The Benefits of Technology-Neutral Spectrum Licences

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1. Executive summary

Technology neutral spectrum licensing is widely recognised as best practice when assigning spectrum to mobile operators. Technology neutral spectrum licences enable mobile operators to refarm spectrum used for GSM (2G) or 3G to 4G and 5G with the timing of the refarming driven by market demand. This maximises spectral efficiency in a technical sense and also maximises efficient use of spectrum. As a result, users benefit from better mobile broadband coverage, higher data speeds and lower mobile data prices than would otherwise be the case.

Spectrum is a scarce resource and efficient use of spectrum is one of the key objectives of spectrum management. The spectral efficiency of 4G coupled with MIMO is such that refarming 850MHz or 900MHz spectrum from 2G to 4G with 4x4MIMO delivers a 15-fold increase in mobile data capacity. For 1800MHz and 1900MHz spectrum, where higher orders of MIMO can be deployed, moving from GSM to 4G delivers a bits/Hz improvement of up to 26 times. These are facts which any regulator aiming for efficient use of spectrum should put centre stage when formulating policy, pricing and technical conditions for mobile spectrum licences.

The higher spectral efficiency of 4G compared to legacy 2G and 3G technology is a key ingredient in delivering the connected society. There is empirical evidence for the economic benefit brought about by introducing 4G mobile broadband technologies:

- *"For a given level of total mobile penetration a 10 per cent substitution from 2G to 3G increases per capita GDP by 0.15 percentage points. … A doubling of mobile data use leads to an increase in the GDP per capita growth rate of 0.5 percentage points."* (Source: The Impact of Mobile Telephony on Economic Growth, Deloitte, 2012)
- "*Doubling the broadband speed will contribute to 0.3% growth compared with the growth rate in the base year".* (Source: Does broadband speed really matter for driving economic growth? Rohman et al, Division of Technology and Society, Department of Technology Management and Economics Chalmers University of Technology, Gothenburg, Sweden, 2012)

2019 will see a ramping-up of commercial launches of 5G. While some 5G deployments are in new mobile broadband frequency bands, such as 3.5GHz (C - band), it is essential that mobile operators have the freedom to refarm existing spectrum holdings to 5G, notably to deploy a 5G coverage layer, in response to market demand. This is particularly relevant for 700MHz and 800MHz spectrum licences, some of which have been licensed as 4G technology specific spectrum but will be useful as a 5G coverage layer. Regulators need not worry that refarming will leave legacy users unserved. It is now possible to 'gracefully refarm' bands so they are used simultaneously for several technologies – including 4G and 5G. This allows a phasing in of the newer technology in line with increasing mobile broadband demand while at the same time supporting legacy users.

The M2M or IoT market has entered a rapid growth phase. Technology neutral spectrum licences are required to allow mobile operators to deploy dedicated networks optimised for IoT. Regulators should adopt a service and technology neutral framework to support IoT or they risk stifling the development of what is also referred to as the 4th industrial revolution.

However, some countries have not yet moved to technology neutral spectrum licences and are still issuing technology specific spectrum licences or have not decoupled spectrum licences from operating licences[1]. This means consumers and businesses do not benefit from the best possible mobile broadband experience and can pay more for an inferior service.

Due to an increase in data traffic enabled by the deployment of 4G, the bandwidth required for a backhaul link from a mobile base station site is now in the Gbit/s range. Licensing conditions for microwave backhaul spectrum must also keep up with mobile access technology development. If spectral efficiency is to be maximised, operators need to be free to deploy the latest technology. Where they still exist, capacity-based microwave spectrum regulatory fee structures need to be replaced so it becomes economically feasible to deploy Gbit backhaul.

2. Definition and history of technology neutrality

2.1 What do we mean by technology neutrality in spectrum licensing?

Technology neutrality is a principle used in many different contexts. In the context of mobile communications, technology neutrality enables the flexible use of subsequent 3GPP standards within licensed frequency bands.

Technology neutrality does not imply that mobile operators can do absolutely anything within a frequency band. There are a great many regulations that govern the deployment of radio communications networks including those designed, for example, to protect other spectrum users and to ensure that radiation limits are not breached.

Frequency bands are harmonised and identified for mobile broadband use[2] at a global – or regional - level at the ITU's World Radiocommunication Conference (WRC). The 3GPP then develops technical standards for radio equipment to make use of these harmonised bands. In practice this means that only standardised technology is used in mobile networks. Therefore, we can define technology neutral spectrum licences as "*licences which allow the deployment of any standards-based technology which complies with regulations in the licensed frequency band*".

The real focus of technology neutrality is to allow mobile operators to replace older equipment in a frequency band with equipment of a newer standard to move from 2G to 3G, or 3G to 4G or 5G. This process is also referred to as spectrum refarming.

There are other areas where technology neutrality also matters. For example, the wireless technology to be used for safety-related vehicle communications (i.e. V2X) should not be prescribed by regulators but it should be left to industry to select the technology based on their assessment of market evolution and technology benefits.

2.2 Moving from mandated technology to technology neutrality

To understand why spectrum licences were historically technology specific we need to look back to 1987, the year in which Europe produced the first GSM technical specification.

[1] It is best practice to issue spectrum licences separately from operating licences. The operating licence, which may be a unified licence, authorises the operation of a public telecommunications network. A spectrum licence confers the right to use the licensed spectrum.

[2] Known as an IMT identification at the ITU

In the early 1980s European countries used several different technologies. Equipment and handsets were very expensive and, with mobile penetration below 2%, the market grew very slowly. The objective of the European Groupe Spécial Mobile (GSM) project was to create a standardised market that was large enough for economies of scale to drive down network equipment and terminal (handset) prices which would in turn allow mass market adoption of mobile telephony.

Additionally, a common standard imposed across all European countries and networks would allow users to roam between countries and networks. By definition this meant that European countries had to mandate the use of GSM to the licences assigned to mobile operators. Consequently, in 1986 the European Commission proposed to mandate the use of GSM in the 900MHz band. The proposal was adopted and became legally binding in all EU countries.

GSM turned out to be a phenomenal success. The decision to develop a European mobile telephony standard resulted in unified, open, standard-based networks which together created a market which was larger than the market in the United States. The economies of scale and other features of the GSM standard eventually led to the global adoption of GSM which resulted in further economies of scale. In contrast, the US did not mandate a standard which allowed US operators to adopt the more successful GSM family's technology.

Initially GSM was specified in 900MHz (3GPP band 8) and subsequently 850MHz (band 5). 1800MHz (band 3) and 1900MHz (band 2) were added later. GSM is also referred to as 2G – 2nd generation mobile – to differentiate it from the earlier analogue cellular mobile technologies.

GSM evolved further to enable data services in the form of GPRS and EDGE. However, GSM was not optimised for data and this led to the development of a new generation - 3G – which is optimised for data. 3G, also referred to as UMTS or WCDMA, is based on a set of standards that comply with the International Mobile Telecommunications-2000 (IMT-2000) specifications of the International Telecommunication Union.

New spectrum was required to deploy 3G networks and initially 3G was standardised in 2100MHz (Band 1 in ITU Regions 1 and 3 and Band 4 in ITU Region 2). Again, it made sense to specify that the 2100MHz band should be used for 3G and hence most 2100MHz spectrum licences were technology specific to 3G.

