Spectrum for Mobile Services in the Middle East

White Paper

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About Plum

Plum offers strategy, policy and regulatory advice on telecommunications, spectrum, online, and audio-visual media issues. We draw on economics, our knowledge of the sector and our clients' perspectives to shape and respond to convergence

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1 Introduction

This White Paper addresses the requirement for sufficient and suitable mobile spectrum, to meet the ever-increasing demand for new services and higher quality of service. It considers how coverage and capacity requirements of end users can be delivered based on best practice around the world and the associated socio-economic benefits that mobile broadband can deliver.

The paper highlights the approaches and specific measures that could be implemented by administrations and governments in the Middle East to maximise the identified benefits arising from mobile services.

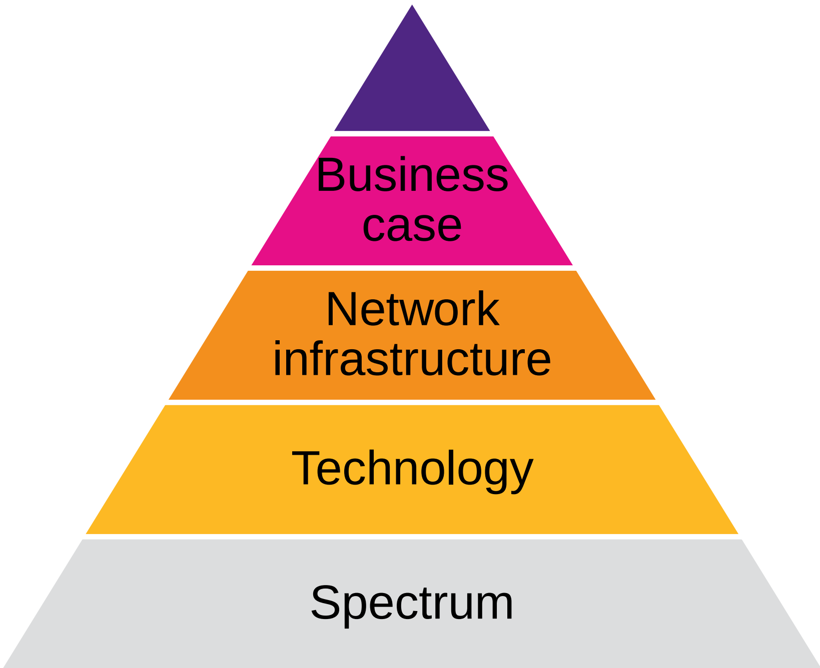
2 The role of spectrum in mobile

To provide the Middle East with a competitive Mobile Service that is both financially feasible and provides a high Quality of Service (QoS) it is important that sufficient mainstream harmonised spectrum is made available in a timely fashion.

The selection of mobile technology for a given spectrum band may be constrained by the size of the allocations or assignments. Hence, constraints on the frequency spectrum available will impact or determine:

- The network infrastructure required; the number of sites, the network capacity and capability and the cost of deployment.
- What an operator can or cannot offer to the users within the constraints of the spectrum.
- A ceiling for how successful an operator business can become by capping certain features and services, or future developments.

Figure 2-1: Key considerations for the delivery of mobile services

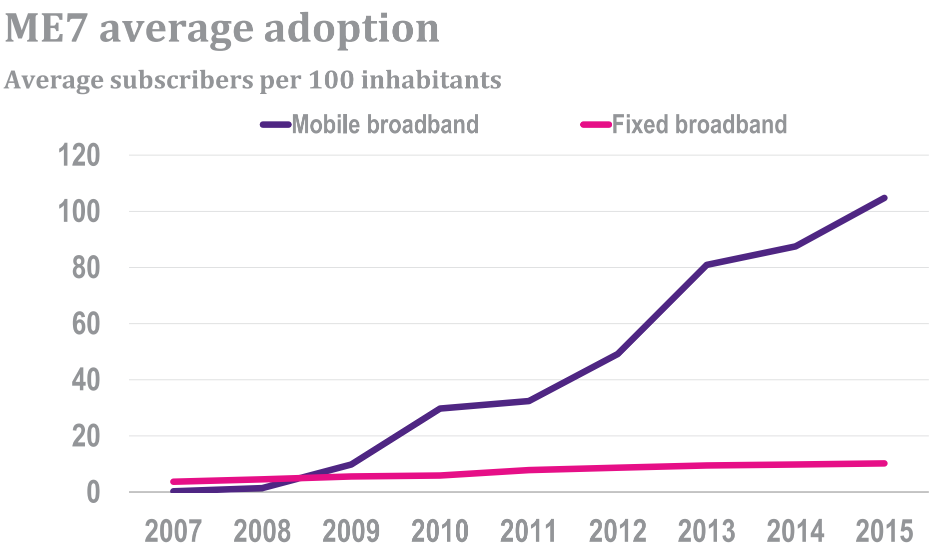


Sufficient contiguous spectrum (from the global ecosystem) enables mobile to deliver an increasing range of innovative digital solutions and services, which in turn enable increased socio-economic benefits.

2.1 The importance of the mobile market

Mobile market services are evolving at an ever-increasing pace; this is even more the case in areas where there is less fixed access infrastructure[1]. In these areas, mobile services are used as a substitute for fixed services[2] in addition to the provision of mobility. This requires additional spectrum resources. Figure 2-2 shows the increasing take up of mobile broadband in comparison to fixed.

Figure 2-2: Comparison of mobile and fixed broadband adoption in Middle East



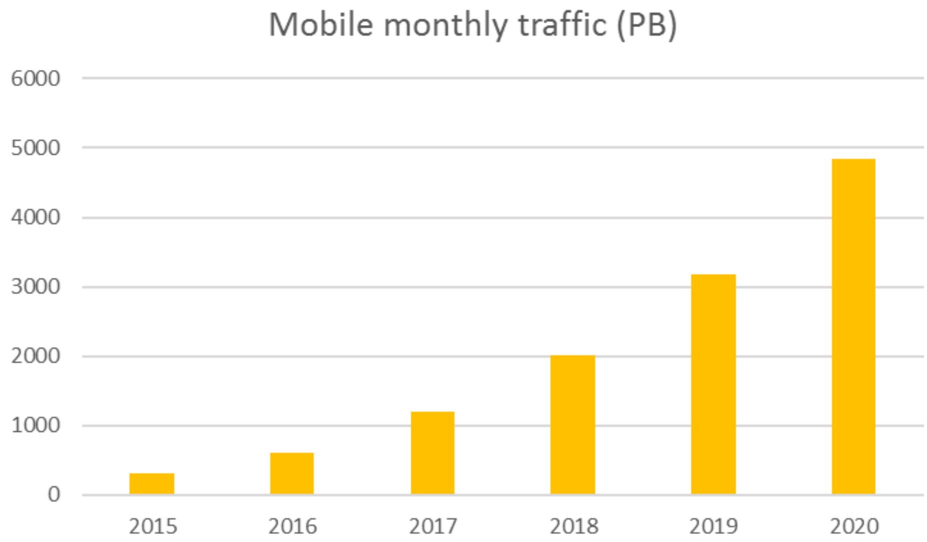
Source: Plum Consulting, ITU

Mobile networks are now predominantly supporting data services (with the exception of legacy 2G networks, although investment in these is very low). Whilst in the future, the forecasts from Cisco and others are that Internet browsing, emails, voice calls and messaging will continue to grow, the higher bandwidth services, mainly video, will grow even faster. Cisco forecasts that video will make up 78% of total mobile traffic by 2021. There will also be a developing market supporting M2M and IoT applications, many of which require low data rates but will play a key role in delivering new services to a wide range of sectors including healthcare, agriculture, smart cities, and transportation.

[1] This can often be due to the difficulty of installing cable and fibre economically

[2] Improvements in both network quality and coverage support this substitution.

Figure 2-3: Traffic growth projections for Middle East and Africa



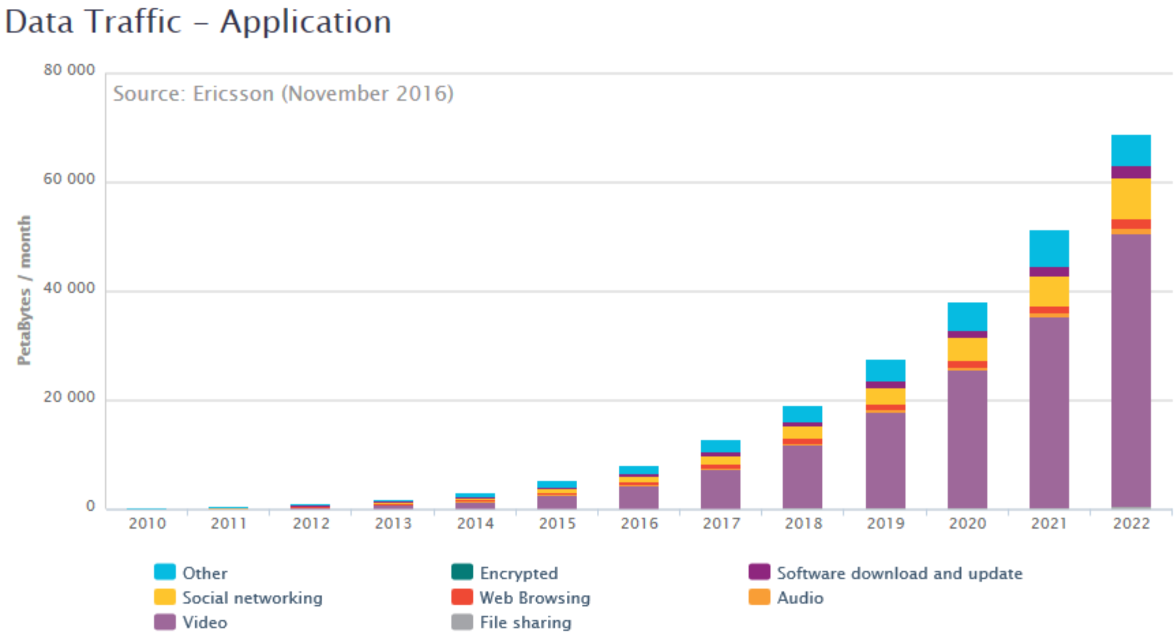
Source: CISCO VNI 2017

Figure 2-3 shows Cisco's projection of total monthly mobile traffic for the ME and Africa regions. Consumer focused services make up much of the total monthly traffic with the expectation that:

- consumer web and other date will increase from 434.02 PB in 2017 to 1113.2 PB in 2020, a 2.5 times increase, and
- consumer video from 627.4 PB to 3270.8 PB, an increase of 5 times over the same period.

Similar increases are forecast by Ericsson as shown in Figure 2-4 below.

Figure 2-4: Traffic growth projections by application



Source: Ericsson (November 2016)

Beyond 2020, networks implemented with the latest 4.5G (and potentially 5G) technology will be better suited to support industrial applications as they utilise more advanced features that deliver appropriate levels of quality of service (QoS) for the services being supported. This could include massive connection capability (support 100 times the current number of devices in a cell), higher speeds (10 Gbps peak rates), lower latency and improved energy performance. This more diverse feature set means that mobile services will not just be high-bandwidth connectivity aimed at the consumer market. The mobile network will become an enabler for businesses to use as a platform that underpins the commercialisation and delivery of their products and services. There is already considerable resource being applied to development of industry vertical applications and this is expected to continue.

The mobile ecosystem is developing rapidly through a combination of development of improved mobile data access capability, broader support of IP services, rapid innovation in the software and applications market and an increasing willingness to adopt. However, it needs enough of the right spectrum for this to happen.

Spectrum to support mobile networks has grown considerably beyond the initial frequency bands of 900 MHz[3], 1800 MHz and 2100 MHz. According to the Global mobile Suppliers Association (GSA) there are now 7037 LTE devices available across the harmonised mobile bands in ITU Regions 1, 2 and 3 and of these the smartphone form factor has the largest eco-system with around 65% of all the different LTE device types. The number of devices available for the paired and un-paired mobile bands[4] are shown below in Figure 2-5 and Figure 2-6:

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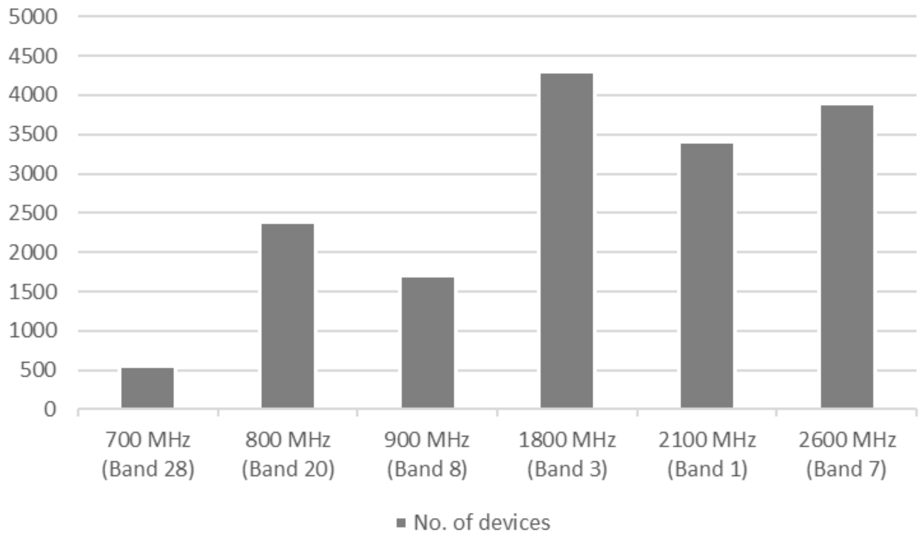
[3] In some countries in the Middle East the 850 MHz band (Region 2 mobile allocation) was used to deploy CDMA technology and this reduced the available 900 MHz spectrum due to potential interference issues.

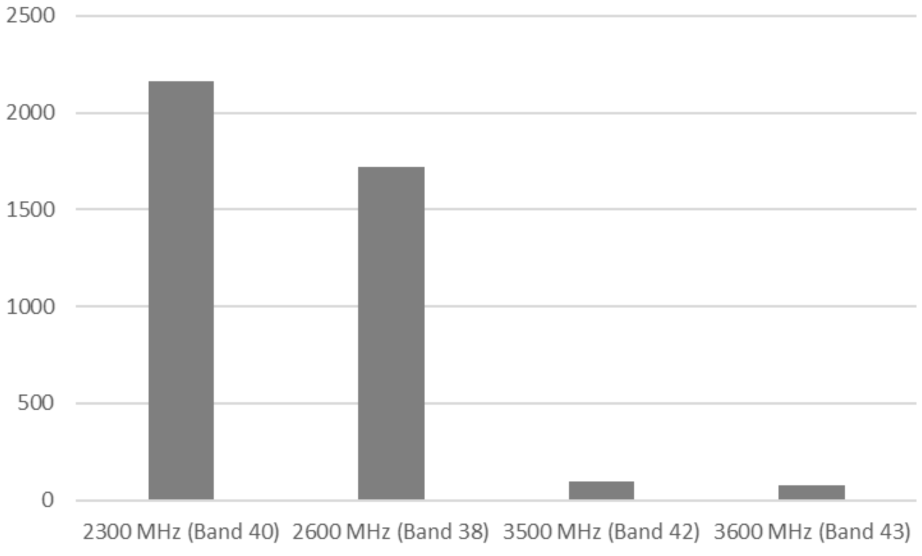
[4] “Status of the LTE Ecosystem”, January 13, 2017

Figure 2-5: LTE devices available in FDD (paired) spectrum by frequency band



Source: GSA data, January 2017

Figure 2-6: LTE devices available in TDD (un-paired) spectrum by frequency band



Source: GSA data, January 2017

The 1800 MHz band has by far the largest ecosystem of devices, approximately 65% of all LTE device types, which is reflected in the number of 1800 MHz networks deployed globally (achieved by refarming 2G spectrum). The first LTE networks were launched in Q4 2009 and at the end of January 2017, according to the GSA, there were 581 commercially launched LTE networks[5], 274 in the 1800 MHz band.

[5] 183 operators were deploying LTE-Advanced or LTE-Advanced Pro technologies in 87 countries

2.2 Impact of mobile

Current and new digital services, such as those noted above, will be important in driving future economic growth in the Middle East[6]. While information and communications services make up a relatively small proportion of the total contribution to the world's economy (1.4% contribution from the mobile ecosystem[7]), their true significance lies in their ability to augment and transform the rest of the economy (3.1% contribution from indirect benefits[8] and increases in productivity[9]). This contribution could be significantly higher in areas where no fixed infrastructure is in place because mobile services also substitute for fixed services.

Telecommunications services have a large economic impact through their contributions to GDP, employment and productivity. Mobile communications, including mobile broadband, are major contributors to these benefits. The impact on GCC countries and Iran are shown in Table 2-1.

Table 2-1: Country-specific impact of Telecommunications

Country	Economic Impact
Bahrain	Overall, telecommunication sector has: • Created 2,600 jobs since 2002 (3,200 employees currently), and • Contributed 4% of GDP in 2015[10].
Iran	The National Broadband Network (of which mobile broadband is part): • Created more than 100,000 jobs, and • Supported the introduction of electronic government in February 2017[11].
Kuwait	In total, Kuwait's telecommunications industry: • Contributed 4.86% of GDP to 2010-2012, and • Total output was approx. $9.54 billion (KWD 2.9 billion)[12]. Total revenue generated by the three main wireless operators in 2014 was approx. $2.47 billion (KWD 753 million)[13].
Oman	Overall, the telecommunication sector: • Provided employment, with full time employees (equivalent) of 4,010 staff by end 2015 (TRA and service providers)[14], and • Generated revenue of approx. $2.1 billion (RO 803.5 million) in 2014. Mobile services contribute 76% of revenue ($1.8 billion)[15].
Qatar	The CRA reported that the telecommunication sector contributed 1.7% of GDP in 2016 (increase from 1.3% in 2014)[16].

[6] In 2015 the GSMA estimated that the contribution to GDP (direct and indirect) was 4% in the MENA region.

[7] Data from the GSM Association report "The Mobile Economy 2017"

[8] Indirect benefits will arise from spending on other goods and services due to earnings and profits from mobile. GSMA estimated this to be around 0.6% of total contribution to GDP in 2016.

[9] Increased productivity arises from use of mobile. GSMA estimated this to be 2.5% of total contribution to GDP in 2016.

[10] http://www.tra.org.bh/en/about-us/background.html

[11] http://www.iran-telecom.info/iran-telecom-market.html

[12] https://prezi.com/d8_zn4jlvqp9/competition-assessment-of-the-kuwait-telecom-sector/

[13] http://www.marketstoday.net/includes/download.php?file=aa_143832.pdf&lang=en&m=analyst

[14] https://www.tra.gov.om/pdf/tra_annual_report_eng.pdf

[15] https://www.tra.gov.om/pdf/annual_report_2014_eng.pdf

Country	Economic Impact
Saudi Arabia	ICT sector estimated to contribute 6% of total GDP by year end-2015 (10% if oil is excluded)[17].
UAE	In 2012, it was estimated that UAE telecommunications sector: • Provided 5% of GDP, and • Employed 7,961 people[18].

The GSMA estimates that the productivity impact of mobile was approximately $58 billion in the Arab States (GCC and non-GCC) in 2014.[19]

Evolution and impact of mobile networks are becoming increasingly important to facilitate economic development. Qatar's Vision 2030 aims for *Suitable Economic Diversification* identifies that "A knowledge-based economy" will be supported by, amongst others, "… a world-class infrastructural backbone" [20,21]. Developing a knowledge-based economy will require access to the Internet and will be essential to support learning and research; the accessibility of mobile broadband will be key to support this.

The Government of Saudi Arabia are the most active in placing importance on digital infrastructure, outlining in their Vision 2030 document[22] that it "is integral to today's advanced industrial activities". The Government set a specific goal "to exceed 90 percent housing coverage [of information technology infrastructure, especially high-speed broadband] in densely populated cities and 66 percent in other urban zones." With this consideration, the accompanying National Transformation Program 2020[23] identifies frequency spectrum available to all telecommunications services (Strategic Objectives 4)[24] and available to provide broadband services to all KSA regions (Strategic Objectives 5), with the aim of increasing the percentage of wireless broadband networks coverage to 70% of remote area, with a minimum speed of 10Mbps[25,26].

Mobile networks are becoming essential to enable international links to the Middle East. The Abu Dhabi Vision 2030[27] (UAE) notes: "Telecommunications developments are facilitating the growing role played by the international trade in services in the share of the global economy", whereas Bahrain Vision 2030[28] plans to "be fully linked to the global trade and information highways by 2030" and notes

[16] http://www.cra.gov.qa/en/news/cra-2016-market-assessment-reflects-maturity-mobile-market-125b-investments-17-gdp-contribution

[17] http://www.citc.gov.sa/en/mediacenter/annualreport/Documents/PR_REP_011Eng.pdf

[18] UAE TRA Annual Report 2015

[19] GSMA, 2016, "The Mobile Economy: Arab Sates 2015." Available at: https://www.gsmaintelligence.com/research/?file=7910cff3a3e6f96219cd50e31d6d3e1c&download

[20] http://www.mdps.gov.qa/en/qnv1/Pages/default.aspx

[21] Abu Dhabi Vision 2030 (UAE) similar notes that "It is vital for Abu Dhabi's involvement in this knowledge economy of the future that it has a world class telecommunications infrastructure…"

[22] http://vision2030.gov.sa/en

[23] http://vision2030.gov.sa/sites/default/files/NTP_En.pdf

[24] Strategic Objectives 4 aims to increase percentage of frequency spectrum available from 42% baseline in 2016 to 80% by 2020.

[25] The third key performance indicator of Strategic Objectives 5 aims to increase wireless broadband networks' coverage (more than 10 Mbps) in remote areas from 12% baseline in 2016 to 70% by 2020.

[26] National Transformation Program 2020, Available at: http://vision2030.gov.sa/sites/default/files/NTP_En.pdf

[27] https://www.ecouncil.ae/PublicationsEn/economic-vision-2030-full-versionEn.pdf

[28] http://www.bahrainedb.com/en/about/Pages/economic%20vision%202030.aspx#.WRMdquXytPZ

telecommunications services as essential to provide a stable base for businesses. Similarly, using mobile to support better connectivity will enable Kuwait to achieve its 2035 Development Plan[29] *Global Position* aim to "enhance Kuwait's regional and global presence in the sphere such as diplomacy, trade, culture and philanthropy."

