Response to the Ofcom Mobile Spectrum Demand Discussion

By Professor William Webb

Mobile Demand Growth

Ofcom has set out three scenarios for mobile data growth, with the central case being 40%/year growth in demand. Given that this has been the average growth rate for many years, and that similar growth rates are being seen around the world, then this is a sensible decision.

Few trends continue forever, and it seems likely that growth rates will eventually slow once users have reached the limit of what they wish to do via their mobile devices. But it is very difficult to predict when such a slowing may occur.

Hence, our view is that the base case of 40% growth is plausible in the short term but likely to be an over-estimate in the medium to long term once growth rates slow. However, this does not materially change the conclusions Ofcom draw, nor our response.

We anticipate the growth will be faster indoors than outdoors, although both will grow. This is because the high data rate applications such as watching video, and potentially in the future AR/VR and metaverse, are more likely to be consumed indoors. This is an important point which informs our conclusions on optimum solutions, described below.

Meeting demand – spectrum availability and technical efficiency

We agree with Ofcom that there are broadly three ways to increase network capacity – spectrum, technical efficiency and more cells. In our view Ofcom may have over-stated the improvements in technical efficiency. Moving from 3G to 4G delivered around 2.5x improvement in dense areas of the network and the technological changes between 4G and 5G are smaller than between 3G and 4G. Early experience with massive MIMO antennas has resulted in lower gains than hoped. Also, the use of higher frequency bands on existing macrocells tends to result in poor coverage towards the cell edge which depresses spectrum efficiency. However, a lower efficiency gain just results in networks becoming congested faster than a higher gain, so again this is not critical for the conclusions we draw below.

We also agree with Ofcom that meeting the capacity growth through additional spectrum is implausible. Even doubling the useful allocation of spectrum to mobile would be extraordinarily difficult, let alone meeting a 10x growth. Further, we agree that spectrum sharing should play some part in the solution. Mobile networks are typically only congested in a small number of cells, so providing spectrum that can only be used, for example, in city centres, might provide useful capacity enhancement while allowing use by others in the vast majority of the country.

Hence, we are in agreement that demand will likely grow and that the traditional levers of spectrum and technical efficiency will not suffice to meet this growth. However, we differ in our view of the solution, as set out below, where we first discuss why outdoor small cells are not appropriate and then set out why indoor solutions are needed.

Why outdoor small cells are not the solution - economics

While outdoor small cells have long been forecast, their deployment has been limited. Most operators have deployed around 2-3 small cells per macrocell sector in dense areas but not gone beyond this. There are both economic and technical reasons for this, in this section we discuss economics while in the next section we discuss technical issues.

While MNOs strive to meet consumer demand, they must do so profitably. To date, consumers have shown little willingness to pay more for increased data, instead expecting ever greater data allowances for the same price over time. Indeed, APRUs have tended to fall even while data usage has grown. Few expect this to change, so total MNO revenue is unlikely to change and may continue to decline slowly. This means that MNOs must remain within the envelope of their current capital expenditure, and indeed when they have suggested otherwise, their share price has tended to drop immediately and significantly.

Small cells are expensive. While a single small cell may only cost perhaps 20-40% as much as a macrocell, many more are needed. A major small cell deployment would require a major increase in capex.

Operators are likely to decide that such investment will be unprofitable and may explore other options, such as gently throttling usage, or compressing video feeds and otherwise finding ways to reduce demand.

There are ways to reduce small cell costs, the most useful of which is to use a neutral host network such that the cost of the cells are shared across all MNOs. However, this is unlikely to reduce costs sufficiently and has other issues such as difficulty of integration with multiple different MNO networks.

Why outdoor small cells are not the solution – technical issues

We have previously undertaken extensive modelling of outdoor small cell networks[1] which shows that they do not deliver the capacity gains expected.

The main reason is that most mobile traffic is indoors but small cells are relatively poor at in-building penetration. Small cells tend to be at a low height, typically only as high as a first floor of a building, and so do not provide coverage on floors above this, whereas in cities there are often tall buildings. They also tend to radiate down a street, resulting in an oblique angle of incidence of the radio wave onto the building and relatively low penetration, other than the buildings immediately around the small cell.

Even where the signal does penetrate the building it is relatively weak. This means that a low rate of modulation needs to be used which in turn results in a low data rate and a high consumption of network bandwidth. So not only is there more traffic indoors, but it is served at a lower spectrum efficiency than the outdoor traffic.

Another issue is that small cells need to "steal" some frequencies from the macrocell, reducing its capacity. Small cells cannot use the same frequency as the macrocell they sit within as this would result in interference. Hence, carriers must be removed from the macrocell and used on the small cells. This means that the macrocell becomes congested sooner unless the small cells can relieve the demand from the macrocell, but as noted above they struggle to do this.

The net result is that small cells are best used in specific areas of very high traffic density such as major shopping streets or train stations. Beyond this, they are likely to carry insufficient traffic to justify their cost and their use of frequencies that could otherwise be deployed on macrocells. Broadly, this results in 2-3 small cells per macrocell sector being optimal, a position that we have already reached.

Hence, for both economic and technical reasons, outdoor small cells are not the solution to the increased network capacity needed.

Why indoor solutions provide the best solution

We have set out above that:

- Much of the traffic demand growth is likely to be indoors.
- Outdoor small cells have poor ability to serve indoor users.

The conclusion from this is that in-building small cells are a better solution. Delivering wireless into the building from outside is hugely inefficient as much of the signal is lost through the walls. But providing it inside makes use of the walls as a way to block external signals and limit interference between buildings. Indoor systems provide excellent targeted capacity at low power levels with reduced interference. This has benefits in terms of capacity, data rate and also in lower energy usage. Indoor systems can readily provide the capacity needed in 2030 and 2035, likely from within current spectrum allocations and without needing significant improvements in technical efficiency.