The first commercial 3G networks were launched in 2003. It soon became apparent that it would be economically impossible to provide wide area 3G coverage using only 2100MHz spectrum. Operators were looking to deploy 3G technology in the 900MHz GSM frequency band. Therefore in 2005 3G was also specified in 900MHz. However, the technology specific nature of 900MHz licences prevented operators from legally deploying 3G in those bands.

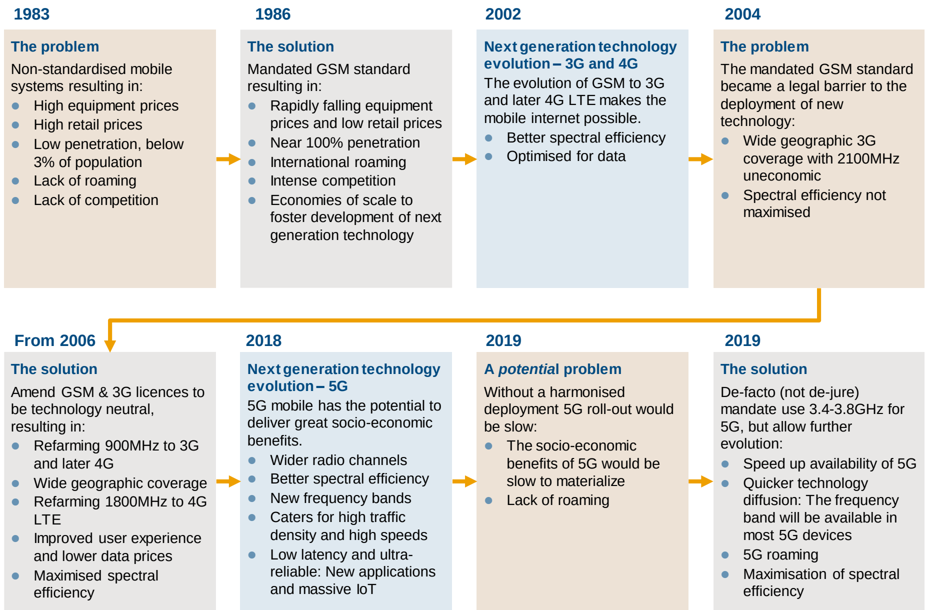
Nevertheless, in 2007 Elisa in Finland launched 3G in 900MHz with the approval of the Finnish telecoms regulatory authority, FICORA. Deploying 3G in 900MHz was in breach of European Union regulation, but it was recognised as a pragmatic development by FICORA which took into account a new reality: By 2007, mobile penetration in Europe had reached 100% and global mobile penetration stood at 50%. In other words, mandating a specific technology had delivered a standardised market which now no longer needed the protection of a mandated standard in order to flourish.

In October 2009 legislation caught up with reality with the publication of the European Commission's Decision "on the harmonisation of the 900MHz and 1800MHz frequency bands for terrestrial systems capable of providing pan-European electronic communications services in the Community". The decision allowed Member States to designate and make available the 900MHz and 1800MHz bands for UMTS (3G) and other terrestrial systems provided such systems can coexist with GSM systems and UMTS. The Decision was adopted on 5 November 2012 and paved the way for the introduction of LTE (4G) and soon 5G in these bands. This is what – in the context of this paper – constitutes technology neutral spectrum licensing for mobile services.

The 2100MHz band was the original 3G band and the technology neutrality decision allowed operators to deploy 4G and later technologies in this band. The decisions to modify the 900, 1800, and 2100MHz spectrum licences to make them technology neutral means that within the EU operators can deploy any standardised technology, including 4G and also 5G New Radio. It also led to the EU adopting the principle of technology neutrality for all mobile radio spectrum licences. All subsequent spectrum assignments such as 800MHz, 700MHz, 2600MHz were and are technology neutral from the outset.

European regulators are keen to promote the deployment of new technology because they recognise the socio-economic benefits this brings. This is relevant in the context of 5G and is addressed later in this report. The success of technology neutrality is evidenced by the fact that the 1800MHz band, originally the second GSM band, is now the world's most widely used band for LTE.

Exhibit 1: Regulating mobile technology use in the European Union



Source: Coleago Consulting Ltd.

3. Technology neutrality: A key element in delivering efficient use of spectrum

3.1 The ITU calls for rapid deployment of the latest technology

Spectrum is a scarce resource and the overriding objective in using spectrum is efficiency. With each generation of mobile communications technology evolution spectral efficiency improves. To achieve the objective of efficient use of spectrum, ideally the latest technology should be put into use as soon as it is available. This is recognised in the Constitution of the International Telecommunications Union (ITU):

Members shall endeavour to limit the number of frequencies and the spectrum used to the minimum essential to provide in a satisfactory manner the necessary services. To that end, they shall endeavour to apply the latest technical advances as soon as possible (Constitution of the International Telecommunication Union, Article 44, Paragraph 1).

The ITU explicitly recognises that the imperative of spectrum management is to ensure efficient use of spectrum and this is achieved by ensuring new technologies with a higher spectral efficiency in terms of bits per Hz are deployed as soon as possible.

Following the ITU prescription, virtually all jurisdictions have made efficient use of spectrum an explicit goal of spectrum policy with many countries incorporating this into relevant legislation, regulation or the mandate that guides the activity of regulatory agencies. Unfortunately, however, there are countries in Asia and Africa who have adopted practices which actively hold back new technology deployment.

In the past technology specific spectrum assignment was the norm – including in Europe - and for good reason. But, as explained below, the European Union and many other markets have subsequently adopted a technology neutral spectrum licensing approach which allows operators to deploy new technology in previously technology specific frequency bands.

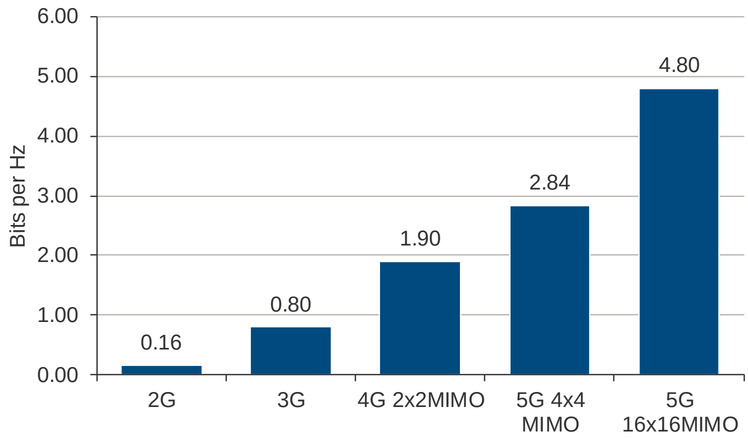
3.2 Mobile technology evolution: Delivering improved spectral efficiency and speed

Since its inception in 1987, GSM has become the global standard for mobile communications. GSM was optimised for voice communication, but the bandwidth required for data communications is vastly bigger than that required for voice communications. While new spectrum is assigned to mobile to cope with the increase in traffic, spectrum is always a scarce resource. Therefore, a key focus of technical development was and is to get the most out of every Hertz of spectrum, i.e. to maximise the spectral efficiency in terms of bits per Hz.