Provision of mobile services can also have a wider economic impact (further discussed in Section 3.3 of this paper). Economic growth can be stimulated by the productivity gains delivered by mobile, particularly mobile broadband. Access to services would support "economic growth [to be] driven by increased productivity in the private sector" (Bahrain's Economic Vision 2030[30]). Mobile can also support inclusion and equality[31], an aim of Oman's Vision 2020[32]: "Enhance the standard of living of citizens and reduce disparities among regions and different income groups, and ensure that all citizens benefit from the development process."

The importance of digital services to the economy will only grow as advancements in technology and deployment bring about changes to the way in which consumers and businesses use communications. Further discussion is provided in Section 3.3.

2.3 Challenges that might restrict the mobile market

Whilst spectrum access is the focus of this white paper as insufficient suitable spectrum[33] will impact the ability of operators to support the full range of mobile services, there are a number of other areas that contribute to the success, or otherwise, of the mobile market and these include:

- Conditions of access to spectrum. If spectrum is made available on unfavourable or unrealistic terms this might lead to spectrum remaining unused. For example, this might be due to high spectrum fees, excessively demanding coverage obligations, constraints applied to mobile deployment in busy or dense areas (often due to other national services) or the potential for in country or cross border interference.
- The regulatory environment. It is essential that the regulatory regime provides certainty to the mobile operators and encourages investment in their networks. For example, international connections and interconnection to backbone networks should be readily available at a transparent and reasonable price. Gaining access to new and existing sites should be a simple, low cost and non-bureaucratic process. Licences should allow operators to develop their networks to match with market demand and be technology-neutral.
- The market. In the Middle East, demographics and geography differ significantly between countries. In many places it is currently not economically or even practically feasible to cover some rural areas; examples (but not limited to) are Saudi Arabia and Iran.
- Operator competition. There is some evidence that three to four mobile network operators have been sustained and supported in large and developed mobile markets, such as the UK and

[29] http://www.newkuwait.gov.kw/pillars-cpt/global-position-en/?lang=en

[30] http://www.bahrainedb.com/en/about/Pages/economic%20vision%202030.aspx#.WRMirOXytPZ

[31] This is further discussed in Section 3.3.3.

[32] http://www.scp.gov.om/en/Page.aspx?I=14

[33] To ensure minimum cost network roll-out it is essential that the frequency bands are harmonised and supported by the standards developed in 3GPP[33] and consequently there is a well- established ecosystem.

Europe[34]. However, the optimum number of operators will vary by country- and market-specific factors. In markets with fewer network operators, operators may be able to invest significantly more in their wholesale and customer services. Regulators will need to monitor, and as necessary act, to ensure that the market is competitive[35], and providing high quality of service and competitive pricing, to benefit consumers. However, in some smaller countries where two or three operators are active - there may not be sufficient consumer demand (subscribers) to support an additional operator and this enhanced competition may lower operator margin and the ability to invest in the network. Additionally, more operators may result in proportionally less spectrum being available to each one and this may have adverse impacts on operators who are capacity constrained. In both instances, the outcome would be a lower quality of service for consumers.

2.4 Mobile spectrum

To meet forecast traffic demands mobile operators have a limited number of options available but after optimising the existing network to the level that is technically and financially feasible, often the only option left is to invest in additional spectrum.

Current bands

The currently harmonised frequency bands that are already licensed or where there are plans to licence in Region 1 are:

Table 2-2: Harmonised spectrum bands for Region 1[36]

Below 1 GHz (3GPP designation)	Above 1 GHz (3GPP designation)
452.5 – 457.5 / 462.5 – 467.5 MHz (Band 31)	1710 – 1785 / 1805 – 1880 MHz (Band 3)
703 – 733 / 758 – 788 MHz (Band 28)[37]	1920 – 1980 / 2110 – 2170 MHz (Band 1)
832 – 862 / 791 – 821 MHz (Band 20)	2300 – 2400 MHz (Band 40)
880 – 915 / 925 – 960 MHz (Band 8)	2500 – 2570 / 2620 – 2690 MHz (Band 7)
	2570 – 2620 (Band 38)

[34] Within the UK, the number of operators has consolidated from five to four following the 2010 merger of Orange and T-Mobile to become EE. However, in 2015, Three's proposal to acquire O2 (and subsequently reduce the number of operators to three) was blocked by the Competition and Markets Authority. In July 2014, the European Commission cleared Telefónica's acquisition of E-Plus which reduced the number of operators in the German market to three.

[35] Competition in consumer markets can also be supported by MVNOs. Oman and Saudi each have four and three MVNOs (in 2015), respectively, who rival the network operators by penetrating key consumer segments (youth and migrant workers). The UAE regulator also aimed to increase market competition with reforms that gained interest from two prospective MVNOs. Source: https://www.gsmaintelligence.com/research/?file=7910cff3a3e6f96219cd50e31d6d3e1c&download

[36] Region 1, as defined by the International Telecommunications Union (ITU), comprises Europe, Africa, the former Soviet Union, Mongolia, and the Middle East west of the Persian Gulf, including Iraq. Iran is located in Region 3 (Asia pacific) but in general the frequency bands are the same with the main difference being the 700 MHz band (Band 28) where there is potentially 703 – 748 MHz paired with 758 – 803 MHz.

[37] It is noted that Saudi has awarded spectrum in the 700 MHz band, namely 698-733 / 753-788 MHz. This overlaps, in part, with Band 68 (700 Middle East) which is for 698 – 728 / 753 – 788 MHz, with additional frequencies from Band 28

Below 1 GHz (3GPP designation)	Above 1 GHz (3GPP designation)
	3400 – 3600 MHz (Band 42)
	3600 – 3800 MHz (Band 43)
Total spectrum below 1 GHz: 200 MHz	**Total spectrum above 1 GHz: 960 MHz**

Future bands

It is essential to be aware of bands that might be adopted in future. In particular, the 1500 MHz band which has been identified as a Supplementary Down Link (SDL) band in Europe in 1427 – 1452 MHz and 1492 – 1518 MHz[38] (SDL has been selected to optimise the use of the available spectrum and to address the increasing trend of asymmetrical traffic in FDD). Additionally, 3GPP has recently identified L-band TDD arrangements as Band 50 (1432 – 1517 MHz, bandwidth 85 MHz) and Band 51 (1427 – 1432 MHz, bandwidth 5 MHz) which may be adopted in the future. There are also studies ongoing in respect of the 2 GHz band with proposals to extend the available spectrum for IMT[39].

There are also WRC-19 candidate bands for 5G[40] namely:

- 24.25 – 27.5 GHz, 37 – 40.5 GHz, 42.5 – 43.5 GHz, 45.5 – 47 GHz, 47.2 – 50.2 GHz, 50.4 – 52.6 GHz, 66 – 76 GHz and 81 – 86 GHz where there are already primary allocations to mobile, and
- 31.8 – 33.4 GHz, 40.5 – 42.5 GHz and 47 – 47.2 GHz where mobile is not currently identified as a primary allocation.

In addition, there is still continued interest in the 27.5 – 29.5 GHz band in the US and South Korea[41] and in Europe the European Commission has mandated CEPT to fast track the 24.25 – 27.5 GHz band to be available for 5G before WRC-19.

In the Arab Spectrum Management Group (ASMG) there is support to undertake studies for the 24.25 – 27.5 GHz, 31.8 – 33.4 GHz, 40.5 – 42.5 GHz and 42.5 – 43.5 GHz bands. A number of bands have been identified for possible early deployment for 5G (IMT-2020), namely: 1427 – 1518 MHz, 3400 – 3600 MHz, 3600 – 3700 – 3800 MHz and 24.25 – 27.5 GHz. In the case of the latter two bands they are not currently allocated to the mobile service / IMT.

Trials are already underway in the region. For example, Etisalat in UAE is focussing on 5G deployments and trials[42], Ooredoo in Qatar has conducted tests on 5G trial systems[43] and STC (Saudi Telecom Company) has agreed to a pre-commercial trial[44].

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[38] The 1452 – 1492 MHz band was already identified for SDL as described in ECC Decision (13)03. This Decision is currently being revised to take account of the extended frequency band now available at 1500 MHz in Europe (mandated by the EU Commission). The band is being studied in the ITU in preparation for WRC-19.

[39] The bands 1980-2010 / 2170-2200 MHz are under study in WRC-19 Agenda item 9.1.1. 3GPP is looking into proposals to add it to LTE bands. The band 2010-2025 MHz is LTE band 34. It can be paired with 2585-2600 MHz (LTE band 16). There are some proposals to identify 2090-2110 & 2200-2215 MHz and pair them with LTE bands 33 & 34.

[40] The World Radio Conference 2015 (WRC-15) identified a number of suitable frequency bands above 20 GHz for 5G. WRC-19 Agenda item 1.13 is addressing WRC-15 Resolution COM 6/20 which identifies a number of frequency bands that were identified for further study (Sharing and compatibility studies).

[41] It was excluded from the list for further study as the 27.5 – 30 GHz band is identified as a core globally allocated Ka-band for the Fixed Satellite Service (FSS).

[42] https://www.khaleejtimes.com/technology/uae-to-see-5g-trial-runs-in-2017

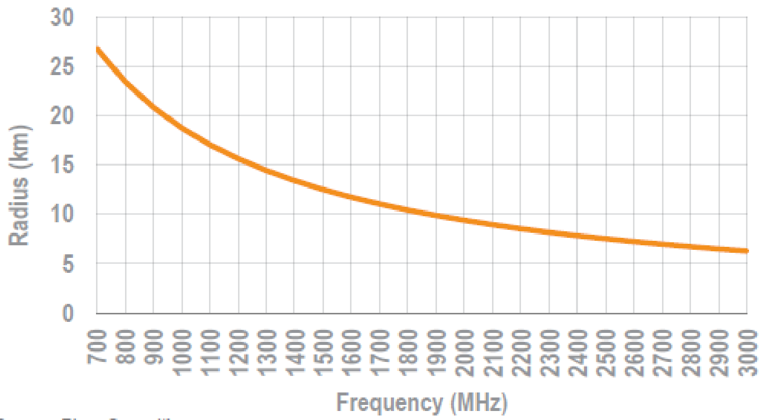
[43] http://www.capacitymedia.com/Article/3646269/Ooredoo-reaches-record-5G-trial-tests-in-Qatar.html

Spectrum characteristics

In general, lower frequency spectrum is best suited to provide large area outdoor coverage and also indoor coverage because of its propagation capabilities. It can allow a network to be rolled out with larger average cell radius so fewer cells are required to provide coverage as shown in Figure 2-7. The ideal spectrum for coverage is typically below 1 GHz. Operators with limited or no spectrum below 1 GHz are at a significant disadvantage in geographic areas where there are no capacity considerations as they have to invest in and deploy many more sites than operators with spectrum below 1 GHz.

However sub-1 GHz bands provide limited bandwidth so it is important that operators can access more than one sub-1GHz frequency band. Carrier aggregation[45] allows support of increased bandwidth. This provides the ability to support higher speed data services in less populated geographic areas.

Figure 2-7: Maximum cell radii by frequency band



Source: Plum Consulting

Once the coverage network layer is achieved, spectrum above 1 GHz is ideally suited to provide additional capacity as it can typically support higher bandwidths (there is more spectrum and it can support wider carriers). It is for this reason that the 1800 MHz band is now extensively used to support an LTE ecosystem. Other bands will increase in importance as licences are awarded and deployments increase and there is likely to remain a degree of substitution between bands such as 2600 MHz and 3600 MHz due to their similar propagation and overall bandwidth characteristics.

FDD vs TDD

In the past, traffic (mainly voice, SMS and low speed data) was symmetrical - similar capacity was required in the uplink and downlink. Paired (FDD) spectrum was ideal for this. Data services on the other hand typically require greater capacity in the downlink (for example, for video). Time division duplexed (TDD) spectrum is more suited to data services as it supports asymmetric downlink versus uplink capacity. The ratio between downlink and uplink may typically be 3:1.

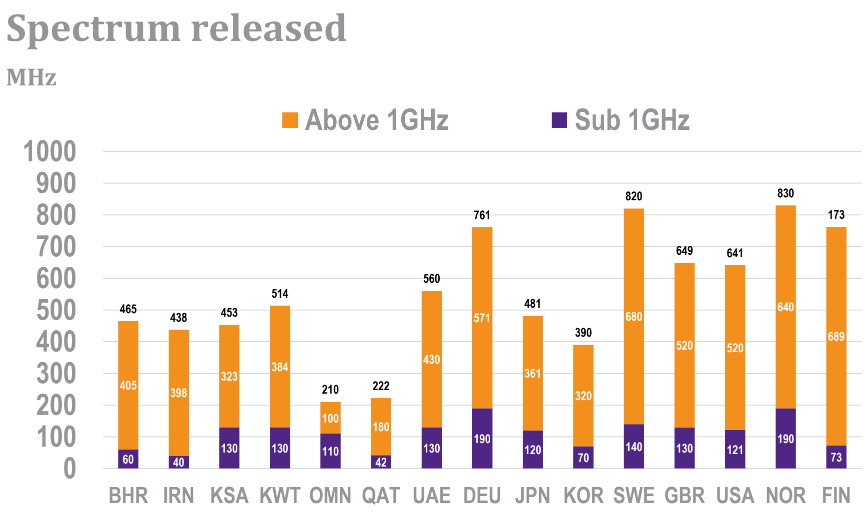
[44] http://www.argaam.com/en/article/articledetail/id/449753

[45] The maximum carrier aggregated bandwidth is 100 MHz. This is based on 5 component carriers each having a maximum bandwidth of 20 MHz (although they can be of different bandwidths). The number of aggregated carriers can be different in the down-link and up-link for FDD. The carriers can be in the same or different frequency bands.

International best practice

In Figure 2-8 we compare spectrum awarded in selected Middle East countries with those in other regions. The majority of the Middle East countries all have access to significantly less spectrum than has been licensed in other benchmark countries. This is particularly relevant when comparing the situation with other countries in Region 1 where spectrum has already been released (refarmed) and awarded in the 800 MHz bands[46] and also the 1500, 2300, 2600 and 3500 MHz bands.

Figure 2-8: Comparison of spectrum supply



Source: Plum Consulting, national regulators

Note that Figure 2-8 shows the spectrum released in frequency bands which may support mobile services if the assignments were awarded on a technology- and service-neutral basis. In some countries, spectrum may be assigned to operators providing fixed wireless access rather than mobile services; therefore, the quantity of spectrum released in the benchmarks shown may be overstated if interpreted as spectrum dedicated for mobile broadband services only.

2.5 Different mobile technologies

Spectrum efficiency in terms of sector throughput per MHz has improved substantially as mobile technology has developed from 2G to 3G and now 4G with the potential for 5G in early deployment in the next 4 to 5 years. In Table 2-3 a comparison is made in terms of relative capacity performance across different radio systems starting with 3.5G (HSPA). Capacity in terms of spectral efficiency has improved, on average, around 2-3 times across successive technology releases, driven largely by advances in physical layer modulation and multiple antenna technologies[47]. 4G is often up to ten times

[46] In a limited number of countries 700 MHz spectrum has also been refarmed and awarded

[47] It should be noted that some of the later capacity increases may not be achievable in handsets where it is difficult to implement large numbers of MIMO antennas.

faster than 3G in real-world use. Carrier aggregation[48], where it is possible to combine multiple cellular frequencies, can support data speeds up to 450 Mbps[49].

Table 2-3: Successive capacity performance improvement across cellular radio systems (indicative)[50]

Common reference	Technology, 3GPP standard	Functional parameters	Downlink peak channel data rate (Mbps)[51]	Successive capacity performance improvement [52]	Cumulative capacity performance improvement
3.5G	HSDPA, 3GPP Rel. 5	WCDMA, 16-QAM	14 (5 MHz band)	× 1	× 1
3.75G	HSPA+, 3GPP Rel. 8	WCDMA, 64-QAM, 2×2 MIMO	42 (5MHz band)	× 3	× 3
3.9G	LTE, 3GPP Rel. 8	OFDMA, 64-QAM, 4 × 4 MIMO[53]	300 (20MHz band)	× 1.79	× 5.37
4G	LTE-A, 3GPP Rel. 10	OFDMA, 64-QAM, 8 × 8 MIMO	3000 (100 MHz band)	× 2	× 10.74
Mean successive capacity performance improvement:				× **2.26**	

Source: Plum Consulting

The specifications for mobile technology standards are defined by 3GPP (3rd Generation Partnership Project). It defines new, more efficient technologies, services and features, in its series of 'Releases'. The recent Releases (13 and 14) support LTE-Advanced Pro, which allows for combined use of licensed and unlicensed bands and increased spectrum aggregation[54], and provision of NB-IoT and LTE-M technologies[55]. LTE-Advanced Pro is viewed as an intermediate standard before 5G which is to be introduced in around 2020[56] with 3GPP Release 15.

In the MENA region, there was still considerable deployment, in 2016, of 2G technologies as shown in Figure 2-9 below. In comparison, in Europe most 2G networks have been refarmed by operators to 3G and 4G technologies as well as new spectrum being awarded that has been deployed for 4G. This

[48] Carrier aggregation is supported in the 3GPP standards

[49] The actual achievable speed will fluctuate depending on how far the user is from the network base station.

[50] Source: Plum Consulting analysis, April 2016.

[51] See: http://www.3gpp.org/technologies/keywords-acronyms/99-hspa , accessed April 2016.

[52] Provided for guidance only (bandwidth normalised to 5 MHz). Peak channel data rates represent potential maximal rates attainable by one user under 'laboratory conditions'. In practical systems, many users share capacity on a system scheduled basis. Further, practical systems introduce performance degradations, such as inter-cell interference, and user capacity is variable according to distance from base station. It is useful however to gain some perspective on the relative levels of performance enhancement across successive systems.

[53] Includes minimal multi-user (MU) MIMO capability.

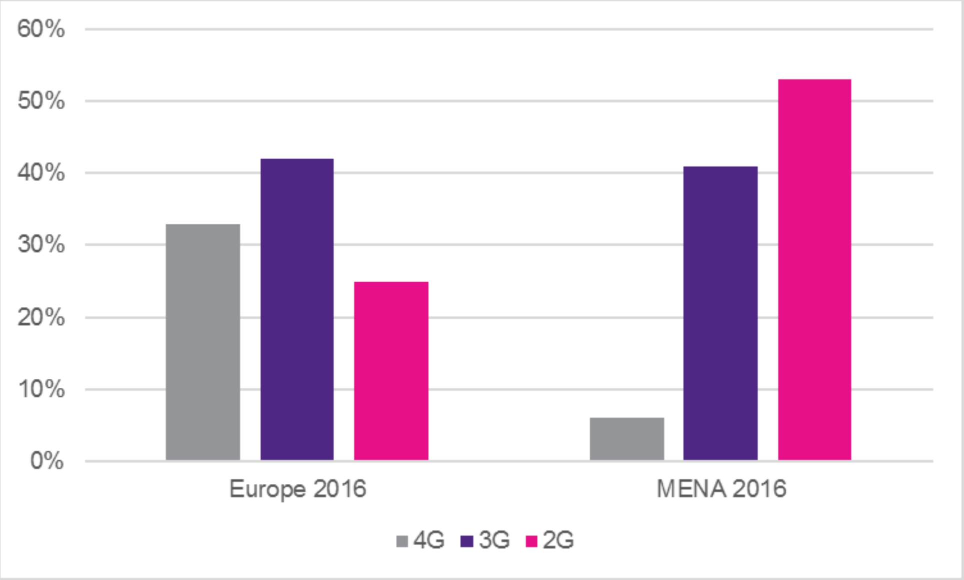
[54] LTE-Advanced Pro increases data speeds and bandwidth and decreases latency.

[55] NB-IoT is narrowband for those devices that require lower speeds and LTE-M has been developed for machine to machine (M2M) applications

[56] There will be earlier releases around 2017 in selected countries.

allows the European operators to continue to support legacy handsets with limited 2G spectrum whilst benefiting from the roll-out of mobile broadband using LTE (4G) technologies.

Figure 2-9: Technology mix in Europe and MENA regions in 2016 and GCC Arab States in 2015 based on percentage of connections[57]



Source: GSMA the mobile economy 2017

[57] The level of smartphone adoption influences the level of connections to 3G and 4G networks.

3 The impact of insufficient spectrum allocation

As the number of mobile subscribers has grown, operators in Middle East countries where there has been limited spectrum allocated have found that they are increasingly constrained by both the capacity of their networks and the profitability of the service they provide. This, combined with regulatory uncertainty over the release of other spectrum bands, makes it difficult for operators to invest in providing their subscribers with sufficient bandwidth and better quality of service.

There are three ways operators can increase network capacity:

i. Access to additional spectrum
ii. Invest in more infrastructure – this will already have been done to the limit of what is technologically and financially feasible. Doubling the number of sites does not provide a doubling of capacity due to the increase in self interference.
iii. Deploy more spectrally efficient technology – this requires refarming of existing mobile spectrum, implementation of latest standards and migration of user terminals

Ideally sufficient spectrum should be available to operators so they can make trade-offs between these options and so deliver a technically and financially efficient solution. Spectrum that is released has to be suitable to meet the traffic and coverage requirements, provide sufficient additional bandwidth and not be over-priced[58]. For a period of time, additional spectrum is required just to allow the operators to refarm current spectrum. Changing from 2G to 4G or even 5G requires new spectrum to start the process and allow the gradual move of the users and so free up the original 2G bands for refarming. Without this flexibility, the business case for expanding the network footprint or investing in new technology and services is higher cost and may not be viable[59]. There is a risk that refarming to more efficient technologies my not take place if 2G services are not refarmed quickly enough. This will foreclose realisation of socio-economic development and benefits. The outcome is users may not gain access to any services in unprofitable geographic areas or they are denied access to higher speed services that are available in many countries where harmonised spectrum and the latest technologies are readily available.

