WHITEPAPER

Accelerating 5G roll-out with spectrum sharing

The time and technology are right for dynamic spectrum access to accelerate the deployment of 5G coverage and capacity in the 3.5 GHz pioneer band

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Introduction

Why 5G demands new approaches to network deployment

With increasing rapidity, the world introduces new mobile technologies. The transition to 5G will be unlike any of its predecessors. 5G is required to provide the data backbone of the economy of the future. As well as delivering high-bandwidth enhanced Mobile Broadband, 5G is expected to turbo-charge the smart cities, autonomous vehicles and smart enterprises that will all be part of the Internet of Things (IoT).

Just as with the deployment of previous mobile technology generations, 5G network operators will need to offer a compelling combination of coverage and capacity. Unlike its predecessors, 5G will have to maximise coverage and spectrum utilisation to deliver the high speeds users expect and the exponential increase in the variety of use cases and services that networks will need to support.

In order to provide high speeds, networks will have to become much denser and this will have an impact on deployment costs. In an environment where subscriber and revenue growth has stalled in recent years, the need for thousands of the small cells to meet 5G speed expectations would require prohibitive and unsustainable levels of investments for mobile network operators under the traditional roll-out model.

Delivering against these goals will require radically different network architectures where new services are virtualised by being defined in software that runs on commercial off-the-shelf hardware and can be deployed rapidly and maintained centrally and efficiently. These requirements are disrupting the infrastructure equipment market as the industry searches for ways to significantly reduce the cost of deploying networks: incumbent vendors, steeped in the traditions and practices of the telecommunications sector, are being challenged by smaller, often nimbler, challengers from IT and software backgrounds.

> “Under the current model a huge amount of spectrum is being wasted.”

5G will always have to coexist with other technologies, old and new. In fact, networks will be heterogeneous (HetNets) in the future, combining 5G, Wi-Fi and other technologies. To facilitate the introduction of 5G, regulators are allocating pioneer spectrum bands in which the new mobile technology can be deployed. Europe has allocated the 3.4-3.8 GHz band; the US will release 3.1-3.55 GHz while China is looking at 3.3-3.6 GHz and Japan 3.6-4.2 GHz. This harmonisation around 3.5 GHz is directing the R&D of communications chipset manufacturers: global volumes will drive down costs and accelerate the implementation of 5G in smartphones at every price point, as well as in many other devices.

But the 3.5 GHz pioneer band offers more limited coverage per base station than GSM’s pioneer bands at 900 MHz, 3G’s at 2100 MHz, or 4G’s which varied by region.

5G will require investment on an unprecedented scale, and therefore new models are required to achieve satisfactory roll-out of 5G within operators' sustainable investment envelopes. The challenge is to give MNOs incentives to invest while stimulating innovation and investment in the 5G ecosystem from new sources.

In most countries 4G coverage is still incomplete eight years after the technology was first introduced. For example, according to ARCEP, the French regulator, while the population coverage of the four licensed operators varies from 98% to 92%, geographic coverage ranges from 86% down to 69%[1]. At the higher pioneer band frequencies, the roll-out of 5G is likely to be considerably slower if the traditional model is adopted: digital divides will be accentuated.

Under the current model a huge amount of spectrum is being wasted: spectrum awarded to MNOs through auctions is reserved for their exclusive use, meaning that in all areas where an MNO is not deploying services, their spectrum is sitting idle. This spectrum could be used by others to provide much needed services to these under-served communities. Removing barriers to spectrum access could empower small local players to contribute to a nation's infrastructure and provide new services which are currently not financially appealing for the large MNOs.

Expanding the market for 5G

A "market expansion" model, as proposed in a report for the UK Government's Department for Digital Culture Media[2] and Sport, can solve these problems in the pioneer 5G bands worldwide. It comprises two different but complementary competition models to reflect the reality that most countries are made up of two broad demographics:

- Densely populated urban areas where the cost-per-head of providing 5G coverage is relatively low and where public policy needs to focus on promoting competition between the MNOs.

> "A spectrum allocation mechanism that delivers spectrum at a much lower cost is required in those areas which are less attractive to the MNOs."