The addition of GPRS and EDGE to the GSM standard facilitated narrow-band mobile data communications, but what was required was technology to enable the mobile internet. The standardisation work of the 3GPP first delivered the UMTS 3G standard, followed by LTE (4G), LTE Advanced and now 5G New Radio.

Better modulation in 3G, then 4G and now 5G and the addition of Multiple-Input and Multiple-Output (MIMO) delivered significant improvements in spectral efficiency as illustrated in **Error! Reference source not found.**. Upgrading technology from GSM to 4G improves the spectral efficiency by a factor of 9. Furthermore, each doubling of MIMO increases average (as opposed to peak) spectral efficiency by a factor of 1.3.

Exhibit 2: Average spectral efficiences



Source: Coleago Consulting Ltd.

For data, GSMA has an average spectral efficiency of 0.16 bits per Hz. For HSPA (3G) this is 0.8 bits per Hz i.e. a 5-fold improvement. In other words, if an operator refarms one 2x5MHz block of 900MHz spectrum from GSM to 3G (HSPA) this would improve throughputs by a factor of 5. Furthermore, if an operator implements 2x2 MIMO in 3G, this increases the average spectral efficiency by 1.3 times to 1.04 bits per Hz. Thus an operator using the same amount of spectrum can deliver 6.5 times higher throughputs compared to GSM. However, MIMO in 3G is relatively rare whereas it is now common in 4G deployments.

4G (LTE) effective spectral efficiency depends on the 3GPP technology release and the age of handsets in the network. If an operator deploys, say, LTE release 10 in the 900MHz band the spectral efficiency gains are even bigger compared to 3G. Without MIMO the spectral efficiency for 4G is 1.46 bits per Hz compared to 0.8 bits/Hz for 3G (HSPA). LTE radios deployed today in sub-1GHz spectrum are invariably 2x2 MIMO hence the spectral efficiency for LTE in 900MHz is 1.9 bits/Hz compared to just 0.16 bits/Hz for GSM. This means if an operator refarms 900MHz from GSM to 4G, data throughout increases by a factor of 11.9.

As regards MIMO, in the frequency range below 1GHz up to 4x4 MIMO is possible. In 1800/1900MHz and 2100MHz up to 16x16 MIMO may be deployed. Hence refarming these bands from GSM or 3G to 4G delivers even greater gains in spectral efficiency.

The spectral efficiency is also important for voice. GSM voice spectral efficiency is only 33% that of data. This is relevant for markets where capacity for voice is an issue. In countries like Afghanistan, using 3G for voice yields enormous benefits in terms of capacity. For mobile phone users this means fewer blocked and dropped calls. For operators it means that investment can be directed to new technology rather than continuing to invest in legacy technology. This is most important for emerging markets where funding network investment, paid for in foreign currency, is always a problem. Moving to 4G (LTE) is even more important because it opens up the possibility of Voice-over-LTE (VoLTE). With VoLTE the spectral efficiency of voice approaches that of data.

The most talked about benefit of 4G over GSM and also 3G is the higher data speeds enabled by 4G. There are many factors contributing to the speed advantage of 4G LTE and LTE Advanced, including spectral efficiency, wide channels and carrier aggregation.

GSM (2G) data speeds were sufficient for messaging and email. 3G with two-carrier aggregation delivers 3G speeds of up to 43 Mbps. 4G enables even higher speeds. On 27th September 2018, Verizon announced that it had reached peak data speeds of 1.45 gigabits per second (Gbps) on LTE in a live commercial environment using six channel carrier aggregation, a key LTE Advanced technology. (Source: Verizon press release, 27 Sep 18, https://www.verizon.com/about/news/verizon-nokia-and-qualcomm-use-lte-advanced-technology-six-carrier-aggregation-reach-145-gbps)

3.3 The focus of spectrum management: Efficient use of spectrum

Spectrum is a scarce resource and hence one key objective of spectrum management is to ensure efficient use of spectrum. Efficient use of spectrum is a multi-dimensional concept. However, ultimately it can be defined as using spectrum in a manner which generates the greatest socio-economic benefit. In the age of mobile broadband, for users of mobile communications this means the ability to transmit the largest amount of data at the highest speed and the lowest cost to the user.

The higher spectral efficiency of 4G compared to GSM or 3G is a key element in delivering the efficiency goal:

- Using 4G (LTE) rather than GSM, operators can produce much higher levels of throughputs for the same cost, also referred to as a lower cost per bit. This enables mobile operators to offer their customers large data bundles without increasing the monthly cost to users. In other words, refarming from 2G to 4G delivers a significant consumer surplus. This is exemplified by the 4G (LTE) data pricing by Vodafone India. For the same price 4G enabled customers receive twice the data volume compared to 3G or 2G customers, see **Error! Reference source not found.** below.

- 4G (LTE) enables data transmission at much greater speeds in terms of Mbps compared to GSM or 3G. Data speeds are the key ingredient in delivering a good user experience. With LTE, apps respond quickly and video downloads as well as video telephony work without stalling or jitter. Regulators who prevent refarming to 4G deny the citizens of their countries the benefit of true mobile broadband enabled by 4G (LTE).
- Access to high speed mobile services also has a positive impact on the economy of the country and this is explained in chapter 4 of this paper.

Therefore, regulators should not prevent refarming or impose an additional cost on operators to make the investment and refarm spectrum used for GSM or 3G to LTE.

In competitive markets the efficiency gain of refarming is passed on to end-users in the form of lower retail prices for mobile data, i.e. there is a consumer surplus. Mobile operators offer larger data bundles for a given price and this is despite the additional investment required to deploy 4G. There is no incremental producer benefit in the sense that there are not incremental cash flows to investors.

- Mobile data traffic grew close to 88% between Q4 2017 and Q4 2018 (Source: Ericsson Mobility Report, Q4 2018). This is made possible because between 2018 and 2020 mobile network operators world-wide are investing US$ 480 billion in their networks, i.e. around US$ 160 billion per year. (Source: The Mobile Economy in 2019, GSMA).The vast majority of this investment is in LTE.
- While there is substantial incremental investment in the network for 4G radios and backhaul - both of which also push up network operational costs - mobile operator revenue is flat or declining as evidenced by research from Bank of America Merrill Lynch: *Globally, average mobile service revenue contracted 2.0% from a year ago as growth in Emerging Markets decelerated and Developed Markets' service revenue continues to decline, albeit at a slower rate. Revenue in developed markets declined -1.6% overall, with Asia-Pacific down 2.3%, North America down 0.6% and Develop EMEA down ~2.8% y/y. Emerging markets' service revenue declined 2.4% in 3Q18 vs. last year's growth of 3.4% with Emerging Asia declining 3.2%, Emerging EMEA flipping to negative 2.3%, and Latin America expanding +2.1%. (Source: Global Wireless Matrix, Bank of America Merrill Lynch, 21 December 2018, page 1)*
- **Error! Reference source not found.** illustrates why we are witnessing hardly any revenue growth when new technology is introduced. When Vodafone India launched 4G, customers with 4G devices and a 4G SIM received 2 GB of data for the same price that 3G customers pay for only 1 GB of data. Vodafone's revenue did not increase but as a result of Vodafone's investment in 4G customers see a 50% reduction in the price per GB of mobile data.
- At the beginning of April 2019, mobile operators in Korea announced their tariffs for 5G mobile. Depending on the tariff plan, in some instances 5G plans are cheaper than 4G plans. In early 2019 AT&T in the USA announced a 5G plan at rate of US$ 4.67 per GB compared to US$ 5 per GB for 4G.