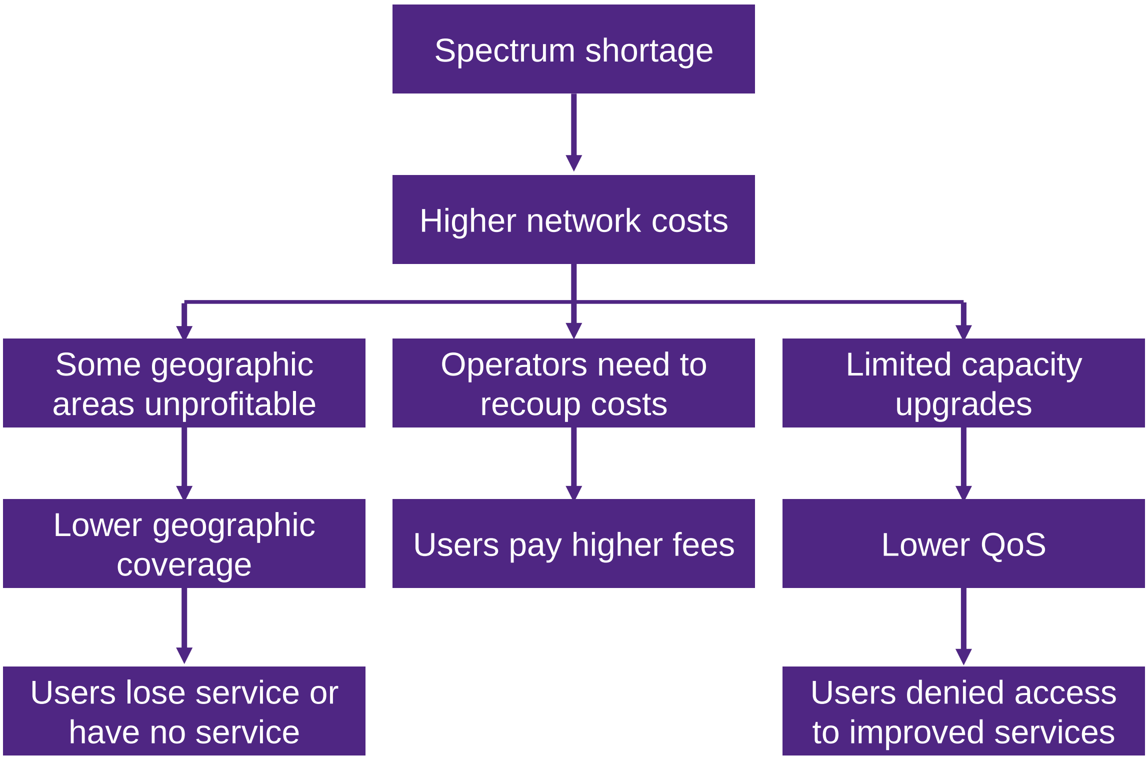
Operators need to make business plans based on the investment and life cycle of a mobile network. This is typically a timeframe of at least 10 years. Hence it is crucial that decisions on the timing for releases of spectrum and the processes to award the spectrum are published at least [3] years in advance[60].

[58] If there is insufficient bandwidth or the frequency band is suboptimum this can increase costs, decrease spectrum efficiency, or lead to poor Quality of Service.

[59] Revenue from 2G services is falling and data revenues are also dropping.

[60] In the case of spectrum roadmaps these should be 5 years – particularly for 5G decisions.

Figure 3-1: How spectrum shortages impact on users



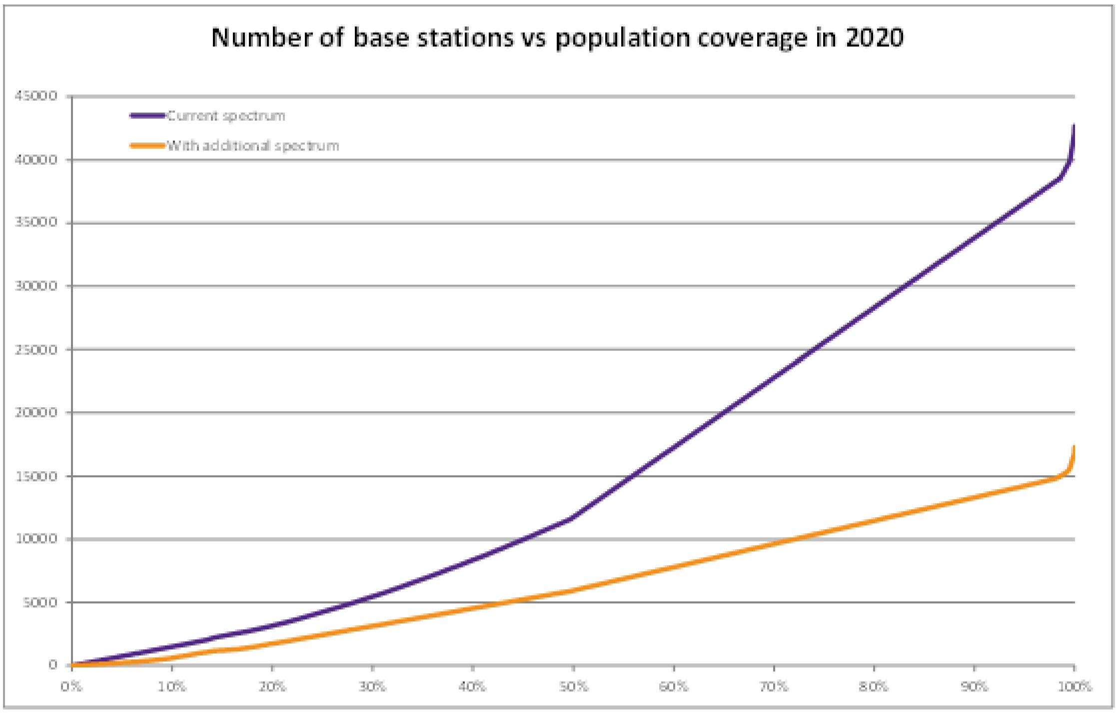
3.1 Impacts on investment

In the case that there is insufficient or non-ideal spectrum for coverage and capacity, it is necessary for operators to deploy more sites and base stations. Figure 3-2 below provides an example of the impact of having access to increased spectrum[61]. The figure shows that, to achieve a certain level of population coverage and provide sufficient capacity for all subscribers covered, operators will need to invest in many more base stations if no new spectrum is released. The requirement to invest in more sites will not only impact on the operator's business plan but also the timescales for network rollout as it will be necessary to develop new sites.

[61] The assumptions in the model which is based on Egypt are:

- Per-subscriber consumption of 2.5 GB per month (usage in Japan in Q316)
- Subscriber penetration of 70%
- LTE only used to deliver MBB for these subscribers
- Some spectrum needs to be reserved for voice service over 2G or 3G
- Number of operators = 3
- Spectrum is assigned equally to all operators
- Current spectrum for LTE (based on assignments from GSMA from 2013):
  - 900 MHz = 2×15 MHz
  - 1800 MHz = 2×20 MHz
  - 2100 MHz = 2×20 MHz
- With additional spectrum for LTE (considers partial release of all other bands):
  - 700 MHz = 2×30 MHz
  - 900 MHz = 2×15 MHz
  - 1800 MHz = 2×45 MHz
  - 2100 MHz = 2×45 MHz
  - 2600 MHz = 2×40 MHz

Figure 3-2: Comparison of number of base stations required depending on spectrum availability



Source: Plum Consulting

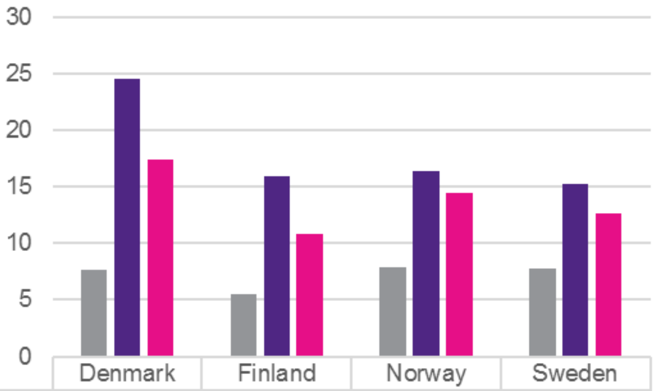
Alternatively, the release of additional spectrum may reduce the level of overall network investment required and allow cost-savings. In effect, deploying additional spectrum can be a substitute to deploying base stations for coverage and capacity. However, operators will generally only choose to use additional spectrum when it is priced below the cost of additional network rollout (base stations, long term maintenance costs etc.). This means that reasonably priced spectrum can lead to a lower-cost network, and additional spectrum can be said to increase efficiency for operators (and cost savings may be passed on to consumers).

Availability of spectrum may incentivise investment into new and existing networks – having access to the resource normally encourages further investment. Competition will improve current levels of investment as operators compete for customer base (manifesting in extending network out to rural or less served areas) and improved quality of service (capacity, data speeds and so on).

3.2 Impacts on quality

The introduction of LTE (4G) has yielded improvements in terms of data speeds and support for mobile broadband services, for those countries where it has been deployed. This is clearly demonstrated when comparing actual measured average download speeds over 3G and 4G networks such as in the Nordic countries.

Figure 3-3: Comparison of data download speeds in the Nordic countries[62]

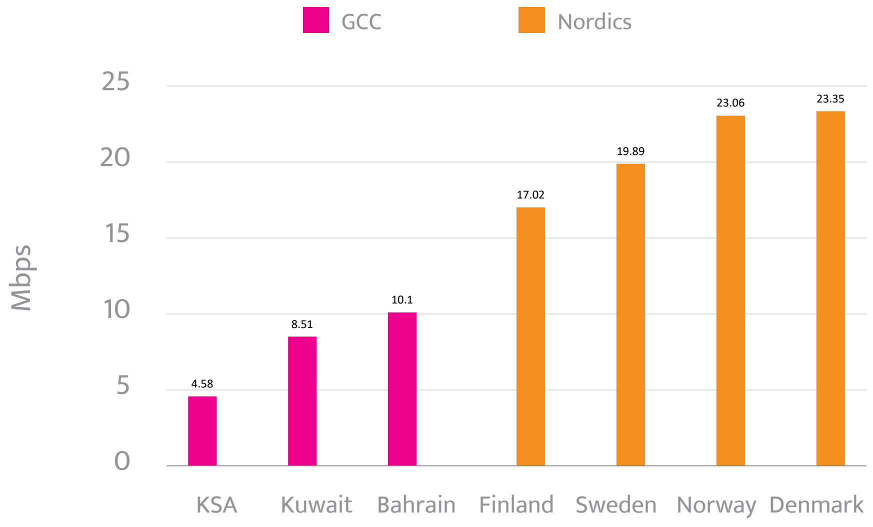


	Denmark	Finland	Norway	Sweden
Average3G D/L speed Mbps	7.68	5.52	7.94	7.73
Average 4G D/L speed Mbps	24.54	15.98	16.37	15.28
Overall D/L speed Mbps	17.41	10.84	14.46	12.66

x

The advantages of deploying 4G and access to increased amounts of spectrum is demonstrated below.

Figure 3-4: Comparison of overall network speed between GCC and Nordic countries[63]



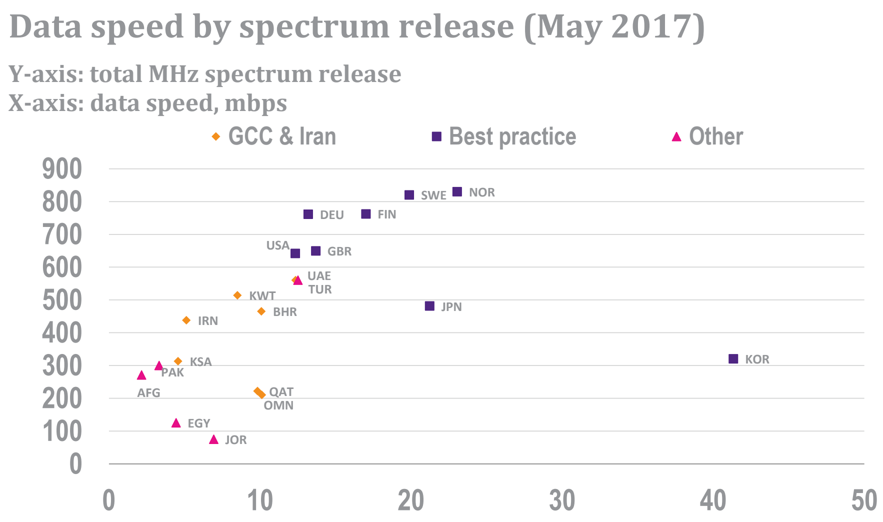
Source: Open Signal data

[62] Open Signal, May 2016, "State of Mobile Networks: Nordics". Available at: https://opensignal.com/reports/2016/05/nordic/state-of-the-mobile-network

[63] Open Signal, August 2016, "Global State of Mobile Networks." Available at: https://opensignal.com/reports/2016/08/global-state-of-the-mobile-network

It can be seen that those countries that have allowed operators to refarm their 2G (and in some cases 3G spectrum) for 4G technologies, and have also awarded further spectrum suitable for LTE deployment, offer much faster overall download data speeds. Figure 3-5 indicates that those countries where spectrum is available for 4G technologies[64] (that is, they have more spectrum awarded) provide much higher average mobile download speeds. So, in general an increase in total spectrum results in an increase in average data speeds and improved QoS.

Figure 3-5: Comparison of average download connection speeds and available spectrum[65,66]



Source: Plum Consulting, national regulators, Open Signal

3.3 Overall economic impact assessment

Efficiency cost-savings and improved quality of service from spectrum release can provide benefits to operators, consumers and wider society. The following section outlines the economic benefits of spectrum release, and implicitly assumes that access and quality of mobile broadband services improve. These are broadly categorised into economic impacts on the GDP, consumer surplus and other unquantifiable benefits.

[64] The recently awarded bands all support 4G

[65] In Korea and also in Japan it is important to be aware that due to the urban building density (narrow streets and high buildings) and the consequential high population density it is feasible to deploy multiple base stations due to the high demand for services and also less technical limitations. The nature of the clutter limits the risk of self interference between base stations and it is possible to deploy lower power base stations and there is also backhaul readily available. This means it has been possible to provide higher density networks and hence higher data download speeds with less spectrum.

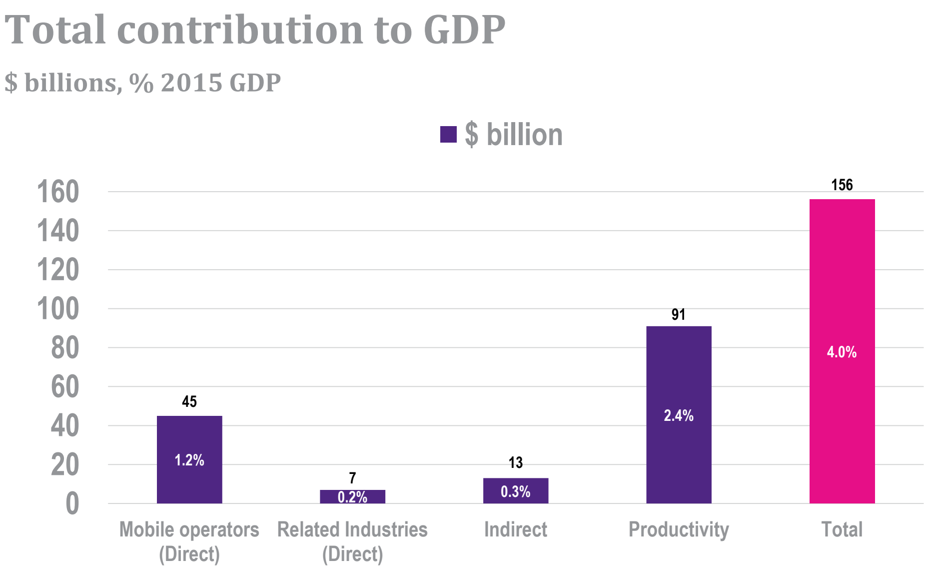
[66] The figure uses Open Signal's data speed measure from 2016 which precedes the award of additional spectrum in Saudi Arabia in June 2017. Therefore, for Saudi Arabia, Figure 3.4 omits 60 MHz in 700 MHz and 80 MHz in 1800 MHz bands from the total bandwidth awarded.

3.3.1 Impact on GDP and employment

The economic benefit from the release of spectrum is primarily due to the improved access to services enabled by mobile broadband, which enhance productivity and mobile sector activity.

The GSMA estimated that the mobile industry contributed $156 billion to the MENA region's GDP in 2015, as shown in Figure 3-6 below.[67] This identifies productivity gains as the mobile sector's largest contributor to GDP growth, equivalent to 2.4% of GDP, as well as the direct and indirect impacts. Overall, this suggests that mobile sector activity is vital to enable wider economic growth.

Figure 3-6:



Source: Plum Consulting, GSMA

The impacts of spectrum release can be categorised as direct and indirect impacts. Firstly, the direct economic benefits of spectrum release will include the cost-efficiency savings of existing operators (avoided costs) and, potentially, investment and employment from entrant mobile network operators which will occur in the short to medium term. Increased quality of mobile broadband services and associated demand for innovative services – supported by mobile broadband – will increase productivity in the medium to long-term.

Indirect benefits of spectrum release will include economic growth caused by productivity enhancements in other industries (benefitting from the increased connectivity that is provided by additional spectrum release and mobile broadband) and innovation in other industries that are supported by mobile-broadband services.

A Brattle Group report for the CTIA[68] acknowledges increase in employment from spectrum release both from induced and multiplier effects. Induced employment will occur when demand increases for technology products and for products supported by mobile broadband. Employment may increase in

[67] GSMA (2016), "The Mobile Economy: Middle East and North Africa 2016." Available at: https://www.gsmaintelligence.com/research/?file=9246bbe14813f73dd85b97a90738c860&download

[68] Brattle Group for CTIA – The Wireless Association (2015), "Mobile Broadband Spectrum: A Vital Resource for the U.S. Economy" Available at: http://www.ctia.org/docs/default-source/default-document-library/brattle_spectrum_051115.pdf

the wider economy via the multiplier effect, as employees from the mobile and tech sectors increase consumption in other goods and services – thus, increasing employment in other sectors.

Benefits from spectrum release (and harmonisation) have also been shown to be equally essential in the Middle East. Analysys Mason's 2012 study for the GSMA considered the economic impact of spectrum release in Saudi Arabia.[69] A summary of the study is presented in Table 3-1.

Table 3-1: Economic impact of spectrum release in KSA (Analysys Mason for GSMA, 2012)

Background	Impact
Macroeconomic study considering the effect of 200 MHz spectrum release for use by mobile operators. • 140 MHz of harmonized spectrum in 2.6 GHz band • 60 MHz of digital dividend spectrum in 700/800 MHz. The study considered the effect of both immediate and delayed (5-year) spectrum release. The model estimates the overall macroeconomic effect as follows: • Step 1: increase mobile broadband penetration from spectrum release • Step 2: impact of additional mobile broadband uptake on GDP • Step 3: effect on GDP growth and employment.	The study concludes that the economic impact of immediate spectrum release to be: • Total GDP gain of approx.$95.6 billion (SAR 358 billion) over 2013 to 2025 (net-present value), • Job creation of 424,000 jobs by 2020. A five-year delay in assigning additional spectrum would reduce economic benefits: • Total GDP gain reduced to $25.6 billion (SAR 96 billion), • Job creation reduced to 75,000 jobs by 2020. The study also finds that enhanced growth in mobile broadband subscriptions would provide $14 billion (SAR 52.4 billion) to GDP by 2020 if immediate spectrum release in 2012.

A number of other studies have analysed the impacts of spectrum release and access to mobile broadband. The particular impacts of GDP, employment and productivity are summarised in Table 3-2 below.

Table 3-2: Summary of GDP impact studies

Author	Background	Impact
CTIA/Brattle (2015) [70]	Value of mobile broadband spectrum	The study summarises the direct and indirect impacts of spectrum release for mobile broadband. The study finds: • Direct impact 2013 on GDP of $172 billion for US revenues and direct employment in wireless industry of 180,000 people. Direct impacts calculated from available statistics. • Uses input-output analysis to determine indirect effects via multipliers. Output multiplier of 2.32 and employment multiplier of 7.47 (from indirect and induced effects). • Wireless industry (companies and employees) spent $400 billion, which contributed $200 billion to US GDP in 2013.

[69] Analysys Mason for GSMA (2014), "The socio-economic benefit of allocating harmonised mobile broadband spectrum in the Kingdom of Saudi Arabia", Ref: 21366-172.

Author	Background	Impact
Recon Analytics (2016)[71]	Study on GDP impact of wireless spectrum	The study considers changes in US over 10-year time period during whilst spectrum was released. Concludes that the 10-year average impact of 100 MHz spectrum release may increase GDP up to $31.0 billion and create an additional 1 million jobs in the US. Also identify that government revenues from wireless industry may by $5.0 billion.
Data Analytics (2014)[72]	Economic benefits of allocating spectrum in South Korea	Uses input-output analysis to assess the impact on GDP and employment in South Korea from additional spectrum assigned for mobile broadband. Conclude that increasing available mobile broadband spectrum by 490 MHz (from 330 MHz to 820 MHz) would: • Overall provide an additional 40.0 trillion Won (approx. $35.8 billion) to economy in 2020 Increase in spectrum will provide 159.6 trillion Won (approx. $142.9 billion) to GDP and create an additional 182,500 jobs over seven years.
Plum (2011) for GSMA[73]	Benefits of releasing mobile spectrum for mobile broadband in Sub-Saharan Africa	Model estimates benefits of mobile broadband take-up from release of 800 MHz and 2.6 GHz spectrum. Impact of spectrum release in 2015 would: • GDP will have increased by additional $82 billion per year and tax revenue increase by $18 billion by 2025. • Provide up to 27 million additional jobs by 2020. • Releasing spectrum in 2020 (five-year delay) will reduce benefits to $50 billion (GDP) and $10 billion (annual government tax revenue).
Plum (2014) for GSMA[74]	Economic and Social Impact of Mobile Broadband in Egypt	Model assesses impact of additional spectrum release[75] and concludes: • Assigning spectrum to existing operators may increase GDP by EGP310bn, tax revenue by EGP47 billion and create up to 1.2 million jobs. • If assigning spectrum to new entrants is less effective by still increases GDP by EGP206bn, government tax revenues by EGP31 billion and an additional 0.8 million jobs. The paper further identifies a range of other unquantifiable benefits for consumers and society.
Katz, Vaterlaus, Zenhäusern and Suter (2010)[76]	The Impact of Broadband on Jobs and the German Economy	Uses input-output analysis to assess the impact of investment in high speed broadband (50 Mbps for 75% households by 2014, 100 Mbps for 50% households by 2020) in Germany on GDP and employment. Concludes that 10% increase in high speed broadband penetration increases GDP by 0.025%.