- A much larger, mostly rural, zone where population density is lower and where the cost-per-head of serving up 5G coverage can appear prohibitive. In these areas, the policy challenge is to secure any infrastructure investment.

Fig.1 Schematic representation of a market expansion zone surrounding a densely populated MNO competitive market zone.

[1] *4G Internet mobile coverage as illustrated https://www.monreseaumobile.fr/ [accessed 16 January 2019]*

[2] *"UK mobile market dynamics, a report or DCMS, July 2018" p55 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/728816/Frontier_report_on_Mobile_Market_Dynamics.pdf*

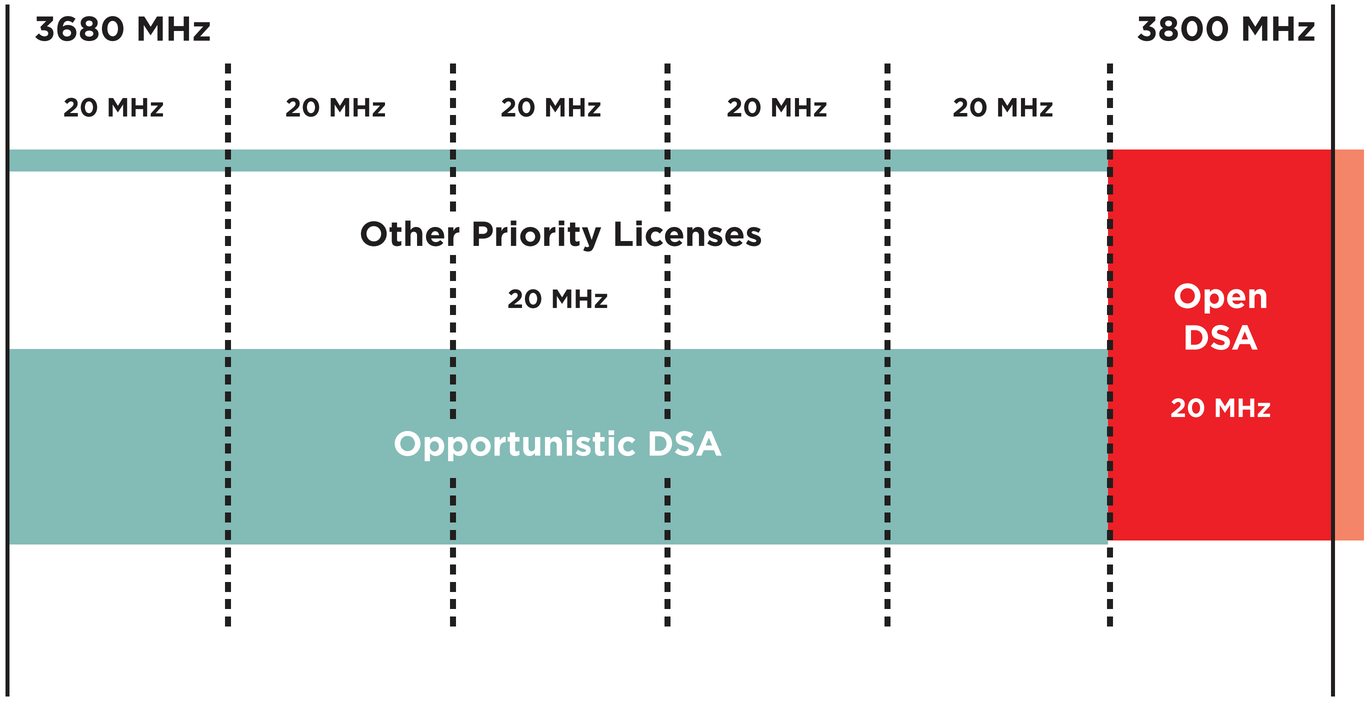

Fig 2: One of the proposed approaches being advanced to use a portion of the 5G pioneer bands in the UK. Approach may vary depending on territory and market requirements.

The market expansion model illustrated in Figure 1 includes two distinct means for releasing 5G radio spectrum:

- An auction remains the most transparent means of arbitrating between the demands of competing apostrophe in urban areas.
- A spectrum allocation mechanism that delivers spectrum at a much lower cost is required in those areas which are less attractive to the MNOs. However, if new entrants are to benefit from affordable 5G devices based on the global economies of scale, the spectrum still needs to be part of the pioneer bands.

