build out fibre and radio backhaul infrastructure;
   - Consult stakeholders to ensure current and proposed future backhaul bands and licensing approaches meet the needs of advanced 4G and 5G networks;
   - Use widely harmonised bands in order to ensure there is a sufficient choice of affordable equipment; and
   - Publish a spectrum roadmap and/or national broadband plan that includes all new backhaul bands, proposed licensing approaches, and proposed changes to existing bands. The roadmap should cover at least the next five years and is continually updated.

Regulators are encouraged to assess, and publish as part of their roadmap, current band occupancy and congestion levels to ensure plans can be put in place, in a timely manner, to make additional spectrum available when needed. This should factor in the time needed to ready new bands for use. It is important to maintain a dialogue with operators to understand their future network deployment plans and the impact this has on backhaul requirements to ensure they can be accommodated.

It is also essential to ensure that regulators review current licensing approaches, channel plans and licence terms, conditions and costs to verify they are supporting the best possible mobile services. As discussed elsewhere in this paper, it is important that current approaches continuously evolve to support wider channels, new technologies and fair pricing with a view to maximising efficient spectrum use and delivering optimum services for consumers and businesses.

It is important that regulators closely consult operators and industry more widely on changes to current backhaul bands. In the coming years there is likely to be some disruption from new 5G access bands and potential additional unlicensed bands that may impact backhaul spectrum. It is vital that these changes consider current and future backhaul needs. This includes proposed measures to support coexistence, including database or usage conditions for any party, so as to ensure these are sufficient and will not harm current or future mobile broadband services.

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