[70] Available at: http://www.ctia.org/docs/default-source/default-document-library/brattle_spectrum_051115.pdf

[71] Available at: http://www.ctia.org/docs/default-source/default-document-library/entner-revisiting-spectrum-final.pdf

[72] Available at: https://www.thinkmind.org/download.php?articleid=data_analytics_2014_4_30...

[73] Available at: http://www.plumconsulting.co.uk/pdfs/Plum_Dec11_Benefits_of_spectrum_for_MBB_in_SSA.pdf

[74] Available at: http://www.gsma.com/spectrum/wp-content/uploads/2014/09/Impact_of_Mobile_Broadband_in_Egypt_v100.pdf

[75] Releasing 700 MHz and 800 MHz spectrum for use by mobile and assigning unallocated 1800 MHz and 2100 MHz spectrum.

[76] Katz, Vaterlaus, Zenhäusern and Suter (2010), "The Impact of Broadband on Jobs and the German Economy", Intereconomics: Review of European Economic Policy, volume 45, issue 1, page 2.

Author	Background	Impact
Czernick, Falck, Kretschmer and Woessmann (2009)[77]	Broadband Infrastructure and Economic Growth	Study uses an instrumental-variable approach to analyse effect of broadband infrastructure on economic growth in OECD countries. Concludes that introduction of broadband increases overall GDP by 2.7 to 3.9%, and a 10% increase in broadband penetration will raise annual GDP growth by 0.9 to 1.5%.
Zhen-Wei Qiang and Rossotto (2009)[78]	Economic Impact of Broadband	World Bank publication summarising economic literature on economic growth and productivity impact of broadband. Study develops an econometric model which finds increasing broadband penetration by 10% will increase GDP per capita growth by 1.21% in high income countries and 1.38% in middle to low income countries.

Spectrum release can also be considered an essential component to facilitate the digital economy. At present, the Middle East's digital economy accounts for 4.1% of GDP.[79] Increase in mobile broadband penetration has been accompanied by an increase in online commerce and access to content services via mobile. Digital McKinsey notes a strong correlation between countries with high McKinsey Digitalisation scores (comprising of numerous factors of uptake of technologies, internet access) and rates of economic growth. Mobile broadband can increase both access to and growth in the Internet Economy, and support the economy during the transition of increased online consumer behaviour.

As discussed in Section 3.2, increasing the availability of spectrum will improve the quality of mobile broadband services. Increased connectivity and speed of mobile broadband can increase work productivity and benefit consumers. Thus, enhanced efficiency from time savings and uninterrupted service connection can lead to overall productivity gains. A spectrum management discussion paper from the Australian regulator, ACMA, in 2015 indicated that productivity growth in the mobile communications sector from mobile broadband is the equivalent to 11.3% per year from 2006 to 2013. The value to households from mobile applications and improved network speeds was AUD3.8 billion or AUD166 per person in 2013.[80]

The implications of spectrum release resulting from lower cost of network investment and improved quality of service, discussed in the previous Sections 3.1 and 3.2, can have substantial benefits to consumers and within society.

3.3.2 Impact on consumer surplus

A key benefit of spectrum release will be increased consumer surplus associated with greater access to mobile broadband and the services it supports. Consumer surplus is a measure of welfare,

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[77] Czernich, Falck, Kretschmer, and Woessmann (2009), "Broadband Infrastructure and Economic Growth", CESIFO working paper no. 2861. Available at: https://www.cesifo-group.de/pls/guestci/download/CESifo%20Working%20Papers%202009/CESifo%20Working%20Papers%20December%202009/cesifo1_wp2861.pdf

[78] Zhen-Wei Qiang and Rossotto (2009), "Economic Impact of broadband", Information and Communication for Development. Available at: http://siteresources.worldbank.org/E×TIC4D/Resources/IC4D_Broadband_35_50.pdf

[79] Digital McKinsey (2016), "Digital Middle East: Transforming the region into a leading digital economy." Available at: file:///C:/Users/User/Downloads/Digital-Middle-East-final-updated.pdf

[80] Australian Communications and Media Authority (2015), "Beyond 2020 – A spectrum management strategy to address the growth in mobile broadband capacity".

considered as the difference between the prices that consumers actually pay and are willing to pay to consume a particular good or service.[81] Potentially, the mobile market may become more price competitive if the cost of network delivery falls and operators have increased margin to allow them to better compete on price. This can increase consumer surplus as consumers pay less for current services or increase consumption of mobile services, namely mobile data or access to higher quality services, as these services become more affordable.

Alternatively, improved quality of service can improve consumer surplus. It is likely that consumers would be willing to pay more for higher quality services, thus as quality of service improves, consumer surplus will increase.[82]

A report by Recon Analytics (2014) acknowledges the importance of consumer surplus and estimates total consumer surplus from the US wireless industry to be $640.9 billion in 2014, of which $126.5 billion is attributed to data services alone.[83] While the estimation of consumer surplus in data services is very difficult, largely due to the way it is bought (often in bundles) and lack of willingness to pay data, if this report is accepted our view is that the importance and trend growth of mobile data would imply that the proportion of consumer surplus from mobile data will be substantially larger in 2017 and will rapidly grow in the future.

3.3.3 Other unquantifiable economic impacts

Spectrum release will also provide other external and social benefits, that are difficult to measure and monetise but are nonetheless present. We implicitly assume that release of spectrum will increase consumption of mobile broadband and the services that it enables. Most commonly cited are services delivered via mobile, where consumer welfare is increased from better connectivity to services and access to information.

Below are some examples of services with wider impacts on the economy.

Healthcare

Mobile solutions for healthcare can increase efficiency in healthcare delivery models whilst reducing costs for healthcare providers and serving more patients. GSMA analysis indicates that m-Health initiatives aimed to improve the management of diabetes in the UAE could lower care costs by $800 per affected patient.[84] Zain reported that health monitoring services (for BMI, electronic records, diabetes monitoring etc.) delivered healthcare-added value of 23.9% in selected Middle Eastern countries.[85] Other estimates suggest that broadband healthcare applications and monitoring may deliver cost savings of 10 % to 20%.[86]

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[81] It is often difficult to calculate reliable estimates for consumer surplus due to insufficient information on elasticity of consumer demand. Thus, our study has not estimated values for consumer surplus.

[82] This assumes that the price paid by the consumer for mobile services is constant (does not change) or will increase at a level that is relatively less than consumers' willingness to pay for higher quality services.

[83] Recon Analytics (2014), *The Wireless Industry: Revisiting Spectrum, The Essential Engine of US Economic Growth*.

[84] GSMA (2015), "Mobile: A Key Enabler of Public Health Strategies in the Gulf". Available at: http://www.gsma.com/connectedliving/mhealth-uae-case-study/

[85] Zain/PWC (2014), "The Socioeconomic Impact of Mobile Telecommunications in the MENA Region". Available at: http://www.zain.com/media/images/resumes/Zain_PWC_Report_2014.pdf

[86] Boston Consulting Group (2011) cited in ITU-UNESCO (2011) "Broadband: a platform for progress".

Education

In the Middle East, adoption of mobile learning is above e-learning.[87] Provision of mobile education solutions can improve accessibility (access to resources and experts), efficiency (cost-savings from automation of organisational processes) and personalise education (greater flexibility and tailored to student needs).[88] In addition, mobile applications and online services can support both formal and informal education. For example, Zain of Kuwait partnered with Hamdan Bin Mohammed e-University (based in UAE) to create mobile education Cloud Campus from which mobile subscribers were able to purchase almost 2,000 apps.[89]

Finance

Access to financial and mobile services online can have transformative effect. 98% of banking customers have a smartphone, though difficulties to access mobile banking has meant that mobile banking use is below 20% of customers.[90] Mobile finance allows complex transactions to be completed remotely, increasing efficiency and improving customer's quality of service. In Qatar, Ooredoo's banking app has been primarily aimed at migrant workers to enable them to send remittances to their home country, with similar apps available from operators in Bahrain and UAE.[91]

Government

Mobile broadband can increase efficiency by reducing the cost of core services[92] and increasing citizens' access to governmental services. The UAE's Smart Dubai initiative focuses on Smart Governance as one of its six key outcomes in order to provide improved resident and visitor experience.[93]

Social change and Inclusion

Additionally, the most marginalised within society can be the greatest beneficiaries of welfare improvement. A report by Qualcomm, Vital Wave and the GSMA identified that access to mobile

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[87] http://www.ambientinsight.com/Resources/Documents/AmbientInsight-2012-2017-Middle-East-Mobile-Learning-Market-Abstract.pdf

[88] http://www.gsma.com/connectedliving/wp-content/uploads/2013/12/meducation_operator_toolkit_Africa1.pdf

[89] GSMA (2013), *mEducation Toolkit.* Available at: http://www.gsma.com/connectedliving/wp-content/uploads/2013/12/meducation_operator_toolkit_Middle-East1.pdf

[90] EY (2015), "Where your customers want you to be: The EY GCC Digital Banking Report 2015". Available at: http://www.ey.com/Publication/vwLUAssets/EY-GCC-digital-banking-report-2015/$FILE/EY-GCC-digital-banking-report-2015.pdf

[91] GSMA (2016), "The Mobile Economy: Arab States 2015". Available at: https://www.gsmaintelligence.com/research/?file=7910cff3a3e6f96219cd50e31d6d3e1c&download

[92] Plum for GSMA (2014), "The Economic and Social Impact of Mobile Broadband in Egypt". Available at: http://www.gsma.com/spectrum/wp-content/uploads/2014/09/Impact_of_Mobile_Broadband_in_Egypt_v100.pdf

[93] Digital McKinsey (2016), "Digital Middle East: Transforming the region into a leading digital economy." Available at: file:///C:/Users/User/Downloads/Digital-Middle-East-final-updated.pdf

broadband is key to enable female empowerment.[94] The report notes that women have less access to broadband services than men and identifies increasing female participation online by 600 million in developing countries could increase global GDP by $13-18 billion. The World Bank Group has also identified increasing access to Internet as key to improve participation and welfare for marginalised groups, such as rural farmers and disabled individuals.[95]

Environmental impacts

In addition, greater connectivity may result in environmental benefits. Better mobile services may allow individuals to work from home, reducing emissions from commuting. Smart grid initiatives to effectively manage electricity demand are underway in Saudi Arabia (a partnership between Mobily and Germalto) and in Qatar (with Qtel and Cisco in partnership)[96]. However, Ericsson acknowledges that the associated innovation from better broadband may increase production of new technology-compatible devices (require resources and producing emissions during manufacture) and new devices will require energy.[97]

Table 3-3: Overview of available m-Applications

Country	Health	Education	Finance	Governance	Environment
Bahrain			✓		
Kuwait	✓				
Oman	✓		✓		
Qatar	✓	✓		✓	✓
Saudi Arabia	✓			✓	✓
UAE	✓	✓	✓	✓	✓

[94] Qualcomm, Vital Wave and GSMA (2014), "Transforming Women's Livelihoods Through Mobile Broadband". Available at: http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2014/02/transforming-women-s-livelihoods-through-mobile-broadband.pdf

[95] World Bank Group (2016), "World Development Report 2016: Digital Dividends", Paper no. 102725. Available at: http://documents.worldbank.org/curated/en/896971468194972881/pdf/102725-PUB-Replacement-PUBLIC.pdf

[96] Zain/PWC (2014), "The Socioeconomic Impact of Mobile Telecommunications in the MENA Region". Available at: http://www.zain.com/media/images/resumes/Zain_PWC_Report_2014.pdf

[97] Ericsson, Arthur D Little and Chalmers University of Technology (2013), "Socioeconomic effects of Broadband Speed". Available at: https://www.ericsson.com/res/thecompany/docs/corporate-responsibility/2013/ericsson-broadband-final-071013.pdf

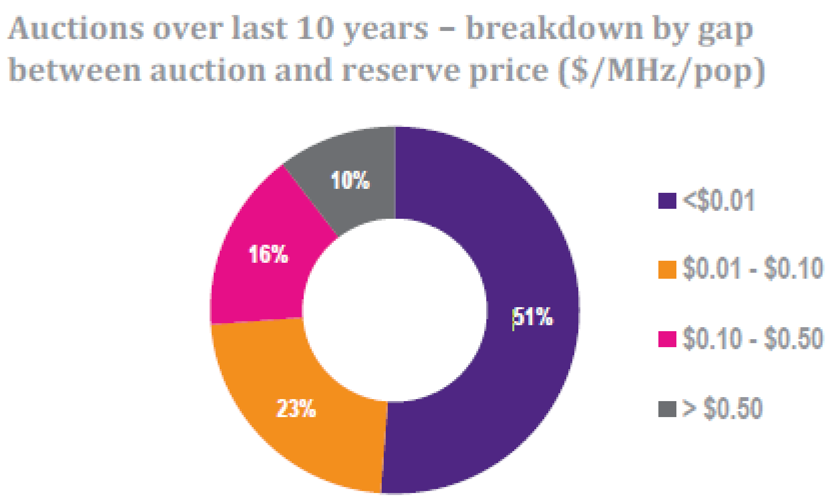
4 Cost of spectrum access

A recent paper by GSMA/NERA (2016) on effective spectrum pricing identified high spectrum prices may cause under investment in the mobile sector.[98] It is essential that spectrum is made available at sensible "market" prices. Mobile operators' revenue growth has been sluggish in recent years as markets mature and there is increasing competitive pressure. Operators are already facing pressure to develop new business models and revenue streams and to invest in deploying 4G networks and rising spectrum prices add further pressure.

Governments have been inadvertently increasing the risks of incurring social costs and creating inefficiencies through higher spectrum fees. Unintended consequences can include delays to network rollout, poorer coverage and service quality, higher prices and negative impacts on investment and innovation.

The increasing use of auctions and in particular the setting of high reserve prices to extract maximum receipts from potential buyers can have detrimental outcomes. Analysis of auction prices over the last 10 years and comparison with reserve prices indicates that in 51% of the auctions the gap between the auction and reserve price is negligible – outcome is equivalent to a direct award at a fixed price.

Figure 4-1: Comparison of auction and reserve prices



Source: Plum Consulting

Also, there are instances where spectrum has been unsold or where changes were required to reserve prices. In Egypt, Orange was not willing to participate when the original LTE licenses offered were seen to be at too high a price and in the Indian auction there were many unsold lots, despite a significant spectrum shortage, because of high reserve prices.

Such outcomes are undesirable as less availability of spectrum means reduced benefits to consumers and society. Though it might be argued that unsold spectrum simply reflects a lack of demand in a particular market, this is hard to substantiate, particularly for spectrum which is globally harmonised

[98] GSMA/NERA (2017), "Effective Spectrum Pricing; Supporting better quality and more affordable mobile services". Available at: http://www.gsma.com/spectrum/wp-content/uploads/2017/02/Effective-Spectrum-Pricing-Full-Web.pdf

and widely implemented. Simply, operators will not invest in spectrum if they foresee that the outcome will not be profitable.

5 International best practice

5.1 Access to spectrum

On a worldwide basis, the amount of spectrum being made available to support mobile broadband, particularly in recent years, has increased considerably (see Figure 2-8). New bands such as 700 MHz and 800 MHz are being refarmed and used, by the mobile operators, to provide greater data capacity in the coverage layer.

In the case of bands above 1 GHz a significant number of countries have refarmed 2300 MHz and 2600 MHz spectrum with a number of countries also addressing the 1500 MHz and 3500 MHz bands as this provides access to spectrum with higher bandwidths (potentially up to 100 MHz channels with carrier aggregation). This provides the opportunity to significantly increase capacity in traffic hot spots and support the higher speeds provided by 4G (LTE) technologies and 5G in the future.

5.1.1 Challenges of repurposing (refarming) spectrum

However, where mobile frequency bands are not available they are often already in use for non-mobile services. Therefore, it may be necessary to cease and move the incumbent services and users before the spectrum can be made available for mobile use. The first step is to identify the services using the bands and those that cannot co-exist with mobile broadband on a co-channel, adjacent channel or geographic basis. Interference analysis identifies potential measures to limit interference[99] and the implications of not moving the incumbents to be assessed. Then, as necessary the different approaches to refarming the spectrum need to be considered. These range from release of spectrum at the end of the licence duration or equipment lifetime to forced migration.

In general, where there is no potential to co-exist, it is necessary to undertake a forced migration to meet timescales to ensure spectrum (and in particular priority bands) is made available to mobile broadband as soon as possible. To move incumbent users there are generally three options:

- Migrate incumbents to alternative spectrum
- Identify ways of compressing incumbent spectrum requirements such as deployment of new technologies
- Move to alternative wired solutions if they are available or can be deployed.

Access to spectrum below 1 GHz

In the case of the 700 MHz and 800 MHz bands, which have been used for TV broadcasting, migration to digital terrestrial broadcasting[100] requires significantly less spectrum.

In Europe, the 800 MHz band (832 – 862 MHz paired with 791 – 821 MHz) has been refarmed from TV to mobile. This provides a total of 2×65 MHz sub 1 GHz spectrum[101] with the opportunity for roll-out

[99] For example, reducing transmitter powers, defining block edge masks, setting uplink / downlink traffic ratios for TDD deployments or requiring the users to undertake coordination between themselves.

[100] Accompanied by analogue TV turn-off

of LTE. Release of this spectrum was achieved by setting the date of the end of 2012 for completion of the switchover from analogue to digital TV and mandating the opening or licensing of the 800 MHz band throughout the EU by 1 January 2013[102].

In practice, mobile licences have been awarded with Germany the first to licence the 800 MHz spectrum in 2010 and the last licences being awarded in Luxembourg and Turkey in 2015[103]. A number of countries, namely Finland, France and Germany, have since replanned their TV networks and this has released 2×45 MHz spectrum in the 700 MHz band (703 – 748 paired with 758 – 803 MHz).

The UK, is undertaking a major digital TV replanning exercise[104] which will be implemented on a phased basis with the aim of releasing the spectrum between 694 and 790 MHz. Ofcom estimated that providing access to the 700 MHz band would provide benefits of between £900m and £1.3 billion as it will enable operators to meet the increased demand for mobile data at a lower cost than would be possible without this additional spectrum. Due to its propagation characteristics it is expected that the band will support improved mobile speeds indoors and in rural areas more cheaply than would otherwise be the case. Ofcom expects that competition in the market will result in a "significant proportion of these benefits being passed on to consumers through lower prices and better quality mobile data services[105]".

Access to spectrum above 1 GHz

Bands such as 1500 MHz, 2300 MHz and 2600 MHz may be used to provide fixed links or access networks where fibre may be an alternative. These bands may also be used by Government or Defence services and there may be the possibility of migrating or compressing these into higher frequency bands. Some bands have been used to provide wireless access and the technology migration path for WiMAX in many countries has been to LTE, so it has been possible to re-award the spectrum on a technology-neutral and service-neutral basis to provide both fixed access and mobile services.

There are a significant number of countries that have licensed both the 2300 MHz and 2600 MHz bands including Australia, China, Hong Kong and South Korea. In Europe, the 2600 MHz band has been licensed by the majority of countries and these licences were awarded for IMT or LTE commencing in 2010 with Finland, France and Germany being early to award the spectrum.

In Italy, where the 1500 MHz band for SDL (supplementary down-link) has been awarded[106] as well as spectrum in the 2600 MHz band, the operators Vodafone and WIND have provided an average 4G download speed of 34.36 Mbps and 23.68 Mbps to 71.63% and 68.06% of their users respectively. This demonstrates the benefits arising from investment in additional spectrum – the speeds and coverage provided by '3' Italy and Wind are significantly less.

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101 2×30 MHz at 800 MHz and 2×35 MHz at 900 MHz

102 See https://ec.europa.eu/digital-single-market/en/delivering-digital-dividend

103 Analogue switch-off date was 17 June 2015 for the Geneva 2006 frequency plan (GE06) for the majority of countries with a few setting the date of 2020

104 Changes in use of the spectrum to mobile broadband will also impact on PMSE (wireless microphones)

105 To the extent that the value of the spectrum to MNOs is not captured by auction revenues.

106 TIM and Vodafone both have access to 1×20 MHz in the 1500 MHz band.

Refarming mobile bands

In addition, the licences should be technology-neutral to facilitate refarming of already available mobile bands to allow deployment of more spectrally efficient technologies. This allows the operators to refarm their spectrum for 4G technologies as best fits their business plans and ensure a market-led approach to service and capacity network planning. Further information is provided in Section 5.5.

5.2 Licensing certainty

It is essential that mobile operators have sufficient certainty to continue investing in their networks. This requires the regulator to:

- Issue licences for a sufficient time for the operators to recoup their investments. Typically, mobile spectrum licences are being awarded for 15 to 20 years and in some cases, such as the UK, indefinitely.
- Establish clear guidelines on the process for licence renewal. Ideally licence renewal should be considered well in advance of expiry (typically 5 years ahead) to fit with the mobile operators' planning cycles.
- Provide consistency in setting of spectrum fees and not introduce significant changes in annual fees part way through the licensing period. Where it is appropriate to increase fees, these should generally be introduced with long notice on a phased basis.
- Ensure that any potential interference (co-channel and adjacent channel) is managed through appropriate licence conditions and agreements with neighbouring countries. The impact of cross-border interference can have a significant impact on the utility of spectrum and the achievable QoS.