To maximise the benefits of the market expansion model, spectrum allocation for the outer zone should ideally comprise two components:

- opportunistic dynamic spectrum access
- light licensing of an "anchor" spectrum band for open dynamic spectrum access.

Opportunistic Dynamic Spectrum Access

Dynamic Spectrum Access (DSA) is an approach to improve the efficiency of wireless spectrum usage by utilising a central geo-location database to co-ordinate allocations in real time. Applying an opportunistic Dynamic Spectrum Access layer across the pioneer band would open up the potential for sharing spectrum assets that would otherwise lie idle. Dynamic Spectrum Access can drive a step-change in ecosystem efficiency. It does this by:

- Allowing all of the scarce 5G pioneer band spectrum to be brought into play at every location. This can deliver an increase in capacity and data speeds as the coverage road maps of competing MNOs diverge.
- Allowing new players to use the spectrum, on an opportunistic basis, in areas the mobile operators are not operating. This improves geographic spectrum efficiency.

Traditionally it has been assumed that rural coverage is challenging in business case terms due to the low population density available to fund cell site investment.

> "DSA provides flexibility for protecting incumbent users of spectrum"

Closer inspection of population distributions shows that the vast majority of the rural population lives in clusters – small towns, villages and hamlets – where the local population density can be at suburban levels. To meet these needs cost-effectively, cells which can deliver coverage and capacity to small areas are needed at the lowest possible cost. This is another reason to use spectrum where the largest global volumes are being generated.

An additional benefit is that DSA provides flexibility for protecting incumbent users of spectrum such as satellite earth stations in the specific locations where they operate, while opening up their spectrum elsewhere.

Lightly licensing "anchor" spectrum

To make optimal use of the market expansion zone, providing security of tenure for new market entrants is important if the the benefits of innovation are to be realised.

Over rural areas the probability of any mobile operator providing coverage is low and the probability of all licensed mobile operators covering the same area is negligible. As of 2018 11% of the UK landmass lacked "good" outdoor 4G coverage[3] from any of the four operators[4].

But the fact that it might happen will chill investment from new entrants. The market expansion model can solve the problem by making available to the market a small amount of "anchor spectrum" (the "Open DSA" block in Figure 2) that will be open on a shared basis. It needs to be priced to match the very fragile business models in rural areas while still covering the cost of running the supporting access management database service.

If a regulator does not include an anchor spectrum, dividing the band illustrated in Figure 2 into 3x40 MHz instead of 6x20 MHz blocks would deliver faster 5G connections and would be a more attractive proposition for mobile operators.

What does this mean in practice?

Figure 3 shows an area of Lincolnshire in central England, an agricultural area that is typical of low-lying rural areas in many countries. WaveDB, Nominet's global platform for dynamic spectrum management, has been applied to the still-to-be-allocated 3.6-3.6-3.8GHz spectrum to predict potential coverage in the UK based on the highly optimistic assumption that all MNOs roll-out their 5G spectrum immediately on all masts providing 4G signal[5].