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[1] William Webb, (2018) "Modelling small cell deployments within a macrocell", Digital Policy, Regulation and Governance, Vol.20 Issue: 1, pp.14-22, https://doi.org/10.1108/DPRG-07-2017-0038

In principle it matters little whether an indoor solution is Wi-Fi, cellular (4G/5G) or another solution. Indeed, Wi-Fi and cellular are very similar in many respects with the same modulation and multiple access approaches (OFDMA), similar bandwidths and similar antenna solutions.

We believe that Wi-Fi is essential but cellular is optional. Wi-Fi is needed since there are many devices that are only able to use Wi-Fi such as tablets, laptops, smart TVs and smart speakers. Cellular is optional since handsets can all use Wi-Fi. There may be some cases where cellular is beneficial such as where higher levels of performance are needed or other attributes such as roaming are important. Combining Wi-Fi and cellular also allows the widest range of spectrum to be used.

Wi-Fi is already present in almost all buildings and is well suited to self-deployment by the building owner. It would benefit from additional spectrum, such as the entire 6GHz band as is currently allocated in the US and is being considered in the UK. It would also benefit from solutions that make roaming simple such that users do not have to select a network and input a password the first time they encounter a new network.

Cellular is rarely deployed within buildings, except those with very high public presence such as airports and entertainment venues. This is despite many decades of the industry attempting to deliver widespread in-building systems with initiatives such as femtocells in 2009 in the 3G era. The reasons for this are broadly that it is uneconomic and intractable for operators to deploy in around 20 million buildings but it is also very difficult for building owners to self-deploy as there is no suitable spectrum bands for them to use. This has changed somewhat in the US with the CBRS shared spectrum initiative that overcomes the spectrum access issue and allows cable operators and others to bundle a 4G/5G modem into a cable modem and Ofcom has spectrum at 3.8-4.2GHz and elsewhere that, with suitable automation of assignment, could for the basis for such deployments.

If there is self-deployment of indoor cellular solutions, then the issue becomes one of interconnection to the mobile networks, such as roaming agreements or similar. At present, these do not work well.

We believe that Ofcom should focus strongly on in-building solutions as the core element of its response to meeting growing data demands and discuss policies it might adopt to do so in the next section.

Implications for future regulation – spectrum and networks

The previous section set out the issues that are impacting indoor solutions. In this section we set out our recommendations for Ofcom to address them.

1. More spectrum for Wi-Fi. We anticipated that Wi-Fi will carry the bulk of in-building traffic. Our modelling suggests that by 2030 Wi-Fi will need all of the 6GHz band in order to do so without congestion. This spectrum should be made available by 2025 at the latest to allow for suitable equipment to be deployed.
2. A Wi-Fi roaming solution. There are already excellent roaming solutions. For example, EduRoam allows students and academics to move between academic institutions across much of Europe without needing to sign into separate locations. Ofcom, or the Government, could open up such a solution to all users and to all owners of Wi-Fi access points. It may well be attractive for many locations such as hotels, hospitality and even offices to become part of such a network, removing the need to tell users about passwords and improving the user experience.
3. Shared spectrum for cellular self-deployment. A sharing solution would allow building owners to deploy 4G/5G solutions. This might be implemented, for example, in the bands 3.8-4.2GHz, in the emerging 4.5-5GHz band or in other bands where cellular handsets can operate. A more advanced solution might automatically enable access to spectrum owned by MNOs which they had not deployed locally.
4. Better overall roaming and interconnection arrangements and obligations such that indoor Wi-Fi and self-deployed cellular solutions can be integrated into the broader set of national networks, enabling usage by all appropriate devices and individuals in an automated and seamless manner.

About William Webb

William is a consultant providing technical and strategic advice across the wireless communications space. His activities include advising CEOs, Government Ministers, regulatory bodies and acting as an Expert Witness. He was President of the IET – Europe's largest Professional Engineering body during 14/15. He has an excellent track record of accurately predicting the future as evidenced by multiple books he has published over the last 22 years which have proven extremely prescient in their analysis of wireless technologies, solutions and applications.

He was one of the founding directors of Neul, a company developing machine-to-machine technologies and networks, which was formed at the start of 2011 and subsequently sold to Huawei in 2014 for $25m when he became CEO of the Weightless SIG, the standards body developing a new global M2M technology, a position he held until 2019. Prior to this William was a Director at Ofcom where he managed a team providing technical advice and performing research across all areas of Ofcom's regulatory remit. He also led some of the major reviews conducted by Ofcom including the Spectrum Framework Review, the development of Spectrum Usage Rights and most recently cognitive or white space policy. Previously, William worked for a range of communications consultancies in the UK in the fields of hardware design, computer simulation, propagation modelling, spectrum management and strategy development. William also spent three years providing strategic management across Motorola's entire communications portfolio, based in Chicago.

William has published 17 books including "The 5G Myth", "Our Digital Future" and "Spectrum Management", over 100 papers, and 18 patents. He is a Visiting Professor at Southampton University, a Fellow of the Royal Academy of Engineering, the IEEE and the IET and a non-executive director at Motability. He was awarded the Honorary Degree of Doctor of Science by Southampton University in recognition of his work on wireless technologies, Honorary Doctor of Technology by Anglia Ruskin University in honour of his contribution to the engineering profession and Honorary Doctor of Science by the University of Hertfordshire in recognition of his contribution to wireless technology and engineering. In 2018 he was awarded the IET's Mountbatten medal, one of its highest honours, in recognition of his contribution to technology entrepreneurship. His biography is included in multiple "Who's Who" publications around the world where he has been honoured with life-time achievement awards. William has a first class honours degree in electronics, a PhD and an MBA.