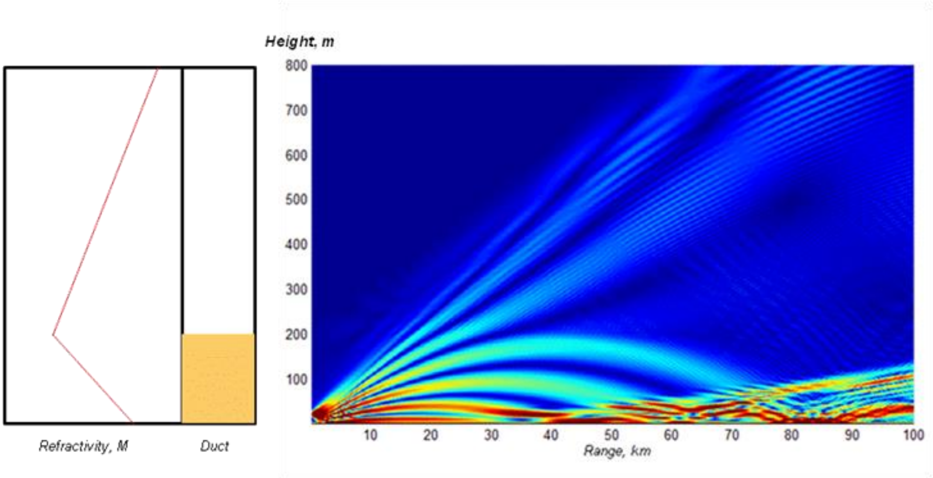
5.3 Cross-border interference management

As noted above it is essential that the potential for interference is managed as this can impact on the utility of the spectrum as well as achievable Quality of Service. It is essential that harmonised channel and band plans are adopted to minimise interference and cross-border agreements are put in place between neighbouring countries. The impact of the interference is likely to be significantly greater in the lower frequency bands where the propagation distances are significantly greater. This means an interfering transmitter in one country can have an impact tens of kilometres inside another country leading at worst to loss of service to, for example, intermittent reductions in data speeds or voice call drop outs.

In the case of countries separated by water there is the added possibility of a short-term propagation enhancement due to evaporation ducting over the sea, as shown in Figure 5.1below, when the radio waves are trapped below an inversion layer and allow long-distance propagation at high signal strength.[107] This can lead to the potential for co-channel interference if non-aligned channel plans are deployed.

[107] The propagation models used in planning either take no account of signal variability with time, or were developed using data from temperate climates where different statistical behaviour would be expected. The question of models appropriate to short-term propagation enhancements in the Asia Pacific area is currently under study within ITU-R Study Group 3, and Aegis

Figure 5.1: Example of ducting



In Table 5-1 we consider the implications of neighbouring countries adopting different harmonised channel plans and services and the potential co-channel and adjacent channel interference scenarios.

Table 5-1: Dominant cross border interference potential

Country A Service and frequency band	Country B Service and frequency band	Dominant cross border interference potential
Analogue TV	Mobile broadband (FDD)	Analogue TV transmitters into mobile base station receivers[108].
DTT 700 MHz	Mobile broadband 700 MHz (FDD)	DTT transmitters into mobile base station receivers. Mobile base station transmitters into consumer TV receivers.
DTT 800 MHz	Mobile broadband 800 MHz (FDD)	DTT transmitters into mobile base station receivers. Mobile base station transmitters into consumer TV receivers.
DTT below 700 MHz (470 – 694 MHz)	Mobile broadband above 700 MHz	Mobile base station transmitters into consumer TV receivers.
Fixed point to point links 1500 MHz	Mobile broadband 1500 MHz	Mobile base station transmitter into fixed link receiver.

Systems are participating in this work. The same study group have also received recent liaison statements seeking guidance on propagation models to reduce the incidence of unintentional roaming, so this topic is currently under active investigation.

[108] To make the 700 and 800 MHz bands available for mobile services requires intensive national re-planning and international coordination activities. It requires the countries to adopt DVB-T2 and MPEG-4 or H.265 as DVB-T2 provides at least a 30% higher transmission capacity as it is more efficient. DVB-T2 also provides improved Single Frequency Network (SFN) performance and supports larger scale networks than DVB-T. It also allows a reduction in the power used at transmitter sites by around 25% while achieving the same coverage. If TV broadcasting is not digitised it means that the potential to reduce demand for spectrum is not available and additionally as analogue broadcasting utilises multiple frequencies co-ordination between neighbouring countries wanting to deploy mobile broadband is likely to be impossible near the borders.

Country A Service and frequency band	Country B Service and frequency band	Dominant cross border interference potential
Mobile broadband 2600 MHz according to Band 41(TDD)	Mobile broadband 2600 MHz according to Band 7 (FDD) and Band 38 (TDD)	Base station transmitter into mobile base station receiver and vice versa.

To alleviate the interference potential, it may be necessary to implement significant separation distances and other mitigation approaches such as reducing transmitter powers to limit such interference as can be seen in the example shown in Figure 6-1. Even if harmonised channel plans are deployed either side of the border, there need to be limits placed on the signal strengths to avoid the potential of unintended subscriber roaming between home and neighbouring mobile networks. In the case of TDD networks there is likely to be a requirement to specify the ratio of up-link versus down-link traffic to avoid the potential for base station to base station interference.[109]

In particular, smaller countries such as Bahrain, Kuwait and Qatar can be severely impacted by cross border interference such that some frequency bands have limited usability. For example, the current use of the 2500 MHz band in Saudi Arabia, where there is a mix of FDD and TDD networks not in accordance with the harmonised channel plan or band plan, will lead to problems with deploying 2500 MHz for IMT in neighbouring countries. Even with harmonised band plans the use of TDD (Band 41) in one country and FDD (Band 38) in another on the other side of the border requires co-ordination to avoid the risk of cross border interference due to base station to base station interference.

The continued use by Iran of analogue TV broadcasting is likely to impact on the use of the 700 and 800MHz bands for mobile services in Iraq, Saudi Arabia, Oman, UAE, Qatar, Bahrain and Kuwait. The only option appears to be to not use the same and adjacent frequencies as the analogue TV transmitters within a defined geographic area from the Iranian border. This potentially requires interference analysis on a case by case, country by country basis.

In Europe, where there are many borders and a similar a mix of small and larger countries as in the Middle East, a number of approaches are adopted to minimise interference. These approaches include:

- All countries conform to relevant EC Decisions. These EC Decisions may define common harmonised band plans for the same spectrum[110] and "associated technical requirements to ensure coexistence between neighboring networks in the absence of bilateral or multilateral agreements between operators of such neighbouring networks". They may also define dates when spectrum should be made available for new services and define dates when existing users and services must be migrated from the band. The advantage of such an approach is that it avoids situations where one country may limit the opportunity of others to deploy latest technologies and services due to cross border interference.
- Neighbouring countries implement agreements that identify preferential and non-preferential frequencies and the associated allowed signal strength threshold levels at set borders (e.g. the regional border or a distance within the regional border). These agreements will typically be

[109] The TDD frame configuration with 3:1 downlink/uplink ratio has been used in a number of countries e.g. India.

[110] For example, EC Decisions 2014/276/EU, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2014.139.01.0018.01.ENG , defines the requirements for the 3400 – 3800 MHz band

based on relevant ECC Recommendations[111]. The calculation of interference is undertaken using the HCM agreement method (harmonised calculation method)[112] and if levels are exceeded then detailed interference analysis is undertaken on a case by case basis.

Similar agreements have been developed based on the HCM approach. In Africa, for example, a cross-border frequency co-ordination agreement providing a harmonised calculation method (HCM4A) was developed as part of the HIPSSA Project[113]. The agreement covers "frequencies between 29.7 MHz and 43.5 GHz for the purposes of preventing mutual harmful interference to the Fixed and Land Mobile Service and optimising the use of the frequency spectrum on the basis of mutual agreements".

5.4 Spectrum strategy roadmap

The ever-increasing demand for mobile broadband means that operators must make investment decisions on whether and how they will meet such demand. Whilst the mobile operator will have an excellent understanding of network costs and also a view on the likely revenues that might be earnt through new services or coverage, the other variable - access to additional spectrum - is very unclear in many countries. This can lead to limited investments in extending the coverage or capacity of networks, substantially different levels of investment in networks in the case of those operators that have licences in multiple countries[114], and high prices for users that require larger amounts of data to reduce demand.

A number of regulators and administrations are now providing information on future spectrum release plans. This has the advantage of not only informing mobile operators of when further spectrum may become available but also forewarns current users of their need to migrate from the spectrum and planned timescales.

The following countries all use a recognised process for informing industry and government on their plans for the future supply and award of spectrum through publication of a single planning document. This document is typically updated on an annual basis to provide, if necessary, latest information and also include any new proposals. Both the Australian and the UK regulators follow a formal consultation process to allow interested parties to comment on the proposals so the final decisions can take into account their views.

Australia: The ACMA consults on, and publishes a five-year spectrum outlook[115] which informs on priorities for spectrum planning and informs ACMA's work plan. They are published each year with the aim of "bringing together in one place information, analysis and work plans" and "giving easy access to information, as well as encouraging collaboration between all users of spectrum".

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[111] For example ECC Recommendation (14)04 for the 2300 – 2400 MHz band (http://www.erodocdb.dk/Docs/doc98/official/pdf/REC1404.PDF) and ECC Recommendation (15)01 (http://www.erodocdb.dk/Docs/doc98/official/pdf/REC1501.PDF)

[112] http://www.hcm-agreement.eu/http/englisch/verwaltung/index_europakarte.htm

[113] The HIPSSA study was undertaken under the global project "ACP-Information and Communications Technologies" programme within the framework of the 9th European Development Fund. This was launched by the ITU and the European Commission to provide "Support for the establishment of harmonised policies for the ICT market in the ACP states".

[114] They will invest in those networks where there is greater certainty of future spectrum supply

[115] http://www.acma.gov.au/Industry/Spectrum/Spectrum-projects/5-Year-Spectrum-Outlook

For example, the most recent, 2016 – 2020 work plan provides an "update on the mobile broadband program and planning for significant technology developments out to 2020—such as 5G and the Internet of Things (IoT)". It also identifies milestone tasks and timings for priority spectrum management activities to be completed over the 2016-17 financial year including the award or consultations associated with the award of spectrum.

Hong Kong: OFCA publishes a spectrum release plan (SRP)[116] to inform the industry of "the potential supply of radio spectrum through an open bidding or tendering process for the following three years". The SRP is part of the implementation of the Radio Spectrum Policy announced by the Government in April 2007. The SRP provides information on the release plan for any new spectrum including the earliest date when it will be released and the target consultative document date. It also provides an update on the latest developments for previous bands that were included in the SRP and the document is updated every year on a rolling basis, or as required.

UK: Ofcom consults on its annual plan which highlights some of the key work areas it aims to deliver over the year. The plan also outlines broader ongoing work to support these goals.

In addition, Ofcom publishes on its website its strategic approach and priorities for managing radio spectrum for the next decade[117]. It details strategic activities including spectrum awards and ongoing projects including award of specific frequency bands as appropriate. A mobile data strategy is also published that lists the priority bands for mobile[118].

5.5 Technology-neutral and service-neutral licences

Refarming currently licensed mobile spectrum can involve amendments to existing licences on renewal or on request of a mobile operator or via initiatives from the regulator to allow the deployment of more spectrally efficient technologies (for example refarming from 2G to 3G or LTE technologies).

It is widely considered best practice for regulators to award technology-neutral and service-neutral licences. This allows for spectrum refarming without requesting the regulator to change licensing conditions.

In some instances of non-technology-neutral licences, changing the technology specified on a licence may be as straight forward as an operator simply placing a request to the regulator. However, some administrations can be reluctant to change the licensing terms during the licence duration; the technology deployments are non-negotiable. Technology-neutral licensing provides the operator with greater autonomy and certainty over their network technology. This should encourage operators to make more appropriate network investments, deploying new and more efficient technologies as appropriate, without delay due to licensing terms. As discussed in Sections 3.2 and 3.3, refarming spectrum from 2G to more efficient technologies can benefit consumer experience (quality of service) and raise GDP and productivity.[119]

[116] http://ofca.gov.hk/filemanager/ofca/common/Industry/broadcasting/spectrum_plan2016_en.pdf for an example SRP for 2016 - 2018

[117] https://www.ofcom.org.uk/spectrum/spectrum-management

[118] https://www.ofcom.org.uk/consultations-and-statements/category-1/mobile-data-strategy provides information on the strategy and associated Ofcom consultation

[119] Due to the difficulty in establishing counterfactual of technology neutrality and lack of publicly available information and studies on the economic impact of technology neutral licensing, quantitative figures for the impact are unavailable.

Similarly, service-neutral licences will provide the necessary flexibility to allow users to deploy those services that are best suited to the market requirements at the time and so encourage efficient usage of spectrum. Consumer trends and recent network deployments demonstrate the migration from fixed to mobile communication services as mobile technologies can support higher and higher broadband speeds. However, the mobile standards support both fixed and mobile deployments so allowing service flexibility will allow an operator to respond to particular geographic and market conditions and provide mobile services as well as fixed access and in-band back haul within their licensed spectrum.

In a number of EU countries (Bulgaria, Cyprus, Latvia, Slovakia and Romania)[120] the existing licences were liberalised to become technology-neutral and service-neutral.

In the UK, for example, Ofcom issued a statement[121] varying the 900, 1800 and 2100 MHz licences to permit the use of 4G technology in each of the bands, thereby aligning conditions with the more recent 800 MHz and 2.6 GHz licences. It was noted that the decision "delivers a long-standing objective to liberalise all mobile licences so as to remove the regulatory barriers to deployment of the latest available mobile technology. Even though operators may not seek to deploy 4G services in the newly liberalised bands in the immediate future, the interests of consumers will be served by the fact that these bands have been liberalised now, ahead of a market led transition to their use for 4G technology in future. As a result, operators can plan and implement a transition to 4G technology in these bands without having to engage in a further regulatory process".

Extending neutral licensing to include service neutrality is increasingly common, and considered best practice, with the European Commission establishing the principles of both technology-neutral and service-neutral licensing in their decision on the 3.6 GHz band in 2014[122], and previously for the 2.6 GHz band. In 2015, Germany's regulator (Bundesnetzagentur) auctioned spectrum in the 700 MHz, 900 MHz and 1800 MHz bands on a technology-neutral and service-neutral basis which allowed for the spectrum to be "used for all applications that consumers want"[123]. Comreg (Ireland) and subsequently Ofcom (UK) awarded 2.6 GHz spectrum on technology-neutral and service-neutral conditions with the objective that such licensing "provides much greater flexibility for the use of spectrum to respond to demand and to be economically efficient"[124].

120 See RSPG15-619 – a draft RSPG Report on Efficient Awards and Efficient Use of Spectrum for consultation. http://rspg-spectrum.eu/wp-content/uploads/2013/11/RSPG15-619-Draft_report-Efficient_Awards_Use_of_Spectrum_PC.pdf

121 This statement followed a consultation. See: https://www.ofcom.org.uk/__data/assets/pdf_file/0023/63932/statement.pdf

122 https://ec.europa.eu/digital-single-market/en/news/36-ghz-decision

123 https://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/Areas/Telecommunications/Companies/TelecomRegulation/FrequencyManagement/ElectronicCommunicationsServices/DemandIdentificationProceedings/DraftDocumentForConsultation_Extract.pdf?__blob=publicationFile&v=2

124 Ofcom, 2012, "The award of 800 MHz and 2.6 GHz spectrum: Information Memorandum", paragraph 8.56. Available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0022/32872/im.pdf

6 Middle East situation compared with international best practice

The approach to the management of mobile spectrum in the Middle East varies between countries:

- There are some where the approach is not consistent with best practice which will lead to issues from lack of efficiencies,
- Others where they are just starting to introduce management approaches that reflect best practice, and
- Those where there is no consistency between countries in terms of the spectrum that is released which will lead to harmonisation issues.

This means that the economic benefits arising from the availability of additional mobile broadband services, with the necessary QoS, may not be maximised in the Middle East.

The different approaches adopted to the management of spectrum, and in particular mobile spectrum, in the Middle East impacts on the:

- Amount of spectrum and different frequency bands available to the mobile operators to meet both coverage and capacity requirements
- The level of certainty provided to operators in terms of continued access to existing licensed spectrum as well as access to future spectrum
- The ability of the operators to invest in and develop their networks to cater for the ever-increasing demand for mobile broadband.

6.1 Comparison between Middle East and international best practice countries

In general, we have noted the following when comparing the Middle East countries with international best practice:

- There is less spectrum licensed for mobile broadband services overall - there is less spectrum available to meet both coverage and capacity requirements. (See Figure 2-8)
- The level of certainty provided to operators in terms of continued access to spectrum as well as access to future spectrum is lower with no clear spectrum roadmaps available in many countries
- The migration to more efficient 4G technologies is slower, due to lack of technology-neutral licences and new spectrum, which will lead to lower average data speeds or lower QoS.

We consider these issues further in the following sections.

6.1.1 Access to spectrum below 1 GHz

900 MHz band

The 900 MHz band was the first spectrum to be awarded for 2G mobile technologies. Initially not all the spectrum was made available and the allocations were based on multiples of the 200 kHz channel bandwidth. This means that there are non-contiguous spectrum blocks and they are not based on multiples of 5 MHz channel bandwidth[125]. Also, not all the band may have been made available (refarmed) for mobile or guard bands have been used between assignments to different operators which is no longer standard licensing practice[126]. There are examples, including Oman and Qatar where it appears that not all the 900 MHz band has been licensed for mobile.

It has generally been best practice to ensure that the entire 900 MHz band is made available for mobile and as part of moving to a technology-neutral licensing approach or re-licensing of spectrum the spectrum blocks have been re-allocated to ensure contiguous frequencies based on multiples of 5 MHz and no guard bands.

700 and 800 MHz bands

The 800 MHz and in some instances the 700 MHz bands have been awarded in Region 1 European countries following the replanning of terrestrial TV and the switchover to digital and release of spectrum for mobile broadband. However, the approach in the Middle East to spectrum refarming in the 700 MHz and 800 MHz bands has been inconsistent between countries, with apparently a significant number of countries still deploying analogue TV and limited visibility of plans and timescales to migrate to digital TV and switch-off the analogue transmitters. In contrast, a select number of countries (Qatar, UAE and Saudi Arabia) have successfully refarmed spectrum in these bands to mobile users though their approaches to the awards differ.

The UAE has fully awarded spectrum in the 800 MHz band to the two main operators. We understand that in Qatar the 800 MHz band is fully awarded to the mobile operators and a government entity.

The CITC auctioned spectrum in the 700 MHz and 1800 MHz bands in June 2017, with 2×25 MHz of 700 MHz spectrum available to wireless providers. CITC identified the release of the 700 MHz to be suitable to support mobile broadband services; releasing spectrum to support mobile broadband services was a key objective of the auction[127]. The 800 MHz band will be released in the future but has been delayed thus far because of legacy issues[128].

There is an urgent need for all countries in the region to complete digital TV switchover, according to an agreed plan, as those countries that want to use the released spectrum for mobile broadband may be limited due to the potential for interference from TV transmitters in neighbouring countries. For example, if a 5kW TV transmitter is deployed to provide service in the Morbagh area of Iran using an omnidirectional antenna then it can potentially interfere into the neighbouring countries (Qatar and

[125] 3G and 4G technologies are generally based on utilising bandwidths that are multiples of 5 MHz.

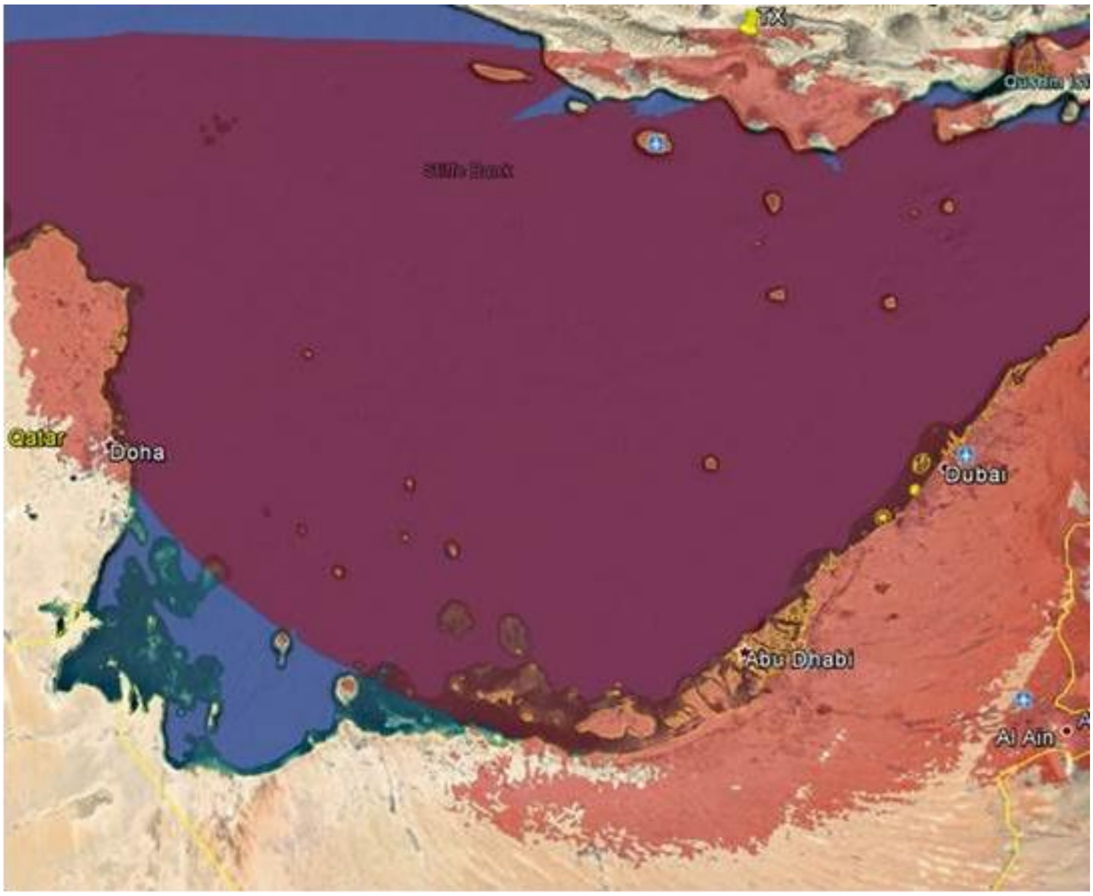
[126] It is the responsibility of the mobile operators to co-ordinate the use of their frequencies with those in adjacent frequencies and where necessary deploy mitigation, such as guard bands, within their licensed spectrum

[127] http://www.citc.gov.sa/en/MediaCenter/PressReleases/Pages/2017060601.aspx

[128] Policy Tracker, 21/06/2017, Four operators succeed in Saudi Arabia's first spectrum auction. Available at: https://www.policytracker.com/headlines/saudi-arabias-first-spectrum-auction-brings-four-winners-1.6-billion

UAE) as shown based on the 1% of time co-channel protection interference contour shown in Figure 6-1.