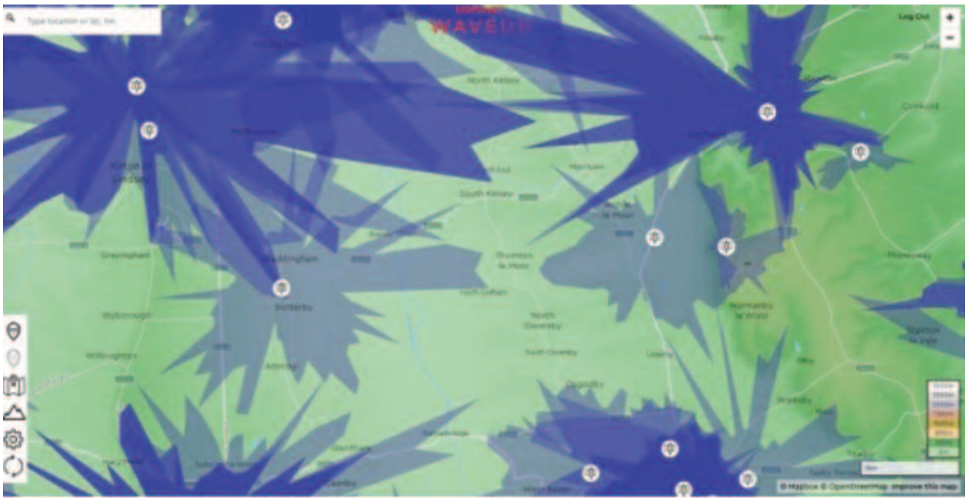

Fig. 3 WaveDB predictive plot of 5G coverage in rural Lincolnshire, England

[3]Ofcom defines "good" 4G service as providing a connection speed of at least 2 Mbps
[4]"Connected Nations Update 2018" Ofcom, https://www.ofcom.org.uk/__data/assets/pdf_file/0019/122194/connected-nations-october-2018.pdf, p10
[5]Based on 2012 4G cell site location data

The example shows that the village of North Owersby stands in a gap in the coverage of all operators. A use-it-or-share-it approach would allow the village to invite an ISP to set up its own microcell in an MNO's 40MHz of spectrum fitting between the areas where the MNO is actually providing coverage. This is shown in Figure 4.

Fig.4 Coverage in-fill from new entrant using the unused spectrum of a licensed MNO

In addition, if the regulator allocates anchor spectrum, the new entrant would have the option to set up a larger, higher-powered cell extending coverage to other neighbouring communities and providing a backstop so that if, in the future, the MNO decides to extend the use of its own spectrum, the local network can continue to function.

Even in heavily populated urban environments, there are applications for the market expansion model. Schools, hospitals, factories and offices can establish private indoor femtocells without disrupting the incumbent's network.

The move towards virtualised network infrastructures could well provide more affordable base station options which could potentially be funded by local communities. Improved flexibility in core networks could allow the integration of new entrant coverage into an MNO's network through new roaming/MVNO business models.

Alternatives to the proposed approach

Are there alternatives to a market expansion model which could contribute to better coverage and geographic spectrum efficiency?

- Imposing a coverage obligation is unlikely to work at 3.5 GHz. Setting the obligation too high would risk no bidders for the spectrum. A "Dutch" auction could find a market value for the coverage obligation, but it is likely to be so low as to offer little gain in geographic spectrum efficiency.
- Imposing a "use-it-or-lease-it" option would enable license holders to lease their unused spectrum. However, to date there has been little evidence of demand for spectrum trading in 4G.

If a market expansion model is perceived to be too much of a regulatory leap, further options exist that would realise some of the benefits, while creating a pathway to further innovation in the future.

- DSA could be restricted to licensed users only. This helps MNOs to access, on an opportunistic basis, much larger spectrum blocks wherever other licence holders are not operating. Whilst this approach enables some of the benefits of the market expansion model, it does not allow new players to enter the market.
- Alternatively, new entrants could be encouraged by opening up DSA to a broader group of "authorised entities" who have demonstrated relevant competence.

Dynamic Spectrum Access databases

With the exception of coverage obligations, all of the options explored above rely on Dynamic Spectrum Access. By understanding the current and intended usage, DSA enables spectrum utilisation to be maximised more effectively than traditional exclusive-use licensing. Using a geo-location database containing details of assets and rules, DSA enables spectrum to be allocated in real-time, based on the location of the user and other considerations such as radio parameters and type of usage. As well as improving efficiency of spectrum use, DSA opens up new market opportunities and promotes innovation.

Crucially, DSA is robust and proven technology, first implemented to manage the TV White Spaces (TVWS).

> “DSA is robust and proven technology ”

TV White Space – the proven proof-of-concept

What is TV White Space?

Worldwide, terrestrial television systems have been switching from analogue to digital broadcasting. As modern digital transmission standards are more efficient than their analogue predecessors, broadcast TV now occupies less spectrum. In many countries the freed-up "digital-dividend" spectrum is being reallocated to mobile operators. In some jurisdictions, operators are being allowed to use this spectrum to offer wide-area 5G coverage which will be particularly beneficial in traditionally underserved rural areas.

As most TV transmission systems are arranged regionally there needs to be space between the channels used in each region to avoid interference between neighbouring regional signals. Low power devices, such as wireless microphones used for program making and special events, occasionally use some of these spare channels, but the remaining channels could be shared for other uses.