The evidence clearly demonstrates that the notion that new technology results in additional revenue for mobile operators is erroneous. Therefore, it is inappropriate to charge operators for technology neutrality.

Exhibit 3: 4G brings lower data prices to consumers, Vodafone India

4G/3G **1 GB + 1GB** **Vodafone India LTE Offer**

MRP	RS. 297
Type	Internet pack
Talktime	RS. 0 — An extra free Gbyte with 4G
Benefit	1 GB @3G/4G speed. Post 1 GB you will be charged 4p/10kb. Additional 1GB data is available only on 4G handset, 4G SIM & 4G network
Validity	28 days

Source: Vodafone India website, June 2017

4. The economic benefit of technology neutrality

4.1 The impact of better mobile broadband speeds on GDP growth

Competition between mobile operators within a country drives innovation and notably investment in the latest mobile technology. Put simply, if an operator introduces 4G in a market it is able to offer not only a higher speed but also lower data prices, i.e. a greater data volume for a given price. Competing operators need to follow, or risk losing customers.

The beneficiaries of spectrum refarming are consumers and businesses who can now make use of affordable mobile broadband services. In short, mobile broadband, high mobile broadband speeds and increased mobile data consumption generate economic benefits. This view is supported by the findings of several studies in developed and emerging markets:

- A study found that refarming spectrum from 2G to 3G accelerates per capita GDP growth. *"For a given level of total mobile penetration a 10 per cent substitution from 2G to 3G increases per capita GDP by 0.15 percentage points."* The same study also found that the higher data volumes enabled by 3G (and by implication 4G and 5G) have a positive economic impact. *"A doubling of mobile data use leads to an increase in the GDP per capita growth rate of 0.5 percentage points."* (Source: The Impact of Mobile Telephony on Economic Growth, Deloitte, 2012)
- The key benefit of refarming spectrum to a new technology is that subsequent mobile generations deliver higher mobile broadband speeds. A study by Chalmers University of Technology investigated whether this would have a positive impact on GDP. "*The study found that the estimated coefficient of broadband speed is statistically significant. Doubling the broadband speed will contribute to 0.3% growth compared with the growth rate in the base year".* (Source: Does broadband speed really matter for driving economic growth? , Rohman et al, Division of Technology and Society, Department of Technology Management and Economics Chalmers University of Technology, Gothenburg, Sweden, 2012)

- 4G (LTE) is the first real mobile broadband technology. Allowing operators to refarm spectrum to 4G and 5G increases mobile broadband use*, "I find that – during this period – the increase in broadband connections per 100 people contributed to a cumulative GDP increase of 4.34% for the countries in the sample. A ten-line increase from 20 to 30 lines per 100 people leads to a 0.82% GDP impact but the effect diminishes with higher adoption rates. An identical ten-line increase from 10 to 20 lines yields 1.40%. This estimate is in line with previous findings by Koutroumpis (2009), Qiang and Rossoto (2009) and Czernich et al (2011)."* (Source: The economic impact of broadband: evidence from OECD countries, Pantelis Koutroumpis, April 2018)

The evidence is clear: Unleashing the competitive forces that drive innovation in mobile broadband should be a priority for policy makers. However, regulators in several countries still prevent market driven refarming or do not issue technology neutral spectrum licences. Such misguided policies come at a great cost to their countries in terms of foregone GDP growth.

The effect of a delay in introducing newer mobile technology has been quantified by the delay in the introduction of 3G in India. Thomas Hazlett estimates that the delayed launch of 3G services in India permanently cost the economy as a whole US$61 billion a year, or a cumulative total of US$1.25 trillion. (Source: Spectrum policy and competition in mobile services. Thomas W. Hazlett, The Policy Paper Series Number 12, May 2011)

4.2 Refarming spectrum from old technology to new technology

The term "refarming" refers to replacing an existing technology in a particular frequency band with a new technology in the same band, for example upgrading from 2G (GSM) to 4G. Operators have to be able to refarm from a legal perspective and need to carefully manage the transition to ensure that legacy customers are still served while satisfying the demands of customers with handsets which can make use of the new technology, such as 4G smartphones.

The issue of technology neutrality is most pressing for the following frequency bands:

- 900MHz and 850MHz where refarming from GSM to 3G and 4G is required
- 1800MHz and 1900MHz where refarming from GSM to 4G is the issue
- 2100MHz where refarming from 3G to LTE is required.

The deployment of 5G is imminent and hence refarming also concerns spectrum bands which were first used for 4G:

- 2600MHz (2500MHz), the 4G capacity band, is slated for early refarming to 5G-NR. During 1H 2019, Sprint in the US is introducing 5G-NR with Massive MIMO (64x64) in 2500MHz (3GPP Band 41), coexisting with current LTE-Advanced network in the band. According to Sprint, this increases data capacity by a factor of up to 10 compared to 4G.
- 800MHz (3GPP Band 20), the first digital dividend in ITU Region 1 (Europe, Middle east and Africa), is deployed as a 4G coverage band and operators who hold two blocks may refarm one block to 5G-NR as a 5G coverage layer. They could also employ the dynamic sharing capabilities of 5G to allow the radio resources in the band to shift between 4G and 5G based on live user demand in each cell.
- 700MHz (3GPP Band 28), the first digital dividend band in ITU Region 2 (Americas) and Region 3 (Asia Pacific) and now also licensed in ITU Region 1. It is a "5G candidate band" in Region 1.
- In North America operators who did not obtain any 600MHz spectrum at auction are looking to use 850MHz (3GPP Band 5) as the 5G coverage layer. The 850MHz was used first for 2G, then 3G and 4G and is now being refarmed to 5G.

As stated in chapter 5, refarming spectrum from older technology such as GSM or 3G to 4G and soon 5G delivers benefits to mobile broadband users. The adoption of LTE enabled handsets is progressing rapidly but in many markets there are still a substantial number of legacy 2G and 3G handset users. Operators seek to optimise network resources and serve all types of customers, 2G, 3G and 4G. In doing so MNOs have to provide coverage and capacity for all technologies.

- As regards coverage, this poses a problem in relation to sub-1 GHz. Many countries, particularly in South-East Asia, are behind in freeing up 700MHz (band 28) and assigning it to mobile. This means below 1 GHz mobile operators only have the 900MHz and is some cases 850MHz band available for wide area coverage. In this narrow frequency assignment, they now have to operate three technologies: 2G, 3G and 4G.
- With regards to capacity, a similar problem arises. Three technologies need to be catered for. This is why operators carefully calibrate the deployment of 4G in the 1800MHz, 1900MHz and 2100MHz bands without affecting quality of service for 2G and 3G customers.