Figure 6-1: Interference contour at 1% of time



Source: Plum Consulting

It is also noted that there is no consensus on whether the 700 MHz or 800 MHz should be identified as the priority band for release in the Middle East – for example in Qatar and the UAE the 800 MHz band has been licensed whereas Saudi Arabia recently auctioned the 700 MHz band for mobile broadband services. This is in part due to the use of CDMA 850, PPDR and obsolete iDEN systems in some countries which means that the 800 MHz band is not available for mobile broadband.

450 MHz band

LTE450 (3GPP Band 31, 452.5-457.5 MHz paired with 462.5-467.5 MHz) is deployed in 8 countries today (Brazil, Denmark, Norway, Sweden, Finland, Russia, Hungary and Armenia) and there are known plans for launch in the Philippines, Indonesia and China. Given the readiness of the technology and its characteristics[129] and the better coverage capability compared with the 700/800/900 MHz mobile spectrum it could be ideal in the Middle East countries, with larger geographic area and areas with low population densities, to increase coverage.

6.1.2 Access to spectrum above 1 GHz

1800 MHz band

The 1800 MHz band was also first released to support 2G technologies but it is now one of the main bands used for 4G. Initially not all the spectrum was made available and the allocations were based on multiples of the 200 kHz channel bandwidth. This is a key band and in all the best practice countries the whole band is available on a technology-neutral basis, spectrum assignments are contiguous and based on multiples of a 5 MHz bandwidth. Any guard bands required between operators are internal within their assignments and operators are responsible for co-ordinating their frequency use. This is very different to the situation in, for example, Qatar where there is unassigned 1800 MHz spectrum.

Saudi Arabia's recent auction of 1800 MHz spectrum released an additional 2×40 MHz of previously unallocated spectrum in paired 5 MHz blocks. As a result, the 1800 MHz band is now fully assigned. Following the auction, the band was replanned to ensure that operators' newly allocated and existing frequencies were in contiguous blocks.

2100 MHz band

The 2100 MHz band was licensed for 3G technologies (UMTS) based on 5 MHz spectrum blocks. It was typically made available to provide increased capacity in network hotspots following on from the 900 and 1800 MHz bands. This band is now being refarmed by operators to deploy 4G technologies. Whilst the FDD (paired) bands have been used, in those countries where TDD (unpaired) spectrum was also awarded it has not been utilised. In the Middle East there remains some spectrum that has not been refarmed or released and there has been the use of unnecessary 5 MHz guard bands between operators' frequency blocks such as in Qatar.

Other high-frequency bands

There has been limited licensing in the majority of the Middle East countries of other capacity bands (1500 MHz, 2300 MHz, 2600 MHz and 3500 MHz) for mobile broadband compared with international best practice. In a number of countries one or more of these bands are currently used to support fixed or government services often with a mix of FDD and TDD technologies and non-contiguous assignments. This means that the spectrum is not suitable, without refarming and reconfiguration, for mobile broadband even if there were some unused frequencies. Limited spectrum restricts the amount of bandwidth that can be licensed and the benefits of higher data capacity and speeds provided by these bands in other countries.

[129] LTE 450 can also support the typical PMR requirements such as Group Call and Push-to-Talk as defined in 3GPP releases 12 and 13.

In a number of countries, such as Saudi Arabia, the only capacity bands that have been licensed for mobile broadband are the 1800 and 2100 MHz bands which is significantly less than the spectrum and bands made available elsewhere. Capacity could be significantly increased by allowing IMT access to the 2300 MHz, 2600 MHz and 3500 MHz bands which will enhance the user experience in Saudi Arabia.

6.1.3 Licensing certainty

Licence renewal

In general, there appear to be no policy statements on the approach to licence renewal (or not). The risk is where there is no stated policy, operators may reduce, or even stop, investment in their networks towards the end of their licences. There needs to be a clear statement that, for example:

- All licenses will be automatically renewed unless there is a reason not to do so. These reasons should be clearly identified and could include, for example, inefficient use of the spectrum, need to reconfigure the band to support larger bandwidths or need to manage interference.
- There will be a consultation and decision made [3] years in advance of licence expiry on the approach to re-award, or otherwise, of the available spectrum.

Licence duration

Typical licence duration is steadily increasing to provide sufficient timescales for operators to recoup their investments in network rollout. According to Plum's spectrum auction database of over 400 spectrum awards the most common licence duration has been 15 years. It is likely that greater economic benefit will arise from longer licence periods, such as 20 years. However, it is useful for regulators to be able to reclaim spectrum easily and this typically leads to shorter licence periods of 10 years.

It would be appropriate for administrations in the Middle East to consider longer licence periods (15 to 20 years) for all new spectrum awards[130].

Fees

Spectrum for mobile broadband tends to be treated differently by regulators compared with spectrum for other uses where users are charged on an annual basis. This spectrum is increasingly being awarded by auction around the world. However, most Middle East countries have tended to rely on fee schedules. These fees schedules are typically being updated to ensure efficient use of spectrum and to match annual fees with the typical fees being paid for the different bands at auction.

[130] The GSMA proposes in their Mobile Policy handbook 2015, http://mph.gsma.com/publicpolicy/handbook/spectrum-management-and-licensing that "new licences should be granted for at least 15 to 20 years to give investors adequate time to realise a reasonable return on their investment".

There is also increasing interest in using auctions for spectrum awards. It will be important that reserve prices are set sufficiently low to encourage competition and so award all the spectrum in the auction.

Regulators in the Middle East need to be more aware of the risks associated with setting annual fees or reserve prices too high and the likely impact on network rollout and investment.

Interference

As well as managing potential interference within a country through appropriate licensing conditions, including technical requirements such as block edge masks and reduced transmitter power levels as necessary, it is essential that cross border interference is managed.

It is noted that there are already interference problems because of the deployment of CDMA 850 in some countries and there appear to be limited cross-border agreements between countries which differs considerably to the European countries where there are agreed interference levels and co-ordination procedures.

6.1.4 Spectrum strategy roadmap

There is a significant difference in the information that is made publicly available on spectrum use, policy, management and in particular future spectrum strategy and plans compared with best practice. Bahrain appears to be the only country that has published a spectrum policy document and this was in 2006[131] and this was followed in 2012 with a revised spectrum plan release statement[132].

The result is very little visibility for the mobile industry, and in particular for the operators, of potential future release of spectrum for the incumbents of when they may need to migrate their services to other technologies and frequencies.

[131] See: http://www.tra.org.bh/media/document/the%202006%20spectrum%20policy.pdf . This Spectrum Policy document was developed after a consultation process and considered all inputs. The TRA and MoT in Bahrain had recognised that developing a long-term spectrum allocation strategy is critical for the future expansion of telecommunications in Bahrain.

[132] See http://www.tra.org.bh/media/document/RevisedSpectrumReleasePlan1.pdf

7 Recommendations

In the following sections we recommend those areas where the approaches adopted in the Middle East could be altered to reflect the approaches used in best practice countries and so enhance the potential economic benefits afforded by mobile broadband services.

7.1 Award of further spectrum and refarming of suitable spectrum

It is essential that additional spectrum is identified and awarded to ensure that the benefits available from mobile broadband, identified in Section 3, can also be experienced in the Middle East. There is a need for spectrum now (both below and above 1 GHz) to support the roll-out of 4G networks and also in the medium to longer term to support the future deployment of 5G[133].

It is likely that spectrum suitable for the deployment of mobile networks will already be allocated to other services and users. Therefore, it will be necessary to identify those bands where it may be easiest to release spectrum and also oversee its clearance. Such decisions are likely to be based on:

- Whether the existing services and planned mobile services can co-exist on a co-channel, adjacent channel or geographic basis. If sharing is feasible this might make release of the spectrum for mobile broadband simpler. It will, however, be necessary to specify technical licence conditions to minimise the potential for interference
- Whether the incumbent users have had access to the spectrum for a considerable period of time and the demand for services is declining so it is difficult to argue the cost benefit of them having continued use of the frequencies when compared with mobile broadband services. In some instances, the licences and equipment might be nearing the end of their lifetime so the users may already be looking to release the spectrum.

However, it is more likely that a forced migration of the incumbents will be necessary and decisions will need to be made based on how the incumbents can be cleared and associated timescales. This is discussed on a band by band basis in Sections 5.1, 6.1.1 and 6.1.2.

In summary there are three tasks that regulators need to complete to clear spectrum (and ensure it stays available for mobile usage):

i. Clear incumbents from the spectrum, potentially by allocating other spectrum for them to use or offering financial incentives for early release.
ii. Set in place technical standards and guard bands that ensure that mobile broadband and other users at lower and higher frequencies do not interfere with each other. Despite the presence of the guard bands, coordination between spectrum users may still be necessary.
iii. Create a system of monitoring and reporting to allow for feedback on interference.

7.2 Licensing

The licensing approaches should be reviewed to ensure there is a clear, transparent and non-discriminatory approach to the renewal of current licences and the award of new spectrum licences. It

[133] The relevant bands will be discussed and identified through the World Radio Conference 2019 (WRC '19) process

is essential that the mobile operators have the necessary certainty to invest in their networks and services as described in Section 5.2.

7.3 Cross-border agreements

There is a risk that without adoption of harmonised frequency bands and usage or appropriate cross-border agreements interference between neighbouring countries will limit the use or QoS of spectrum for mobile broadband.

7.4 Spectrum strategy roadmap

There is no single spectrum strategy roadmap that can be developed and applied to all the Middle East countries as the markets and spectrum availability varies country by country. However, in all cases the starting point has to be the ITU allocations and associated decisions made at World Radio Conferences and the specific priorities for future spectrum management identified by each regulator and administration.

Spectrum strategy plans for access to mobile broadband spectrum are a key consideration but it is also important to address other services as well. For example, strategies on fixed links spectrum are important in terms of fixed wireless access as well as provision of backhaul for mobile broadband.

7.5 Market based decisions

There is increasing acceptance that the administration and regulator is not always best positioned to identify when there should be investments made in networks such as to support deployment of more efficient technologies or deployment of new services. This means that the award of spectrum should allow the operators to make decisions on technology and services based on the licence conditions that are established to avoid interference into other spectrum users. This allows licences to be awarded on a technology (and service) neutral basis.

7.6 Summary of specific recommendations

Table 7-1 below provides an overview of some specific recommendations for each country based on publicly available information that is provided in the Appendices. This should not be taken as a complete list of recommendations, but rather indicative of where regulators and governments should focus their efforts based on public information.

Table 7-1: Overview of specific recommendations by country

Recommendation	Bahrain	Iran	Kuwait	Oman	Qatar	Saudi Arabia	UAE
Complete digital terrestrial TV (DTV) switchover	✓ (Planned 2013)	✓					

Recommendation	Bahrain	Iran	Kuwait	Oman	Qatar	Saudi Arabia	UAE
Refarm and award any remaining spectrum not licensed for mobile broadband in the 900, 1800 and 2100 MHz bands	✓		✓	✓	✓		
Ensure that operators have access to contiguous spectrum in each frequency band		✓					
Ensure that spectrum is available in multiples of 5 MHz blocks to support deployment of 3G/4G/5G technologies as determined by the operators	✓			✓		✓ (Note 1)	
Remove any unnecessary guard bands between operators' frequencies and replace with obligations for operators to manage adjacent channel interference					✓ (Note 2)		
Refarm 2300, 2600 and 3500 MHz bands based on current users and ease of releasing the spectrum	✓	✓	✓		✓	✓	✓
Award spectrum released in the 2300, 2600 or 3500 MHz bands based on harmonised 3GPP band plans for Region 1	✓	✓	✓	✓	✓	✓	✓
Start the process of releasing other potential mobile bands such as 450 MHz (Note 3) and 1500 MHz	✓	✓	✓	✓	✓	✓	✓
Follow the activities in preparations for WRC-19 and developments for 5G. Start identifying the refarming requirements to release further spectrum that may be identified.	✓	✓	✓	✓	✓	✓	
Ensure existing licences are technology-neutral		✓		✓			
Ensure all new licences are technology-neutral	✓	✓	✓	✓	✓	✓ (Note 4)	✓
Licence conditions should include technical requirements to avoid interference in country and cross-border	✓	✓	✓	✓	✓	✓	✓
Cross-border agreements should be put in place for all frequency bands	✓	✓	✓	✓	✓	✓	
Develop, consult on and publish a spectrum roadmap	✓	✓	✓	✓	✓	✓	
Regularly update the spectrum roadmap (ideally every 3 years)	✓	✓	✓	✓	✓	✓	

Note 1: Legacy award in 2600 MHz and 3500 MHz bands may not all be in 5 MHz blocks and should be reviewed when appropriate.

Note 2: The 5 MHz guard bands in the 2100 MHz band might have been to allow future expansion and ensure contiguous frequencies

Note 3: 450 MHz band could potentially be useful to provide coverage in rural areas in countries such as Iran, Oman and Saudi Arabia.

Note 4: Recent awards of IMT spectrum are under technology- and service-neutral licences. Legacy licences should be reviewed when next awarded.

Appendix A: Bahrain

The Telecommunications Regulatory Authority (TRA) in Bahrain was established in 2002. Its aim is to carry out its duties independently, transparently and to be non-discriminatory. The Kingdom of Bahrain was ranked 27th globally for communications technology (ICT) by the International Telecommunications Union (ITU) in 2015[134]. Since 2002 more than 2,600 jobs have been created – a 50% increase – and the industry has accounted to 4% of the GDP[135].

According to the TRA 2015 Annual Report[136], by the end of 2015 the mobile penetration was 187%, up from 177% at the end of 2014, with more than 2.54 million subscribers. Broadband penetration was 145%. In the telecommunications sector, there were 3,200 employees.

The latest Annual Market Indicators Report from the TRA[137] indicated that "yearly usage of Mobile broadband doubled between 2014 and 2015".

A.1 Services operating in bands identified for mobile

In Bahrain, the National Frequency Plan was last updated in 2009[138]. It does however provide an indication of those services that might be deployed in the bands identified for mobile broadband and the applicable national allocations that apply.

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[134] Bahrain News Agency, 30 November 2015, "Bahrain tops Arab World in ICT performance indicators." Available at: http://www.bna.bh/portal/en/news/698870

[135] http://www.tra.org.bh/en/about-us/background.html

[136] http://www.tra.org.bh/traFinal/tra2015en.pdf

[137] http://www.tra.org.bh/en/press-releases/%D9%82%D8%B7%D8%A7%D8%B9-%D8%A7%D9%84%D8%A7%D8%AA%D8%B5%D8%A7%D9%84%D8%A7%D8%AA-%D9%8A%D8%AD%D9%82%D9%82-450-%D9%85%D9%84%D9%8A%D9%88%D9%86-%D8%AF%D9%8A%D9%86%D8%A7%D8%B1-%D8%A8%D8%AD%D8%B1%D9%8A.html

[138] http://www.tra.org.bh/media/document/The%202009%20National%20Frequency%20Plan.pdf

Table A-1: Allocations and use of mobile frequency bands in Bahrain

Frequency Band	National Allocation	Major Utilisation	Other information
452.5 – 457.5 / 462.5 – 467.5 MHz (Band 31)	FIXED, MOBILE	Government and civil private, public fixed and mobile	450 – 455 MHz may be paired with 460 – 465 MHz 455 – 456 MHz may be paired with 465 – 466 MHz, and 456 – 459 MHz may be paired with 466 – 469 MHz Footnote BHR11 says "The band 450 – 470 MHz is a candidate band for a variety of modern mobile technologies including GSM, TETRA, IS95, IMT as well as a residual band for analogue single and two frequency conventional and trunked mobile networks. A strategy for the future use of this band will be elaborated by the SSCC."
703 – 733 / 758 – 788 MHz (Band 28)	470 – 790 MHz BROADCASTING	Broadcasting band IV/V analogue & digital TV GE06 Plan SAB	Also, SRD's and LPD's on secondary basis
832 – 862 / 791 – 821 MHz (Band 20)	FIXED, MOBILE, BROADCASTING	Broadcasting band IV/V analogue & digital TV GE06 Plan IMT candidate	Fixed service, private use, on a national primary basis (Note 1)
880 – 915 / 925 – 960 MHz (Band 8)	862 – 960 MHz FIXED, MOBILE	Public and private fixed and GSM	IMT candidate
1427 – 1518 MHz	1427 – 1429 MHz SPACE OPERATION, FIXED, MOBILE 1429 – 1452 MHz FIXED, MOBILE 1452 – 1492 MHz FIXED, MOBILE, BROADCASTING, BROADCASTING SATELLITE 1492 – 1518 MHz FIXED, MOBILE	Public fixed Government and public fixed Government and public fixed Public fixed	

Frequency Band	National Allocation	Major Utilisation	Other information
1710 – 1785 / 1805 – 1880 MHz (Band 3)	1710 – 1930 MHz FIXED, MOBILE	Public fixed and mobile	
1920 – 1980 / 2110 – 2170 MHz (Band 1)	1710 – 1930 MHz FIXED, MOBILE 1930 – 1970 MHz FIXED, MOBILE 1970 – 1980 MHz FIXED, MOBILE 2110 – 2160 MHz FIXED, MOBILE 2160 – 2170 MHz FIXED, MOBILE	Public fixed and mobile Public fixed and mobile, IMT 2000 IMT 2000 Public fixed and mobile, IMT2000 IMT 2000	
2300 – 2400 MHz (Band 40)	2300 – 2450 MHz FIXED, MOBILE	Government fixed and mobile	IMT candidate band – strategy to be elaborated by the SSCC
2500 – 2570 / 2620 – 2690 MHz (Band 7) 2570 – 2620 (Band 38)	2500 – 2520 MHz FIXED, MOBILE, MOBILE-SATELLITE 2520 – 2655 MHz FIXED, MOBILE, BROADCASTING SATELLITE 2655 – 2670 MHz FIXED, MOBILE, BROADCASTING SATELLITE 2670 – 2690 MHz FIXED, MOBILE	Government mobile, low power mobile cameras Government fixed and mobile Government mobile, low power mobile cameras Government mobile, low power mobile cameras	IMT candidate band – strategy to be elaborated by the SSCC See Note 1
3400 – 3600 MHz (Band 42)	FIXED, FIXED-SATELLITE	Public FWA operators	Operator 1: 3410 – 3455 MHz / 3500 – 3545 MHz Operator 2: 3455 – 3500 MHz / 3545 – 3590 MHz
3600 – 3800 MHz (Band 43)	3600 – 4200 MHz FIXED, FIXED-SATELLITE	3600 – 3700 MHz Government fixed and mobile	

Source: National Frequency Plan

Note 1: At the Spectrum Strategy Coordination Committee meeting it was agreed to allocate the range 790 – 862 MHz to mobile broadband (LTE) in addition to the 2.6 GHz band that was formerly allocated for the same application[139].

In 2006 two voice and data operating concessions were awarded, by auction, to Menatelecom and MTC-Vodafone Bahrain[140]. Menatelecom launched a national WiMAX network in 2007 using 802.16e technology[141] and in September 2013 launched a LTE network in the 3.5 GHz band[142] in tandem with its WiMAX network. It is expected that all users will now have migrated to LTE as Menatelecom offered users a free LTE device in exchange for their WiMAX devices. Zain Bahrain also has provided WiMAX in the 3.5 GHz band[143].

In 2009 TRA undertook a consultation on "Management – Current and Future Requirement – Release Plan". This consultation considered aspects of the spectrum framework, spectrum rights, refarming approaches and spectrum licensing including the mobile frequency bands. In 2012 TRA published a report on the outcome of the consultation[144]. Responses to the consultation were received from licensed operators in Bahrain, international satellite operators, national and international associations and manufacturing industry. In terms of the different potential mobile broadband frequency bands it was noted that:

- 450 – 470 MHz: "The number of assignments in this frequency range to non IMT mobile systems has been reviewed, which are considerable. Furthermore, the topography and size of the Kingdom is such that public services using higher frequencies can be rolled out over the whole territory without too much difficulty.
- 824 – 834 / 869 – 879 MHz: It was decided not to allow this band in Bahrain despite some support from respondents. "The Authority in common with most GCC regulatory authorities believes that the band 790 – 862 MHz should in future be used for the provision of IMT and converged services, in a technology-neutral manner, provided that alternative allotments and assignments can be realised for digital terrestrial television and ancillary broadcasting applications in spectrum below 790 MHz". "The entire range 694 – 862 MHz will be included in a national review of IMT spectrum to be finalised in 2015[145]".
- 3600 – 3700 MHz: "Concerning the bands 3600 – 3700 MHz and 5470 – 5725 MHz, these bands are not currently available for public telecommunications operators in the Kingdom. The Authority does not foresee any immediate possibility of changing this situation. As to the need for future additional spectrum to support 20 MHz channelling, the Authority recognises that this may be a future requirement …". "It should also be noted that the restrictions imposed on the Kingdom's

[139] http://www.bahrain.bh/wps/portal/!ut/p/a0/hc7BbsIwEATQX9lLzjZBhHLMoSriQiUkmvqCLGdJ3Ni7ib0h7d839Ad6nNHTaJRRjT_JkH76z4plseGZT3Y5nXW3Kl_Kkt9tXXZ-r_fv-eijrw05dkNTpP9SoT_81TaZWxjEJfotqsOPHyElsuCEVuueIhZ5m7wYInoZc6BvgoogkQLishfQIeUQnaY6QJVnB7gccc2o9_T1eQ4xeBFfY8-JsxgwJ8xwkA9_hubBwCi0k23peOd0xITmEUm92ahzePn4Be_VfMQ!!/

[140] https://www.telegeography.com/products/commsupdate/articles/2006/12/18/business-as-usual-after-wimax-auction-defeat-says-batelco/

[141] https://www.telegeography.com/products/commsupdate/articles/2008/11/24/mena-telecom-launches-nationwide-wimax-network/

[142] https://www.telegeography.com/products/commsupdate/articles/2013/09/20/batelco-zain-viva-awarded-additional-4g-spectrum-licences/

[143] https://www.telegeography.com/products/commsupdate/articles/2011/04/12/zain-bahrain-upgrades-wimax-network/

[144] http://www.tra.org.bh/media/document/ReportonSpectrumReleasePlanConsultationFina1l.pdf

[145] No information has been found on the 2015 review

two licensees in the band 3400 – 3600 MHz prohibiting the introduction of mobility in this frequency band were lifted on 16 February 2012”.