DSA provides access to these available channels, which are known as white spaces.

TVWS Physical Characteristics

Depending on the availability of channels in an area, TVWS can offer tens of Mbps per channel over several kilometres. There is potential to increase the bandwidth to offer up to 100 Mbps by combining multiple channels. One of the attractive features of TVWS is that it uses lower frequencies compared to Wi-Fi and mobile networks, thus allowing the signal to travel over much greater distances and penetrate permanent obstacles such as trees, as well as travel around terrain allowing non-line of sight connections.

The availability of TVWS channels does vary depending on location and time of the day. The speed and availability of the service is not guaranteed, as within this spectrum range TV broadcasters and wireless microphones take priority. In addition, TVWS users share the available channels with any other users in that particular area, which may have an impact on the performance of the connection. TVWS therefore performs best in rural areas where the spectrum is generally less congested. An investigation of the TVWS opportunity in Germany based on the adoption of the model rules proposed by the Dynamic Spectrum Alliance is presented in Figure 5.

"TVWS therefore performs best in rural areas where the spectrum is generally less congested"

In order to transmit on TVWS channels, devices are required to contact a regulator-approved TVWS database to check the availability of channels in their area. Devices send their location to the database, and in return they receive a list of available channels and the power at which they are permitted to transmit on each. Devices are required to check in with the database periodically, typically every 15 minutes, to ensure they remain clear of TV broadcasts and wireless microphone users.

TVWS also enables a tiered sharing framework, prioritising certain users depending on regulators' policy requirements. The principles proven with TVWS are frequency agnostic and are applicable to other bands. To date Canada, Colombia, Singapore, South Africa, South Korea, Trinidad & Tobago, UK, and USA have passed TVWS regulations.