Refarming does not mean that older technologies are no longer available to serve customers with 2G or 3G handsets. Todays' technology allows 'graceful refarming' of spectrum from 2G or 3G to 4G or 4G to 5G. LTE can be introduced in, for example, 1.4 or 3 MHz of 900MHz spectrum so that 2G or 3G can run simultaneously in the same 5MHz block. Or, for example, if an operator has 2x10MHz of 700MHz spectrum, 4G and 5G can run alongside, each in a 2x5MHz block but in the same radio.

Assigning spectrum to different technologies is adjusted based on demand. Operators observe the decline in GSM voice traffic and 3G data traffic and the growth in 4G data traffic. Based on this they make refarming decisions to ensure that:

- Each customer group, irrespective of the technology of their handsets, is served well in terms of quality of service and coverage.
- For mobile broadband services the production cost per bit is as low as possible.
- As a consequence of achieving a lower cost per bit, mobile broadband customers pay as little as possible per Gbyte of data.

Clearly, it would not be helpful to have a telecoms regulator mandate the pace of refarming because they do not know how traffic will evolve month by month. Refarming decisions are best left to operators because this delivers benefits to end users in terms of the best possible user experience and low retail prices.

However, in several countries operators have been or are still prevented from reacting to market demand because national regulatory agencies keep in place outdated technology specific spectrum licences which prevent the deployment of new technology in 900/850MHz, 1800/1900MHz and 2100MHz.

4.3 Switching off 2G and 3G networks to extract greater economic value from spectrum

The decommissioning of legacy 2G and 3G networks is gathering pace. Some operators in Asia, including Taiwan, Macau, Japan, Hong Kong, Singapore, and Korea have already switched off their 2G networks. Some operators plan to leave a thin 2G layer open for many years and switch off 3G before 2G.

Operators determine the timing of decommissioning legacy technology in relation to the evolution of their customer base and the market they operate in. Relevant factors include:

- Number of 2G / 3G customers
- Traffic generated by customers with 2G / 3G devices
- Progress on VoLTE enablement among the 4G customer base

- Contractual requirements in relation to 2G / 3G IoT (M2M) customers

While operators may anticipate the evolution of these factors, final decisions as to when to turn off 2G or 3G are made close to actual dates. It is imperative that operators have the flexibility to decide for themselves the timing of decommissioning legacy technology and refarm spectrum to newer technology based on market demand and business needs.

Some network operators have taken proactive steps to migrate customers to 4G in order to accelerate the switch-off date of 2G or 3G. It is not practical nor indeed helpful for a regulator to mandate the timing of switch-off for the operators.

The flexibility required in 2G and 3G switch-off timing is one more reason why it is important to have technology neutral spectrum licences. As long as a mobile operator is obliged to use whole bands for 2G and 3G in parallel to 4G due to technology-specific licences, a disproportionate amount of spectrum is tied up serving a shrinking number of legacy technology customers. As explained in section 3.2, 4G is a much more spectrally efficient technology delivering a higher throughput and speed. In short, gradually moving to 4G or even 5G based on user demand will improve the user experience for mobile broadband customers and extract greater societal value from spectrum. Therefore, regulators should not delay the timely decommissioning of legacy 2G and 3G networks.

There may be instances where regulators are concerned with service continuity for users who have not yet acquired a 4G handset. As mentioned in section 4.2 above, the issue is mitigated by the use of 'graceful refarming', i.e. new technology can be introduced without entirely switching off 2G or 3G. Nevertheless, these concerns are legitimate because in low-income countries it is usually the poorest citizens in a country who are affected by 2G or 3G shutdowns. However, regulators could use other mechanisms to maintain a minimum service, for example by using the Universal Service Fund to pay for one operator to keep a thin 2G layer in operation, possibly with other operators roaming onto this GSM network, or by funding a scheme to replace legacy 2G/3G handsets.

5. Spectrum for 5G and IoT

5.1 5G will be introduced in new and existing frequency bands

5G will be introduced in low (sub-1 GHz), mid (1 to 6GHz) and high frequency (24GHz and above) bands. Some of the spectrum has not previously been used for mobile services and these are referred to as new bands. Other bands are already in use for mobile (referred to as 'existing bands') but in time will be refarmed to 5G.

Exhibit 4: Low, mid and high frequency bands for 5G

Category	Frequency range	Comment
Low-bands	< 1 GHz	Mostly existing bands, but depending on the region and timing of spectrum assignment 700MHz and 600MHz may go straight to 5G
Mid-bands	1 GHz to 2.6 GHz	Mostly existing bands which will be refarmed, but depending on the country some new bands e.g. 2300MHz may go straight to 5G
Mid-bands	3.3 GHz to 6 GHz	These are normally new bands for *mobile* usage so will be used by mobile operators for 5G. Notably there is some legacy fixed-wireless access (e.g. LTE or WiMAX).
High bands	> 24 GHz	New bands for 5G

Source: Coleago Consulting Ltd.

New frequency bands

New frequency bands that have typically not previously been used for mobile broadband include 3GHz (3.3 to 4.2 GHz), 26 GHz, 28 GHz, 40, 66-71 GHz – and in some cases 600 MHz and 700 MHz (explained in more detail below). Consistent with best practice, we expect that these bands will be assigned to mobile network operators (MNOs) as technology neutral licences but MNOs are expected to use them for 5G NR from the outset - in the same way that MNOs used new 4G bands (800MHz, 2600MHz) for 4G from the outset.

Regulators should verify during the consultation stage prior to a spectrum assignment whether a potential licensee has the intention to deploy non-5G technology. If this is the case, an agreement is required to support 5G as a national priority (e.g. agreeing base frame structures, facilitating negotiations between participants etc). This is unlikely to happen but it is possible in two situations, particularly in the 3.5 GHz frequency range:

- 3.5 GHz spectrum is set-aside for non-MNOs such as industrial users (verticals) who do not plan to use 5G-NR
- If legacy 3.5 GHz Fixed Wireless Access (FWA) licences are made technology neutral and the incumbent does not plan to deploy 5G-NR.

In these instances, a discussion with the operators needs to take place at national level to reach consensus without undermining the development of 5G. These discussions are foreseen to be more complex if private networks are expected to operate in the band. This is due mainly to the large number of diverse users, their varied needs and their limited spectrum assets to address their requirements using alternative bands.

To avoid such issues, regulators should aim to defragment the 3.5 GHz band to maximise the spectrum that can be made available for 5G and should refrain from setting aside spectrum for verticals and other usage which may complicate commercial 5G deployments. However, if 3GHz spectrum is set aside for non-mobile operators or verticals, then these users should be required to align their frame structure and synchronise with the mobile operators.

Existing frequency bands

Existing frequency bands below 3 GHz will be gradually refarmed. Ultimately this will include all existing bands but refarming will start earlier in some bands and later in others. Not only will different bands be refarmed at different times, but even within a particular frequency band reframing will be gradual. This is the case when 4G is introduced in 1800MHz. Initially MNOs refarmed 2x5MHz to LTE while running 2G in the remainder of their 1800MHz spectrum holdings.