- 2300 MHz: It was decided “that the overall interests of the Kingdom will be best served by not implementing advanced IMT services in the 2.3 GHz band”.
- 2600 MHz: “Given the agreement to complete the licensing of post 3G public mobile systems in the 2.6 GHz band by Q1 2013, the Kingdom intends to initiate discussions with neighbouring countries to ensure the efficient use of this band. In particular, in order to maximise the amount of spectrum available to the Kingdom it will be necessary for neighbouring countries to harmonise their frequency allocation plan for the 2.6 GHz band, this could increase the amount of spectrum available for assignment in the Kingdom as technical measures could be put in place to reduce interference in border areas”. “It should be noted that the 2.6 GHz band has to date been used by governmental services in the Kingdom however in March 2012 the Kingdom released a significant amount of spectrum in this band for public mobile telecommunications applications. Initially 2×40 MHz of paired spectrum will be available for public mobile telecommunications systems and the remaining 2×30 MHz will become available not later than end December 2014. However, there is likely to be a single licensing award process for the entirety of all IMT spectrum”.

The spectrum release plan provided in the report is as follows.

Spectrum Consultation Report - Current and Future Spectrum Requirements

ANNEX 3 – Telecommunication Spectrum Release Plan (SRP)

Frequency Band	Application	Target Release Date	Award Mechanism	Additional Information including details of actual frequencies for release (if different from Column 1)
880 – 960 MHz	Mobile, IMT – 900	Q4 2012-Q1 2013	Comparative or Market Process [9]	880 – 885.6 MHz UL/925-930.6 MHz DL
880 – 960 MHz	Railway IMT - R	TBD	TBD[10]	876 – 880 MHz paired with 921 – 925 MHz. Subject to the building and operation of a railway network
1518 – 1675 MHz	GMPCS	Q4 2012	FCFS	1518-1559 MHz DL/1626.5-1660.5 MHz & 1668 – 1675 MHz UL. All mobile satellite operators may offer GMPCS services subject to licensing
1710 – 1880 MHz	Mobile, IMT - 1800	Q4 2012-Q1 2013	Comparative or Market Process [11]	1750 – 1760 MHz UL /1845-1855 MHz DL 1780 – 1785 MHz UL/ 1875-1880 MHz DL
1900-2170 MHz	Mobile, IMT-2100	Q4 2012-Q1 2013	Comparative or Market Process [12]	1945-1950 MHz UL/2135-2140 MHz DL, 1965-1980 MHz UL/ 2155-2170 MHz DL and 1905 – 1920 MHz
2500-2690 MHz	Mobile, IMT-2600	Q4 2012-Q1 2013 (2x40 MHz) Q4 2014 (2x30 MHz)	Comparative or Market Process [13] [14]	2500-2570 MHz UL / 2620-2690 MHz DL

[9] An integrated International Mobile Telecommunications (IMT) spectrum award process is planned which is likely to be either a comparative process or a market based process.
[10] An appropriate licence award process will be developed for the entity operating the Kingdom's future railway telecommunications network and the entities owning and operating railway locomotives and rolling-stock in the Kingdom.
[11] As Footnote 9
[12] As Footnote 9
[13] As Footnote 9
[14] A single Award Process finalised by Q1 2013 will cover the entirety of the 2 x 70 MHz sub-bands despite a later release date for 2x30 MHz of the available spectrum.

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A.2 Licensing

There are three mobile operators in Bahrain. The first mobile operator was the government-owned Batelco (Bahrain Telecommunications Company) and they were followed by Zain who were granted the second mobile spectrum licence in 2003. In 2008, the third mobile service provider, VIVA Bahrain, was licensed. More recently Menatelecom[146], originally, a Wireless Local Loop (WLL) operator has been offering access and mobile services using its 3.5 GHz spectrum but does not have the status as the fourth mobile operator[147].

TRA planned an auction of 900, 1800, 2100 and 2600 MHz bands in 2013 but this was cancelled after a legal challenge as only the three existing mobile operators could bid[148]. Subsequently it is understood that the 900, 1800 and 2100 MHz bands were awarded to the three mobile operators to use for current technologies and LTE. Due to this, and the technology-neutral licence awarded to the third mobile operator in 2008, it is assumed all licences are now technology-neutral.

Whilst it is apparent that TRA planned to release the 2600 MHz band for mobile broadband services there is a potential cross border interference consideration that should be resolved first before any spectrum is awarded. CITC in Saudi Arabia has recently awarded the 2600 MHz band based on the band plan 41 which is for TDD arrangements, Saudi Arabia and Bahrain are only geographically separated by less than 30 km over water so it is important that the band plan adopted in Bahrain and cross border agreements between the two relevant administrations ensure that the risks of interference are minimised.

A.3 Spectrum roadmap

The TRA has issued a National Telecommunication Plan every 4 years with the fourth plan being approved in May 2016[149]. In the latest Plan, it specifically notes the increased demand for mobile broadband services and the consequential need for spectrum release. However, there is no information on the specific bands that might be made available and associated timescales. However, the SSCC (Spectrum Strategy Coordination Committee) has adopted the 2.6 GHz band allocation plan and technical specifications for 4G and 5G mobile technologies[150].

In fact, in the third National Telecommunications Plan it had similarly been noted the need to establish LTE infrastructure and the provision of services and that the international norm that had emerged was the "implementation in the 2.6GHz, 2.3GHz and 800MHz bands. Manufacturers of terminal equipment have focused on these bands, and thus terminals for these bands may exhibit the highest economies of scale".[151]

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[146] It is understood that Menatelecom's original fixed wireless licence for operating in the 3.5 GHz band was amended by TRA to remove all mobility restrictions (!6 February 2012). Menatelecom has refarmed the spectrum from WiMAX to LTE and LTE-Advanced.

[147] In TRA's Fourth National Telecommunications Plan it notes the uncertainty of a fourth entrant may be deterring investment from the 3 incumbent operators.

[148] https://www.telegeography.com/products/commsupdate/articles/2011/04/12/zain-bahrain-upgrades-wimax-network/

[149] http://www.tra.org.bh/media/document/NTP4_EnglishTranslation_May20161.pdf

[150] https://www.tradearabia.com/index.php?/news/IT_319340.html

[151] http://www.tra.org.bh/en/national-telecommunications-plans/ Third National Telecommunications Plan

A.4 Conclusions and recommendations

In all the mobile frequency bands, there is spectrum that is not assigned for mobile. The spectrum awarded to Zain in the 900 MHz band is not contiguous and is not ideal for refarming to 3G or 4G as the blocks are not based on multiples of 5 MHz bandwidth. The only bands definitely licensed for mobile are the 900 MHz, 1800 MHz and 2100 MHz bands. The 3.5 GHz band was awarded in 2006 to provide National Fixed Wireless Services (NFWS) and Menatelecom and Zain were both awarded spectrum. It is understood that this spectrum is now being used by Menatelecom to provide mobile services having migrated from WiMAX to LTE technology. There has been no award of spectrum in the 800 MHz, 2300 MHz and 2600 MHz bands although it was TRA's intention to award the 2600 MHz band. This is somewhat surprising noting the Government's comments in the third National Telecommunications Plan that "withholding of appropriate frequencies … has proven to be a hindrance to the efficient establishment of LTE infrastructure and the provision of services".

It is recommended that:

- The 2600 MHz band should be awarded for mobile broadband as soon as possible but first the cross-border interference needs to be considered and coordination undertaken with Saudi Arabia for this band. This is a key 4G band with an extensive eco-system and can be used immediately to provide capacity at hot spots in the networks and support the increasing demand for higher speed mobile broadband.
- The "unassigned" spectrum in the 900 MHz, 1800 MHz and 2100 MHz bands should also be awarded as soon as possible noting that there may be a need, as part of the award process, to reconfigure the band to ideally provide contiguous spectrum based on 5 MHz blocks.
- The 800 MHz band should be made available for award following it being identified for allocation for mobile broadband services. It can provide the advantage of in-building penetration making it possible to provide services indoors from externally located base stations.
- In addition to the four yearly National Telecommunications Plan, TRA should also publish a spectrum roadmap that updates spectrum users on future plans – this should not just address mobile broadband, although this is an important area, but also plans for any other release or refarming of spectrum for other services. Ideally this should be forward looking for 5 years and be updated on a regular basis (such as yearly). Consultation with industry prior to final publication provides an ideal opportunity for TRA to develop a good understanding of future spectrum demand and associated issues.

Appendix B: Iran

The Communications Regulatory Authority (CRA) was established in 2003. Mobile services are provided by three mobile network operators and a number of MVNO (Mobile Virtual Network Operators) licensees[152].

The number of mobile phone subscribers is estimated to be 88.7 million in 2017[153]. Smartphones made up over 40% of the total retail mobile phone market in 2015 and usage was increasing – in 2016 there were 47m smartphone users. The low cost of voice calls has increased mobile penetration. Mobile data services currently account for a small proportion of total revenue but that should alter with the launch of 3G HSPA and 4G LTE services. Also two operators, Irancell and ISP MobinNet, have migrated from WiMAX to TD-LTE technology[154].

Iran has developed its 6th Development Plan for 2016 – 2021 and this includes a number of initiatives for telecommunications including increasing internet bandwidth and encouraging investment. In January 2017, the minister of ICT explained the expansion of access to high speed internet over the country and noted that "around 400 towns and cities have access to 3G and around 350 cities to fourth generation mobile internet access". The plan is to increase bandwidth from 4 Gb/s to 17 Gb/s by the end of 2017. Many ministries use the National Broadband Network and it has created more than 100,000 jobs and electronic government was to begin by February 2017[155].

Iran is located in ITU Region 3 but is adjacent to other GCC countries in ITU Region 1. It therefore is important that it takes into account cross border use and ideally adopts harmonised spectrum bans common to both Region 1 and Region 3 wherever possible to minimise the potential for cross border interference.

B.1 Services operating in bands identified for mobile

Iran is located within ITU Region 3. Information available on current use of spectrum identified for mobile was provided in response to a Questionnaire in the Asia Pacific Telecommunity (APT) on mobile band usage, as shown below:

[152] In July 2016, a total of nineteen companies passed the criteria to be granted an MVNO licence (http://techrasa.com/2016/07/18/19-mobile-virtual-network-operators-launch-iran/). The licensees were required to seek an agreement with one of three mobile operators as a host within six months of the licence issue date otherwise they would lose their licences. In March 2017, the country's largest ISP, Shatel Group was given permission to offer full MVNO services under the brand name Shatel Mobile. In addition, HiWeb (in partnership with Vodafone) was also awarded a licence to offer SIM cards (https://www.budde.com.au/Research/Iran-Telecoms-Mobile-and-Broadband-Statistics-and-Analyses).

[153] https://www.budde.com.au/Research/Iran-Telecoms-Mobile-and-Broadband-Statistics-and-Analyses

[154] Irancell was granted a WiMAX licence in 2009 to provide services in six provinces and the network was deployed in twenty-nine cities (https://irancell.ir/portal/home/?news/27092/27059/143945/TDD-LTE-License-Granted-to-Irancell) and was awarded a nationwide TD-LTE licence in August 2015.

[155] http://www.iran-telecom.info/iran-telecom-market.html

Iran (Islamic Republic of)	
UMTS 900 MHz	880 – 890 / 925 – 935
GSM 900 MHz	890-915 / 935-960
GSM 1800 MHz	1710-1714 / 1805-1809 1725-1740 / 1820-1840 1770-1785 / 1865-1880
UMTS 1800 MHz	1725-1740 / 1820-1840 1740-1750/ 1835-1845 1765-1785 / 1860-1880
DECT 1800 MHz	1880-1900
UMTS 2100 MHz	1935-1975 / 2125-2170
LTE 2500 MHz	2550-2570 / 2670-2690 FDD 2570-2620 TDD
BWA systems	3422-3474.5 / 3479-3500 TDD 3522-3564.5 / 3569-3600 TDD

Source: APT-AWG-REP-15Rev.4_APT_Report_on_Mobile_Band_Usage, September 2016. (This data was provided in March 2015 and not changed for the 2016 version of the report)[156].

In the case of the 3.5 GHz band, it is noted that the operators are migrating from WiMAX to LTE technology[157]. This in theory allows them to also provide mobility as well as fixed wireless access depending on the conditions in their licences.

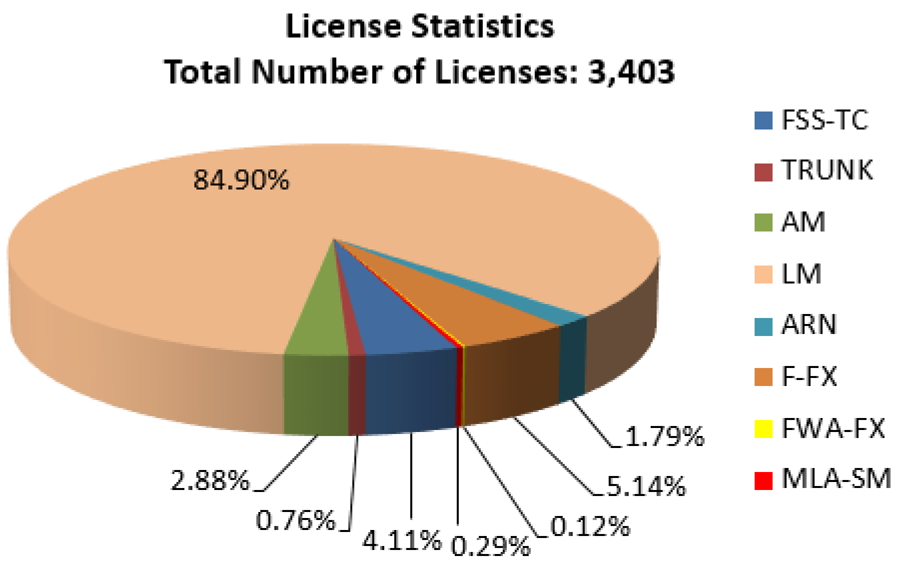
Based on information provided by CRA[158] to the SATRC meeting in March 2014 (Document 09) there is significant use of land mobile (LM) in Iran.

[156] There appears to be a couple of errors in the frequencies identified for the 3500 MHz band. The band is FDD and the relevant frequency ranges are 3422 – 3474.5 / 3522 – 3574.5 MHz

[157] https://www.telegeography.com/products/commsupdate/articles/2017/02/03/mobinnet-launches-td-lte/

[158] At the SATRC Action Plan Phase IV: 2nd Meeting of the SATRC Working Group on Spectrum, 11 – 12 March 2014, Tehran, Iran. http://www.apt.int/SAPIV-WGSPEC-02.

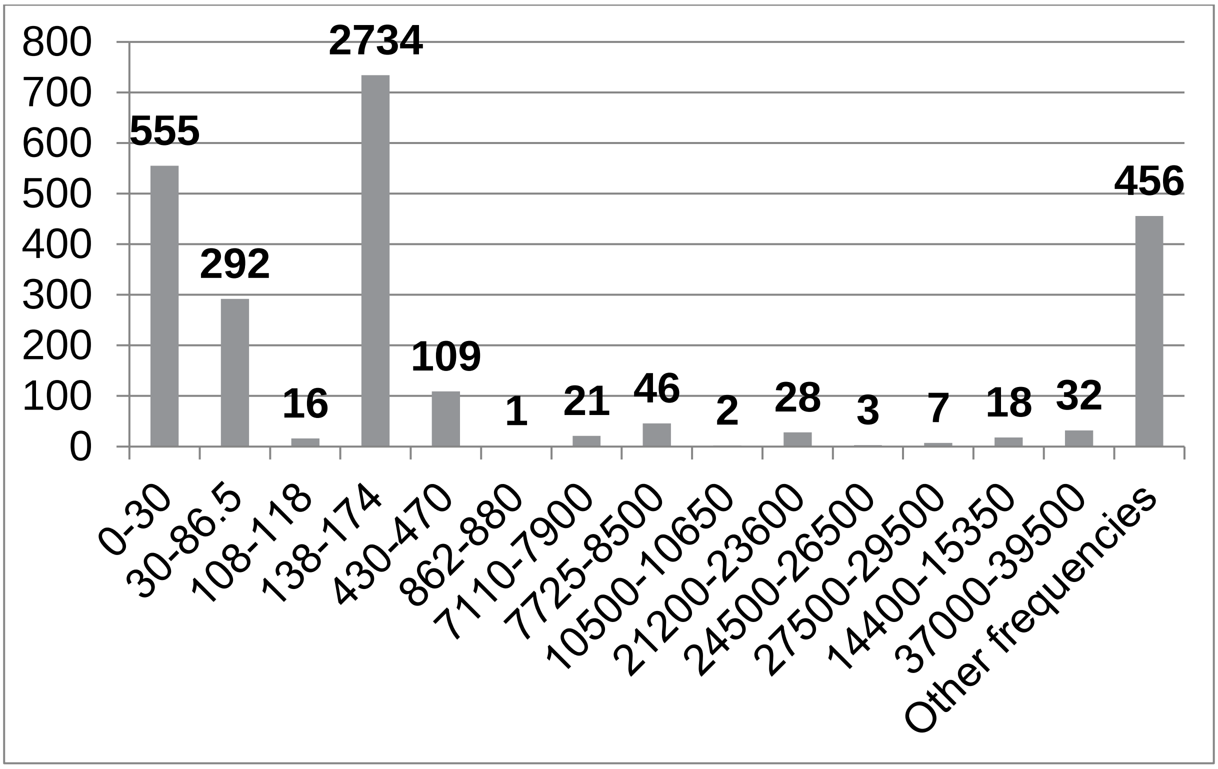
Figure B-1: Licences in Iran in 2015



Source: TRA input document on "National Spectrum Management" into SATRC Working Group Meeting, March 2014

In terms of number of licences by frequency band TRA also provided the information in Figure B-2. This shows the use of the 430 – 470 MHz band which we expect to be mainly for land mobile.

Figure B-2: Number of licences by frequency band



Source: TRA input document on "National Spectrum Management" into SATRC Working Group Meeting, March 2014

In another input presentation to the same SATRC Working Group Meeting[159] in 2014, it was noted that Iran has already introduced DTTB in almost all the cities according to the DVB-T standard. The Iran Broadcasting organisation was responsible for implementing DTTB throughout the country. Only the government-owned television channel can broadcast over terrestrial and there were plans for the channel to be switched over to digital.

In respect of the 1500 MHz band, the allocations in Iran are the same as in other Middle East countries (viz FIXED, MOBILE and also BROADCASTING for 1452 – 1492 MHz). The use of the 1452 – 1492 band for broadcasting was specifically identified for DAB (Digital Audio Broadcasting terrestrial and satellite) or DRM (Digital Radio Mondiale). Despite some limited deployments, the cost of the terrestrial networks was not economically viable and digital terrestrial broadcasting has instead been deployed in lower (for example, VHF) bands. There was a single broadcasting satellite network deployed to provide educational services to Africa and Asia. The remaining spectrum has typically been used for low capacity point to point links (such as less than 64 kbps up to a maximum of 8 Mbps) according to the ITU-R channel plans (1350 – 1375 / 1492 – 1517 MHz and 1375 – 1400 MHz / 1427 – 1452 MHz).

[159] "Status of DSO in SATRC countries", Slide 7, Document -13

B.2 Licensing

There has been a mix of national and regional licence awards with licences typically for a 10-year or 15-year duration[160]. It appears that licences may have been technology specific but refarming of the spectrum has been allowed to support more efficient technologies (such as 2G to 3G and 4G at 900 MHz and WiMAX to TD-LTE). For example, MTN Irancell signed an agreement with the CRA, in August 2014, to cover 3G and higher generation technologies[161].

Temporary licences have also been issued – for example, trial licences to deploy new technologies as well as ones to allow provision of services such as to Laser telecom in 2007 to provide WiMAX.

In October 2015, the regulator (CRA) announced a tender for 2300, 2600 and 3500 MHz bands. The bands were designated for TDD use (such as TD-LTE). Existing fixed broadband service providers could bid for the 2300 and 2600 MHz bands while the band 3500 MHz was open for all bidders[162]. However, it does not appear that the tender took place.

B.3 Spectrum roadmap

There does not appear to be a publicly available spectrum roadmap. A tender was announced for above 1 GHz spectrum but there is no further information. Nor are there any details available on terrestrial TV digital switchover except for ITU-D information that the process is ongoing and no indications when sub 1 GHz spectrum might be awarded for mobile.

B.4 Conclusions and recommendations

Euromonitor[163] commented that while Iran "is home to the largest internet user and mobile subscriber base in the Middle East though the quality of services has lagged due to network under investment".

There have been delays placed on the roll-out of 3G services by providing exclusivity to RighTel until September 2014 and also apparently in the award of other frequency bands for mobile broadband. Also, there has been a mix of national and regional licensing with no reported clear objectives and benefits arising from this approach.

4G networks became available in Iran far later than the benchmark countries which will have delayed the availability of higher speed data services and improved QoS.

There is no clear visibility on when further spectrum will be licensed for mobile broadband although, based on announcements of a planned tender, it appears that un-paired spectrum is available in the 2300, 2600 and 3500 MHz bands. Nor is there any information on digital switchover and release of spectrum below 1 GHz.

It is recommended that:

- Spectrum in the 900, 1800 and 2100 MHz bands is reconfigured into 5 MHz blocks and contiguous spectrum is made available to the three main mobile operators.