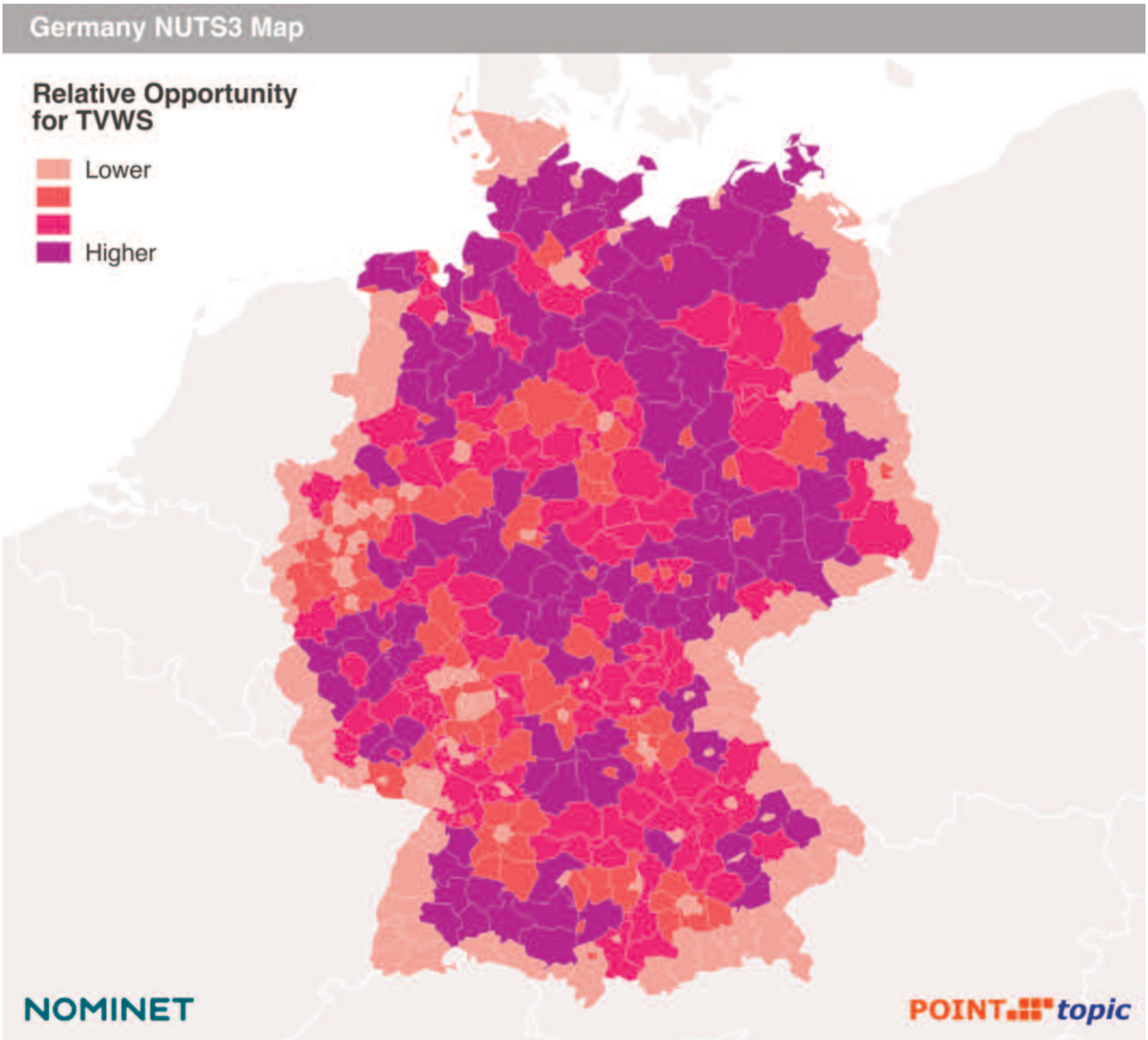

Fig 5. Relative opportunity for TVWS in Germany based on channel availability and population density[6]

The lessons learned from TVWS have been used to develop a more ambitious and dynamic framework for CBRS (Citizens Broadband Radio Service) in the United States. The CBRS framework is based on three-tiered spectrum sharing. It is designed to ensure coexistence between incumbent users, who cannot provide any information a *priori* to a central database, and other users, some of whom may require priority over others. In the US, incumbents are generally the armed forces using networks operating close to coastal areas or in military bases. The first commercial deployments of CBRS are expected in the first half of 2019.

Experience shows that a sharing framework can be set-up in less time and with less effort than is usually required to design and run an auction.

[6]*Underserved Europe and the TV White Space opportunity, Nominet, May 2018 https://s3-eu-west-1.amazonaws.com/nominet-prod/wp-content/uploads/2018/05/03074356/Nominet_ETECH_Report_EuroTVWS.pdf*

Conclusions: a new approach for a new technology

A market expansion model and a new approach to spectrum management will be critical to fully realising the benefits of 5G. DSA can unlock benefits for all stakeholders.

Regulators benefit from:

- Unleashing the benefits of 5G extremely quickly. In the traditional auction model, access to 5G must wait until each MNO rolls-out its coverage across the country. As previous generations have shown, this happens with varying speed depending on the commercial strategies of each MNO. The market expansion model could inject ISPs and other new entrants into the ecosystem to accelerate the provision of coverage and stimulate new and innovative use cases.
- Dynamic Spectrum Access achieves more efficient use of spectrum than exclusive-user licensing.
- Dynamic Spectrum Access can incentivise sharing through the concept of a hierarchy of 'tiered' users within a given frequency band.

Nations benefit from:

- Short-term and long-term economic gains. Successful roll-out of 5G will boost the economy, particularly for first movers. More rapid roll-out increases the economic dividend. For the UK, it has been forecast that the economic impact of 5G in the UK could be around £112bn in 2020, rising to £164bn in 2030. Taking a first-mover position would increase the 2030 economic impact to £198bn[7].
- Opening-up otherwise unnecessary fallow spectrum can also boost the economy by encouraging new entrant service providers and application developers.

Operators benefit from:

- Overall market growth stimulated by increased innovation from new entrants.
- New revenue opportunities in areas they do not cover directly through new roaming/MVNO business models with new entrant coverage suppliers.
- Opportunistic access to competitors' spectrum.

[7]Future Communications Challenge Group Interim Report, January 2017, p3, UK Government's Department for Digital, Culture, Media and Sport (DCMS) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/582640/FCCG_Interim_Report.pdf

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