As discussed previously, 3GPP 5G standards allow 4G and 5G to coexist in the same band in a single radio either side by side, say each with 2x5MHz or using Dynamic Spectrum Sharing. This allows ‘graceful refarming’ by aligning the spectrum resources used for 5G with the diffusion of 5G capable devices among an MNO’s customer base. At the Mobile World Congress in February 2019, Ericsson and Intel demonstrated 4G combined with 5G dynamic spectrum sharing enabling 4G and 5G traffic to run simultaneously on the same frequency carrier. For every millisecond, the split of simultaneous 4G and 5G capacity is adjusted to secure an optimal performance for any mix of 4G and 5G active devices on the network. This minimises spectrum wastage and results in excellent support for different types of users.

5.2 The 700MHz band

700MHz (Band 28) has been labelled a 5G candidate band, in the sense that in Region 1 it is likely to be used as the first 5G coverage layer. However, under no circumstances should 700MHz (band 28) be described as a 5G band, chiefly because it is already used for 4G. 700MHz (3GPP band 28) is already widely deployed in Asia, Australia, New Zealand, and Latin America as a 4G (LTE) coverage layer. There is an excellent eco-system as most 4G smartphones feature band 28.

Several countries in South East Asia and Latin America have to assign the 700MHz spectrum to mobile operators. As stated above, while the 700MHz band has been labelled a "5G candidate band" this does not mean that 5G should be mandatory.

- For operators in countries which have not yet assigned 700MHz, once it is assigned to mobile operators their primary objective will be to roll out a 4G coverage layer. Many of their customers will already have 4G handsets which include the 700MHz (Band 28). These customers would immediately benefit from the availability of 700MHz 4G coverage.
- As of February 2019, there are no smartphones which support 5G-NR. If there were a regulatory obligation to use the 700MHz band for 5G-NR, the capacity would be wasted because existing smartphones do not have 5G-NR.

This leads to the conclusion that 700MHz should be assigned adhering to the principle of technology neutrality. This would allow operators to initially operate the 700MHz as 4G and migrate to 5G later.

The most recent radios are multi-mode and allow for Dynamic Spectrum Sharing, i.e., they support 4G and 5G. For example, an operator who obtains 2x10MHz of 700MHz spectrum might initially use the full 2x10 for 4G. Over time more and more users will obtain 5G handsets and once this reaches a critical mass, the operator would gradually switch spectrum resources to 5G. The timing of this decision depends on technology diffusion among the customer base (i.e. the market) and can even be done dynamically so spectrum resources automatically shift according to demand in the cell. Therefore, the decision as to when to deploy 5G should be market led - decided by the operator - rather than by regulatory requirement.

5.3 The 600MHz band

The 600MHz band is in use in the US and will soon be deployed in Canada. The band illustrates the benefit of technology neutrality when assigning new bands to MNOs.

- In February 2017, T-Mobile of the US acquired 600MHz spectrum and deployed 4G in this band. At that time the 5G-NR 3GPP specification had not yet been finalised and hence only 4G smartphones with 600MHz were available. In 2019 5G smartphones in 600MHz are becoming available and T-Mobile will use part of its 600MHz spectrum for 5G as a coverage layer.
- In Canada, the 600MHz spectrum has been assigned only in 2019 and will be fully available in 2020. By then handsets which incorporate 600MHz 5G-NR will be available and Canadian MNOs are likely to run 4G and 5G in this band.

In both cases, the salient point is that the radio equipment that is being installed by MNOs is software defined, i.e. it is both 4G and 5G. This further illustrates that it does not make sense to restrict the use of spectrum to a particular technology.

5.4 Refarming existing spectrum licences to 5G

All 3GPP frequency bands used for 2G, 3G or 4G have now been specified for 5G. As explained in Chapter 4.2 above, the process of refarming spectrum to 5G has started. In time all existing frequency bands will be refarmed to 5G. In most cases refarming will start prior to licence expiry but this poses a problem in some countries because spectrum has been licensed technology specific for 4G. This tends to be the case for 800MHz (3GPP Band 20) and 2600MHz (3GPP Band 7) in some African and Asian countries.

- Senegal provides an example of issuing a technology specific 4G licence. The 800MHz licence issued to SONATEL (Décret n° 2016-1081 du 03 août 2016 portant approbation de la convention de concession et du cahier des charges de la SONATEL, 3 août 2016) has a duration of 17 years and is technology specific to 4G, i.e. it refers to 4G spectrum. It is highly likely that prior to the expiration of the 4G licence that the operator will want to refarm at least on 2x5MHz block of the 800MHz to 5G.

In Bangladesh following the 4G auction completed in 2018 spectrum licences are labelled “technology neutral” but operators require a 4G operating licence. It does not make sense to introduce technology neutrality in the spectrum licence but restrict the operating licence to 4G. Furthermore, under Article 18. Spectrum Assignment, the licence condition states that “The Licensee shall take prior permission and/or License from the Commission for usage of spectrum beyond 4G/LTE technology.” This means in effect the spectrum licences are not technology neutral. The mobile operators had to pay to convert existing 2G spectrum holdings in the 900 and 1800 MHz bands into technology neutral spectrum. The issue of technology neutrality for new spectrum licences is highly relevant because several regulators do not appreciate that in issuing 4G technology specific spectrum licences they are highly likely to bring about a situation that leads to a delay in the introduction of 5G. There are several reasons why issuing licences restricted to 4G is particularly inappropriate:

- Operators who deploy 4G radios will in fact deploy multi-mode radios which are capable of 4G and 5G with a software upgrade. Today’s specifications allow 4G and 5G to operate in the same radio. This means the future refarming from 4G to 5G is easier compared to the refarming from 2G to 3G or 3G to 4G.
- 2019 will see a ramp-up of commercial 5G mobile deployments, i.e. 5G is already a reality. Regulators who issue 4G spectrum licences are limiting the use of spectrum to what will in 10 years’ time be a legacy technology.

5.5 5G policy objectives and technology neutrality

Given its potential to transform economies, most policy makers aim for a timely introduction of 5G in their respective countries. Spectrum assignment can play a role in this but does not warrant a departure from the principle of technology neutrality. European policy provides a good example of this:

The Commission’s Communication ‘Connectivity for a Competitive Digital Single Market — Towards a European Gigabit Society’ (6) sets out new connectivity objectives for the Union to be achieved through the widespread deployment and take-up of very high-capacity networks. To this end, the Commission’s Communication ‘5G for Europe: An Action Plan’ (7) identifies the need for action at the EU level, including the identification and harmonisation of spectrum for 5G based on the opinion of the Radio Spectrum Policy Group (RSPG), in order to ensure the objective of uninterrupted 5G coverage in all urban areas and major terrestrial transport paths by 2025.

Clearly, rolling out 5G is an overriding policy objective. In line with the EU decision, the conditions for licences in 3.4-3.8GHz set by several European regulators mandate that operators meet certain 5G deployment targets - but crucially it is left to MNOs to decide in which bands 5G should be deployed and which of these are used to meet any targets. For example, in Germany the regulator Bundesnetzagentur mandates the deployment of 1,000 5G base stations by the end of 2022 and requires high speeds as well as low latency (Source: Entscheidung, 26. Nov 2018). However, the terms of the licence do not mandate that this must be achieved with 3.5GHz spectrum, i.e. the 3.5GHz licences are technology neutral.

In this way we can see that 5G policy objectives can still be met without needing to compromise the principle of technology neutrality. As stated above, it is unlikely that an MNO would want to use a technology other than 5G is this band. Technology neutrality remains important over the 15 to 20-year term of 3.5 GHz licences as it empowers operators to gradually upgrade to technologies beyond 5G as they become available.

5.6 Technology neutrality in the context of IoT and verticals

The M2M or IoT market has entered a rapid growth phase. Technical developments that enable low-power wide area IoT as well as massive machine type communication are important components of developing the digital economy.

Regulators should adopt a service and technology neutral framework to support IoT rather than stifling development. Regulatory restrictions of the technology to be used would be particularly harmful in this fast-growing market. Mobile operators should not be prevented from deploying the latest cellular IoT technologies in their licensed spectrum bands.

Two 3GPP standards LTE-M (also known as eMTC, LTE Cat-M1) and NB-IoT (also known as LTE Cat-NB1) are expected to be central to delivering on the vast potential of the Internet of Things by offering major advantages over legacy alternatives. However, technology-specific licences will restrict their usage and thus the potential for countries to benefit from advanced IoT.

Building new NB-IoT and LTE-M networks may also help carriers move IoT customers off aging 2G cellular networks. It is of course essential to migrate legacy M2M customers from GSM or 3G to new technology, or else the spectrum cannot be completely refarmed to 4G and 5G. This again reinforces the need for existing mobile licences to be technology neutral – especially given the use of existing infrastructure will enable rapid IoT rollouts.

6. Policy and regulatory consideration to deliver efficient use of spectrum

6.1 Technology restrictive practices persist in some countries

The European Union's mandated use of GSM in 900/850MHz and 1800/1900MHz was copied in most other markets but without taking on board the rationale for doing so. However instead of following the example of the European Union and adopting a pragmatic approach to modifying licences to allow operators to deploy 3G and 4G technology, many countries in Asia and Africa retained a restrictive approach.

Making existing spectrum licences technology neutral became to be seen by some governments as a revenue raising opportunity. This held back the deployment of new technology which meant consumers and business did not benefit from the best possible mobile broadband services and also suffer from higher prices than would otherwise be the case.

Regulators who prevent operators from using the latest technology in any frequency band are very likely to be in conflict with their own mandate to ensure efficient use of spectrum as well as the Constitution of the ITU. Not only is this bad practice from a purely regulatory viewpoint but more importantly MNOs paying again for licences they have already purchased is damaging for the economies of these countries.

Charging for making spectrum technology neutral is effectively a barrier to investment because it introduces a disincentive to invest in new technology. This runs contrary to the fundamentals of economic management. Investment should be actively encouraged and not disincentivised through what becomes effectively a refarming tax.

6.2 Government initiatives are needed to accelerate the transition to 4G and 5G

Virtually all governments explicitly recognise the need to take action in order not to fall behind in making 5G services available to businesses and consumers. Technology neutral spectrum licences are part of this.

As explained above, moving to a spectrally more efficient technology accelerates GDP growth and results in a significant improvement in the mobile data user experience. Rightly governments seek to maximise efficient use of spectrum as well as consumer benefit. Therefore, rather than holding up the refarming of spectrum used for 2G and 3G to 4G and later 5G, telecoms regulators should seek to create the conditions which accelerate refarming.

The key to facilitate rapid technology migration is to accelerate the diffusion of 4G and later 5G devices. This might include a public information campaign to raise awareness. Parallels can be drawn to the initiative to raise public awareness to facilitate migration from analogue to digital TV in order to deliver the digital dividend.

Governments might also consider lower import duties on 4G enabled handsets to close the retail price gap between simple 2G phones and 4G phones.

6.3 Technology neutrality and spectrum licence renewal

Spectrum licence renewal provides an opportunity to re-write spectrum licences to make the technology neutral. However, tying technology neutrality to spectrum licence renewal is likely to delay the introduction of 4G and 5G in existing frequency assignments.

In some cases, transitional issues may arise in a situation where competing mobile operators within a country have different licence expiry dates. If technology neutrality is tied to the renewal, then this may create a market distortion because one operator might be able to introduce 4G in the 900MHz band whereas others may not be able to do so. In this situation the operator who can deploy 4G in sub-1GHz spectrum would have gained a competitive advantage in terms of 4G coverage, i.e. there may be a 4G monopoly in certain geographical areas. To avoid such an outcome, it would be best to apply the principle of technology neutrality as early as possible - without waiting for the spectrum licence renewal date - to all spectrum licences in all frequency bands simultaneously.

6.4 Microwave backhaul spectrum licences adapted for the age of mobile broadband

An estimated 56% of backhaul connections are by means of microwave (MW) (Source: Mobile backhaul options Spectrum analysis and recommendations, GSMA, November 2018, page 2). In most countries the licensing regime for MW backhaul was developed in the days of GSM when there was relatively little data traffic and backhaul link capacity in the order of Mbit/s was sufficient. Since then, we have seen an exponential increase in mobile data traffic. The bandwidth required for a backhaul link from a mobile base station site is now in the Gbit/s range, i.e. a thousand-fold increase. With LTE Advanced and later 5G backhaul bandwidth requirements not only increase driven by the growth in traffic, but also by the lower latency requirements.

This means that licensing conditions for MW backhaul must keep up with mobile access technology development:

- If spectral efficiency is to be maximised, operators need to be free to deploy the latest technology. Outdated technical licence conditions should be replaced with conditions that reflect the latest advances in spectrum management and interference mitigation.
- Regulatory or licensing fees for backhaul spectrum must not be based on capacity (Mbit/s) or they will become unsustainable. In several countries in Africa and Asia charging for backhaul spectrum is based on formula that increases spectrum fees proportionally to the link capacity in terms of Mbit/s or proportionally to the amount of spectrum in terms of MHz. The thousand-fold increase in required capacity would increase backhaul costs by a factor of a thousand. Clearly this is not sustainable.

7. Conclusion

The refarming of spectrum from legacy 2G and 3G technology to 4G and soon 5G delivers significant benefits in terms of spectral efficiency and efficient use of spectrum. Efficient use of spectrum and consumer welfare are key policy goals. Therefore, telecoms regulators should take steps to make all existing spectrum licences technology neutral.

Rather than slowing down the process of refarming spectrum to 4G and hindering investment in new technology by delaying technology neutrality and / or charging operators additional fees, regulators should welcome and encourage the process. Studies have shown that better mobile broadband speeds resulting from the transition to 4G accelerate GDP growth and deliver significant consumer surplus.

While spectrum licence renewal provides an opportunity to re-issue spectrum licences as technology neutral, regulators should not delay the introduction to technology neutrality while waiting for the expiry dates of spectrum licences.

When assigning new spectrum, regulators should do so in a technology neutral manner or at the very least not restrict the introduction of successor technologies, such as 5G and in the longer term any evolution of 5G.

8. Case studies

8.1 Introduction

Assigning technology neutral spectrum rights has been considered best practice for over a decade. Consequently, most regulators around the world, including those in the European Union, North America, Singapore, Hong Kong and Australia have adopted the principle of technology neutrality for mobile spectrum licences.

There is a pattern where countries with a liberal regulatory regime and which adopted technology neutrality early on delivered the best outcome for their countries, as is evidenced by two examples:

- In Europe, Finland was the first to allow the 900MHz to be technology neutral which meant mobile users benefited from far greater geographic 3G coverage than other European countries.
- In Asia, technology neutrality in Singapore resulted in one of the world's most advanced mobile markets where consumers are the beneficiaries of high speed, low latency and low-cost mobile communications services.

However, some countries in a misguided attempt to extract additional revenue from spectrum licensing held back technology neutrality and still are not fully committed to the principle of market led deployment of new technology in mobile networks. Below we present two case studies which demonstrate the socio-economic damage caused by such restrictive practices.

8.2 Bangladesh: The 4G laggard is likely to become a 5G laggard

For many years mobile users in Bangladesh have suffered from a low grade of voice service and extremely low data speeds because BTRC, the telecoms regulator, did not make available sufficient spectrum and did not allow operators to refarm spectrum to 4G. This restrictive policy was driven by the desire to extract the maximum revenue from auctioning additional spectrum. BTRC only allowed the deployment of 4G in existing and new spectrum following the conclusion of the spectrum auction in February 2018. As a result, Bangladesh acquired the dubious distinction of being one of the last – if not the last – country to benefit from 4G, behind Afghanistan and behind African countries with a much lower per capita GDP than Bangladesh.

"*We are not happy*" was how Shahjahan Mahmood, Chairman of the Bangladeshi Telecoms Regulator BTRC, assessed the outcome of the spectrum auction which concluded on 13th February 2018.

BTRC had put up for auction 36 MHz of 1800MHz, 50 MHz of 2100MHz, and 6.8 MHz of 900MHz spectrum. Having set a reserve price of US$ 540 million for 1800MHz spectrum, US$ 675 million for 2100MHz, and US$ 102 million for 900MHz, BTRC expected to receive US$ 1,317 million from operators. In the event Grameenphone bought 10MHz of 1800MHz spectrum and Banglalink 11.2MHz whereas Robi did not buy any spectrum . The state-owned operator TeleTalk did not even show up for the auction. Total auction receipts amounted to only US$ 464 million, i.e. 65% below the BTRC's target and 66% of the spectrum remained unsold. This was a strikingly bad outcome in terms of raising revenue and clearly shows that the strategy not to introduce technology neutrality did not pay off.

The macro-economic cost of the delay in introducing 4G can be calculated using the findings of the Chalmers University study cited in chapter 4 above. The study found that a doubling of broadband speeds contributes an additional 0.3% of GDP growth. 4G was launched in Asia from 2012 onwards. For example, 4G was introduced in Pakistan in September 2014. Had it not been for prohibition on refarming spectrum to 4G, mobile operators in Bangladesh would have launched 4G service in 2015. In the event, the regulatory obstacle delayed the launch of 4G to 2019. By using the difference in the spectral efficiency between 3G (0.8 bit/Hz) and 4G with 2x2MIMO (1.9 bits/ HZ) as a proxy we can calculate the uplift in broadband speed by a factor 2.38. Refarming 1800MHz spectrum from GSM to 4G would have generated an incremental annual growth of GDP of 0.36%. Over the 4-year period 2015 to 2018 this amounts to US$ 2.99 bn. This is GDP forgone due to not making spectrum licences technology neutral. Set against this, the auction receipts of US$ 464 million are relatively small.

In the wake of the BTRC imposed long delay in the introduction of 4G in Bangladesh, Government policy may change. "*Bangladesh will be one of the first countries in the world to deploy the 5G mobile technology … this is my promise for the next election*", announced Sajeeb Wazed Joy, the Prime Minister's ICT affairs adviser (Dhaka, 25th of July).

However, the chances of delivering this promise are slim. Under Article 18. Spectrum Assignment, the licence condition set out the following:

- 18.02 The spectrum assigned in favour of the Licensee as a technology neutral shall be usable/applicable to 4G/LTE and beyond technology.
- 18.03 The Licensee shall take prior permission and/or License from the Commission for usage of spectrum beyond 4G/LTE technology.

This means in effect the spectrum licences are not technology neutral. This being Bangladesh, operators are likely to experience delays and might have to pay additional fees when they want to introduce 5G.

8.3 Ghana: Competitive distortion by creating an LTE monopoly

Prior to the 800MHz spectrum in December 2015 mobile operating licences in Ghana were not technology neutral. This meant Ghanaian businesses and consumers could not benefit from 4G mobile services until 2016 whereas, for example, in Angola 4G was launched four years earlier in 2012.

In 2015 the NCA, the regulatory authority of Ghana, set extremely high reserve prices for 800MHz (Band 20) spectrum. The 800MHz licences were technology neutral. The mobile operators in Ghana advised the NCA that with the extremely high prices for spectrum there was no business case. In the event only MTN bought 800MHz spectrum and proceeded to launch 4G in that band thus becoming the monopoly mobile 4G provider. From a regulatory perspective this was a sub-optimal outcome because competition and telecoms policy should focus on fostering competition and not damaging it.

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Finally, in December 2018, a second operator (Vodafone) acquired 800MHz spectrum and with it the right to launch 4G services. However, AirtelTigo (a company created through the merger of the previously independent operators Airtel and Tigo) and Glo still do not offer 4G.

Competition was not the only casualty of the misguided approach to technology neutrality. The NCA could have decided to make 1800MHz licences technology neutral. This would have enabled operators to use the spectrum in part for GSM and in part for 4G. Indeed, some of the newer equipment had software defined radios and operators would have been able to launch 4G cheaply and quickly. Instead by only allowing 4G in 800MHz the NCA imposes additional network capital expenditure on operators. This is not in the interest of the operators or their customers. Of course, the 800MHz radio has to be imported and paid for in foreign currency and hence it is also detrimental to the country’s balance of payments.

Appendices

Appendix A: Spectral efficiency

Exhibit 5: Average spectral efficiencies - detail

	Sub-1GHz and above			Above 1GHz	
Bits / Hz	No MIMO	2x2 MIMO	4x4 MIMO	8x8 MIMO	16x16 MIMO
2G	0.16	n/a	n/a	n/a	n/a
3G	0.80	1.04	n/a	n/a	n/a
4G	1.46	1.90	2.47	3.21	4.17
5G	1.68	2.19	2.84	3.69	4.80

Source: Coleago Consulting Ltd.

Appendix B: GDP loss in Bangladesh

Exhibit 6: GDP lost due to delay in 4G

US$ bn	2014	2015	2016	2017	2018
GDP	172.85	195.08	221.42	248.72	285.82
Annual GDP loss	-	0.62	0.69	0.79	0.89
Cumulative GDP loss	-	0.62	1.31	2.10	2.99

Source: Trading Economics and Coleago Consulting

Drivers:

Increase in GDP growth for double broadband speed: 0.3%

Average spectral efficiency of 3G: 0.8 bits/Hz

Average spectral efficiency for 4G with 4x4MIMO: 1.9 bits/Hz

Increase in mobile broadband speed from refarming: 2.38 times