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[160] Source: GSMA licensing database

[161] http://telecomist.com/topics/iran/page/2/

[162] https://www.telegeography.com/products/commsupdate/articles/2015/10/21/iran-launches-new-wireless-broadband-auction/

[163] Iran Digital Consumer Landscape Country Briefing

- The spectrum that was planned to be licensed in 2015 (2300, 2600 and 3500 MHz) should be awarded as soon as possible according to the 3GPP band plans and on a technology- and service-neutral basis.
- Digital switchover is completed and the spectrum, which may include 700MHz (Band 28) and 800MHz (Band 20), is released and is awarded for mobile broadband to enhance the LTE coverage across the country. Also, the Digital switchover progress can minimise the cross-border interference to neighbouring countries which have already started to deploy LTE in their digital dividend bands.
- A spectrum roadmap should be developed that identifies what spectrum will be made available, the associated timescales and any future plans (such as considerations for 5G).

Appendix C: Kuwait

The regulation of telecommunications sector is in a state of transition. The Ministry of Communications regulated the sector until 2016 and is the monopoly operator of fixed telecoms in Kuwait. It was reported that the ministry would set up a Telecom and Information Technology Authority, which would be responsible for offering the fixed line services for privatisation[164]. The launch of the new Communication and Information Technology Regulatory Authority (CITRA) took place in February 2016. The authority has broad powers to 'regulate, supervise and oversee' the telecommunications sector.

Kuwait’s telecom market is advanced and the country also has one of the highest mobile penetration levels, which was 190.3% at the end of 2013. More recent data indicates that the penetration levels in Kuwait reached approximately 221% by the end of Q1-15. The country is one of the first markets in the region that deployed the 4G LTE network[165] with the Viva network in 2011.

Zain has the highest market share of about 37% while Viva and Ooredoo capture over 31% each. Viva joined the market in 2008 and rose quickly to capture market share against the existing two players[166]. Zain (former state-owned incumbent) and Ooredoo (formerly known as Wataniya) became cellular operators in 1999[167]. Viva became operational in 2008 and 3G licences were awarded to all three operators in the same year[168].

164 http://www.capacitymedia.com/Article/3539912/Kuwait-to-privatise-fixed-telecoms-network.html

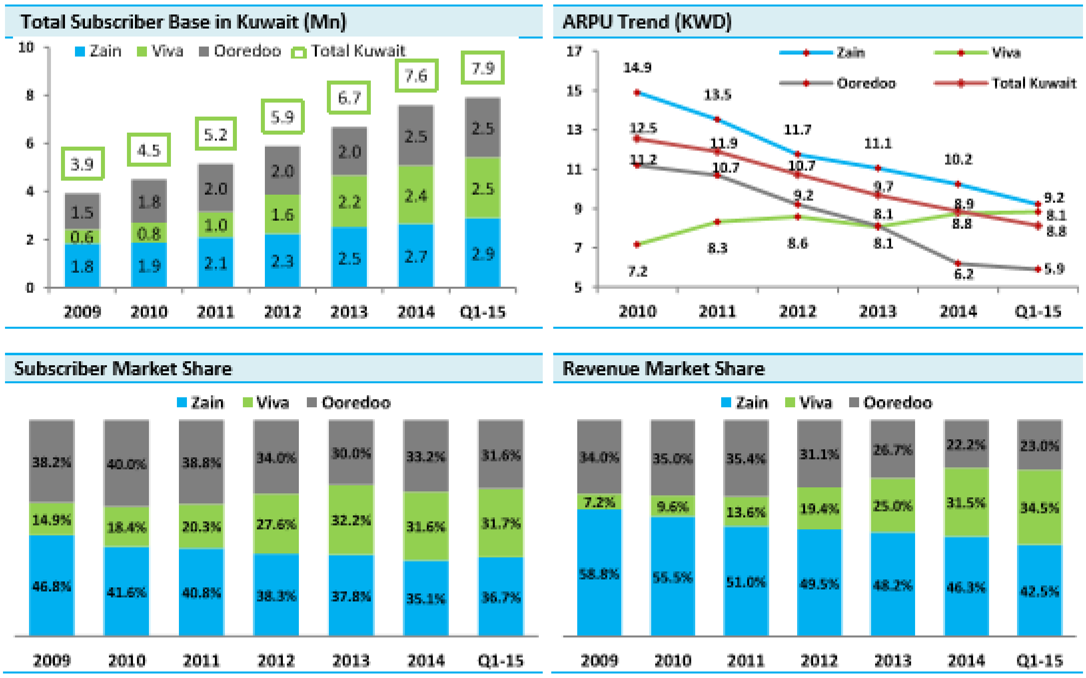
165 http://www.kamconline.com/Temp/Reports/78e311e9-b95b-4dd1-9246-4248b114b762.pdf

166 https://www.budde.com.au/Research/Kuwait-Telecoms-Mobile-Broadband-and-Digital-Media-Statistics-and-Analyses

167 http://www.infomercatiesteri.it/public/images/paesi/107/files/Kuwait%20Telecom%20Industry_pdf%202_13%20Capitalstandards.pdf

168 http://news.kuwaittimes.net/kuwait-telecom-market-viva-listing-kuwait-leads-gcc-mobile-mobile-broadband-penetration/

Figure C-1: Kuwait market data[165]



Sources: KAMCO Research and Company Financials

C.1 Services operating in bands identified for mobile

The latest Plan of National Frequency Band Allocations (National Table of Frequency Allocations)[169] is from February 2009. It does however provide an indication of those services that might be deployed in the bands identified for mobile broadband and the applicable national allocations that apply.

Table C-1: Allocations and use of mobile frequency bands in Kuwait

Frequency Band	National Allocation	Other information
452.5 – 457.5 / 462.5 – 467.5 MHz (Band 31)	450 – 460 and 460 – 470 MHz FIXED, MOBILE	Bands 455 – 460 MHz / 465 – 470 MHz identified for government use
703 – 733 / 758 – 788 MHz (Band 28)	470 – 790 MHz BROADCASTING	
832 – 862 / 791 – 821 MHz (Band 20)	790 – 862 MHz BROADCASTING, MOBILE	Allocation to mobile was to come into effect from 17 June 2015

[169] http://moc.gov.kw/rfld/material/material3.PDF

Frequency Band	National Allocation	Other information
880 – 915 / 925 – 960 MHz (Band 8)	862 – 890 MHz FIXED, MOBILE, BROADCASTING 880 – 942 – 960 MHz MOBILE	880 – 960 MHz identified for mobile (GSM band)
1427 – 1518 MHz	1427 – 1429 MHz SPACE OPERATION (E-s), FIXED, MOBILE 1429 – 1452 MHz FIXED, MOBILE 1452 - 1492 MHz FIXED, MOBILE, BROADCASTING, BROADCASTING-SATELLITE 1492 - 1518 MHz FIXED, MOBILE	
1710 – 1785 / 1805 – 1880 MHz (Band 3)	1710 – 1930 MHz FIXED, MOBILE	1710 – 1735 MHz / 1805 – 1830 MHz fixed 1735 – 1785 MHz / 1830 – 1880 MHz mobile
1920 – 1980 / 2110 – 2170 MHz (Band 1)	1710 – 1930 MHz FIXED, MOBILE 1930 – 1980 MHz FIXED, MOBILE 2110 – 2120 MHz FIXED, MOBILE, SPACE RESEARCH 2120 – 2170 MHz FIXED, MOBILE	1920 – 1980 MHz / 2110 – 2170 MHz identified as UMTS / 3G band
2300 – 2400 MHz (Band 40)	FIXED, MOBILE	Identified for FWA

Frequency Band	National Allocation	Other information
2500 – 2570 / 2620 – 2690 MHz (Band 7) 2570 – 2620 (Band 38)	2500 – 2520 MHz FIXED, MOBILE 2520 – 2670 MHz FIXED, MOBILE, BROADCASTING SATELLITE 2670 – 2690 MHz FIXED, MOBILE	2500 – 2690 MHz identified for FWA
3400 – 3600 MHz (Band 42)	FIXED, MOBILE	Identified for FWA
3600 – 3800 MHz (Band 43)	FIXED, FIXED SATELLITE	Identified for Downlink Satellite Earth Station

Source: Plan of National Frequency Band Allocations, 2009

According to the CDG[170] there are two CDMA 800 networks operated by the Ministry of Communications. The cdmaOne network was launched in 1998.

Mada Communications replaced its WiMAX network in 2012 using InfiNet's solutions (point-to-multipoint) to overcome some operational issues[171] and increase capacity to meet the demand for higher bandwidth. It is believed that Mada Communications is the only fixed broadband wireless provider as in the ITU profile (2015) for Kuwait it is noted that there is a monopoly.

C.2 Licensing

Based on the country's key Telecoms Law establishing the authority[172] each public telecommunication network must have a licence to provide services. In addition, there is a requirement for radio spectrum licences that were previously issued by the Ministry of Communications[173].

There are three major operators: Zain Kuwait, Viva and Ooredoo, all offering UMTS and LTE services and deploying or exploring LTE-A services[174].

170 http://www.cdg.org/worldwide/index.asp

171 http://infinetwireless.com/success-stories/infinet-ireless-enables-mada-to-provide-reliable-ireless-solutions-to-the-hole-of-kuait

172 https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiI7u-Wh5LTAhUIJ8AKHaqXBPkQFggaMAA&url=https%3A%2F%2Fwww.dlapiperintelligence.com%2Fsystem%2Fmodules%2Fza.co.heliosdesign.dla.lotw.telecoms%2Ffunctions%2Fhandbook.pdf%3Fcountry-1%3DBI%26country-2%3DKW&usg=AFQjCNGWSkCoZGocwcTv0XGMTAsuTVXFrA

173 http://moc.gov.kw/rfld/indexAe.html

174 http://www.prnewswire.com/news-releases/middle-east---mobile-network-operators-and-mvnos-300275123.html

C.3 Spectrum roadmap

There are no indications that a spectrum roadmap has been provided previously or that the new regulatory authority will provide such information.

C.4 Conclusions and recommendations

The main IMT frequency bands have been licensed in Kuwait and the licences appear to now be technology-neutral with the operators able to refarm their spectrum as fits the market and their roll-out plans. There are 3 mobile operators with roughly equivalent market shares

It is recommended that:

- CITRA monitor the 800 MHz band for any potential interference as it is understood that Saudi Arabia, with which Kuwait shares a border, is using the 800 MHz band for PPDR and legacy iDEN systems.
- CITRA should examine the potential for releasing the part of the 1800 MHz band that is currently allocated to fixed services
- CITRA put in place a spectrum roadmap plan and, as part of this, consider the issues and potential of releasing the 2.3 GHz and 3.5 GHz bands that were identified for Fixed Wireless Access. Also, the plan should consider potential future requirements for 5G.
- CITRA adopt technical and service neutral licensing approach to releasing new frequency bands to allow mobile operators the necessary flexibility to refarm to new technologies as necessary to meet user and service demand. This will maximise spectrum efficiency and support national ICT development in Kuwait.

Appendix D: Oman

There were 6.99 million subscribers to mobile in 2016 compared with 0.28 to fixed broadband and 0.48 to fixed-line telephony[175]. This high market penetration and increasing demand for mobile broadband (around half of Ooredoo's mobile revenues come from data services) are requiring increasing investment in the mobile networks.

In 2016, a National Broadband Strategy (NBS) was approved by the government with the aim of overcoming "several challenges, such as the low percentage of fixed broadband take-up with slower growth and high cost of broadband, compared with GDP per head benchmarked across the region and globally". Closing the digital divide was also a key consideration with the aim of providing rural areas with a basic capacity broadband network by 2020. The strategy aims to overcome constraints on the expansion of mobile broadband coverage[176] and this includes access to spectrum and towers, backhaul and increasing competition in the provision of broadband services[177]. "The Sultanate's NBS is designed in a manner to ensure that it is in line with the other national strategies in a bid to maximize their prevalence and the socioeconomic benefits generated by it" [178].

D.1 Services operating in bands identified for mobile

The latest National Frequency Table[179] is from 2014 and updated the 2011 version to take account of World Radio Conference 2012 (WRC-12). Between 2011 and this latest frequency table a number of frequency bands are no longer shown as being shared between civil and military but as being solely for civil utilisation.

Table D-1: Allocations and use of mobile frequency bands in Oman

Frequency Band	National Allocation	User category and major utilisation	Other information
452.5 – 457.5 / 462.5 – 467.5 MHz (Band 31)	450 – 470 MHz FIXED, MOBILE	CIVIL IMT	CDMA450/3G
703 – 733 / 758 – 788 MHz (Band 28)	BROADCASTING	CIVIL Analogue TV and DVB-T according to Regional Agreement GE06	Wireless audio applications according to Decision of TRA N. 133/2008

175 https://www.budde.com.au/Research/Oman-Telecoms-Mobile-Broadband-and-Digital-Media-Statistics-and-Analyses

176 23% of the population live in rural areas

177 http://timesofoman.com/article/89397/Oman/Science-/Oman%27s-NBS-approval-expected-to-propel-broadband-service-availability

178 http://www.motc.gov.om/DefaultEn.aspx?pageID=QtUKYQRBk%2FcZul9xLyO%2F9A%3D%3D&typeID=lJHlc66Pfg47VVok1eTw%2Fw%3D%3D

179 http://smu.tra.gov.om/publications/national-plan

Frequency Band	National Allocation	User category and major utilisation	Other information
832 – 862 / 791 – 821 MHz (Band 20)	FIXED, MOBILE, BROADCASTING	CIVIL Broadcasting was major utilisation. Analogue TV and DVB-T according to Regional Agreement GE06	Allocation to mobile effective from 17 June 2015.
880 – 915 / 925 – 960 MHz (Band 8)	LAND MOBILE	CIVIL EGSM 880 – 915 / 925 – 935 MHz GSM 900 890 – 915 / 935 – 960 MHz	GSM-R 876 – 880 / 921 – 925 MHz
1427 – 1518 MHz	1427 – 1429 MHz SPACE OPERATION, FIXED, MOBILE 1429 – 1452 MHz FIXED, MOBILE 1452 – 1492 MHz FIXED, MOBILE, BROADCASTING, BROADCASTING SATELLITE 1492 – 1518 MHz FIXED, MOBILE	SHARED Fixed links SHARED Fixed links CIVIL T-DAB S-DAB SHARED Fixed links	Low capacity fixed links Low capacity fixed links Low capacity fixed links
1710 – 1785 / 1805 – 1880 MHz (Band 3)	1710 – 1785 MHz LAND MOBILE 1800 – 1880 MHz MOBILE	CIVIL GSM-1800, IMT 1710 – 1785 / 1805 – 1880 MHz CIVIL	
1920 – 1980 / 2110 – 2170 MHz (Band 1)	1920 – 1980 MHz LAND MOBILE 2110 – 2120 MHz LAND MOBILE SPACE RESEARCH 2120 – 2170 MHz LAND MOBILE	CIVIL IMT CIVIL IMT CIVIL IMT	UMTS
2300 – 2400 MHz (Band 40)	FIXED, MOBILE	CIVIL IMT	Previously shared band

Frequency Band	National Allocation	User category and major utilisation	Other information
2500 – 2570 / 2620 – 2690 MHz (Band 7) 2570 – 2620 (Band 38)	2500 – 2520 MHz FIXED, MOBILE 2520 – 2655 MHz FIXED, MOBILE, BROADCASTING SATELLITE 2655 – 2670 MHz FIXED, MOBILE, BROADCASTING SATELLITE 2670 – 2690 MHz FIXED, MOBILE	CIVIL IMT CIVIL IMT SHARED IMT CIVIL IMT	Previously shared band Previously shared band
3400 – 3600 MHz (Band 42)	FIXED, FIXED SATELLITE	CIVIL Broadband Wireless Access	Band might be redefined for IMT in the future
3600 – 3800 MHz (Band 43)	3600 – 4200 MHz FIXED, FIXED SATELLITE	CIVIL Broadband Wireless Access FSS Fixed links	3600 – 3800 MHz priority for FSS networks

The move from shared bands provides the potential to use for mobile broadband. 3500 MHz band used for BWA and may be made available for IMT in the future. Fixed links (low capacity narrowband) will need migrating from 1500 MHz band. It is not expected there will be significant use of the spectrum identified at 1452 – 1492 MHz for broadcasting if refarming was undertaken at the time of the allocation decision.

D.2 Licensing

There are currently two licensed mobile operators in Oman (Omantel and Ooredoo (formerly Nawras)) and two active MVNOs (FRiENDi mobile and Renna Mobile).

TRA issued an Information Memorandum for a third mobile operator with a closing date of 26 December 2016[180]. The closing date was extended until 6 March 2017 and it is understood that bids have been submitted by STC and Zain (Kuwait)[181]. TRA stated that it considers that the enhancement of competition in the mobile telecom services market will be of significant benefit to consumers and the economy of the sultanate. "The availability of a range of additional radio spectrum that could be deployed is expected to provide a multitude of mobile telecom services, particularly mobile broadband,

[180] https://www.tra.gov.om/pdf/3MNO-im-document-announcement.pdf

[181] http://www.muscatdaily.com/Archive/Oman/Saudi-STC-Kuwaiti-Zain-telecom-firms-bid-for-Oman-s-third-mobile-operator-licence-50g1

to consumers in the sultanate," it said. According to TRA's Information Memorandum, the qualified bidders will be shortlisted and announced by August 14 and the ultimate licence winner will be announced on September 4.

Omantel (mobile) and Ooredoo (as Nawras) have Class I licenses that specify which technologies they can use as part of the licence conditions. Frequency authorisations come under this Class I licence. The Ooredoo licence specified that it is a 3G only licence but this must have been recently updated due to the award of spectrum to deploy 4G. Omantel's licence is for 2G and specifies that if available 3G technology may be used and the term will be no less favourable – again the expectation is it will have been updated to 4G.

Each Class I license was originally awarded for a duration of 15 years (and the same would apply to associated spectrum assignments). Omantel's licence was assigned in 2004 and Ooredoo's in 2005[182].

D.3 Spectrum roadmap

There are no indications that a spectrum roadmap has been provided, although it is noted that spectrum was released as part of the National Broadband Strategy (NBS) in 2012 and there is a more recent 2016 NBS that notes the importance of mobile broadband to provide services in rural areas and the need for further spectrum. It would seem appropriate that a spectrum roadmap should be published to complement the aims of the NBS.

D.4 Conclusions and recommendations

It appears that spectrum has been licensed in all the current main mobile broadband frequency bands (800, 900, 1800, 2100, 2300 and 2600 MHz bands). However, it is less clear whether there is the potential to refarm and award further frequencies in these bands to support the objectives of the 2016 National Broadband Strategy. It might also be beneficial to consider the potential of releasing the 450 MHz band to provide 4G (LTE) coverage in the rural areas.

A third mobile licensed operator will require access to both coverage and capacity frequency bands. TRA has indicated that there is availability of a range of spectrum.

It is recommended that:

- TRA should consider all the currently licensed frequency bands and identify further spectrum that can be released for mobile broadband to meet both coverage and capacity requirements. In particular the aim should be to maximise the available bandwidth in the frequency bands above-1 GHz.
- TRA should look at the potential for deploying LTE 450 to provide coverage in rural areas as well as supporting the requirements of Land Mobile users.
- All spectrum that is licensed to the mobile operators should ideally be contiguous in any frequency band and based on multiples of 5 MHz bandwidth.

182 https://www.tra.gov.om/class-i

- All licences should be technology-neutral although it is noted that refarming of bands for the latest technologies has been allowed.
- A spectrum roadmap, including 5G potential spectrum such as C-band, L-band and mmWave band, should be developed to complement the National Broadband Strategy published in 2016.

Appendix E: Qatar

The Communications Regulatory Authority (CRA) in the State of Qatar was established as an independent regulator in 2014. One of its responsibilities is to monitor the markets and it has found that the telecommunications sector, in 2016, "contributed 1.7% to Qatar's GDP (up from 1.3% in 2014)"[183]. CRA also reported "investments of around QAR 1.25 billion, which is around 12% of the service providers' revenues, in infrastructure and services and in preparation for future technologies". Consumers have been benefiting from innovative services and products and new business models.

In regards the mobile market Qatar has one of the highest penetration rates in the MENA region with 176% - only UAE and Bahrain have higher rates. It is considered to be a mature market with revenues remaining unchanged from 2015. There is also a developed fixed line market with 99% of Qatar's households located in areas where there is a fibre optic network and around 90% of these subscribed to data speeds of 10 Mbps and above.

E.1 Services operating in bands identified for mobile

In Qatar, the National Frequency Allocation Plan (NFAP) is regularly updated with the most recent dated November 2016[184]. This version will have taken into account the outcome of the World Radio Conference in 2015 (WRC-15). In the table below, the relevant information on the national allocations and major use is provided for the 3GPP harmonised mobile broadband frequencies.

Table E-1: Allocations and use of mobile frequency bands in Qatar

Frequency Band	National Allocation	Major Utilisation	Other information
452.5 – 457.5 / 462.5 – 467.5 MHz (Band 31)	450 – 455 MHz FIXED, MOBILE	PMR / PAMR, Digital Land Mobile (DMO), on-site paging	
	455 – 456 MHz FIXED, MOBILE	PMR / PAMR, on-site paging	
	456 – 470 MHz FIXED, MOBILE	PMR / PAMR, on-site paging, maritime on-board communications	456 – 459 MHz fixed telemetry
703 – 733 / 758 – 788 MHz (Band 28)	694 – 790 MHz MOBILE	IMT, Radio Microphones	Also allocated to fixed
832 – 862 / 791 – 821 MHz (Band 20)	790 – 862 MHz FIXED, MOBILE	IMT, Radio Microphones	

[183] http://www.cra.gov.qa/en/news/cra-2016-market-assessment-reflects-maturity-mobile-market-125b-investments-17-gdp-contribution

[184] http://www.cra.gov.qa/sites/default/files/Qatar%20National%20Frequency%20Allocation%20Plan%20%28NFAP%29_0.pdf

Frequency Band	National Allocation	Major Utilisation	Other information
880 – 915 / 925 – 960 MHz (Band 8)	880 – 960 MHz FIXED, MOBILE	Railway: 876 – 880 MHz / 921 – 925 MHz E-GSM: 880 – 890 MHz / 925 – 935 MHz GSM: 890 – 915 MHz / 935 – 960 MHz	
1427 – 1518 MHz	1427 – 1429 MHz SPACE OPERATION, FIXED, MOBILE 1429 – 1452 MHz FIXED, MOBILE 1452 – 1492 MHz FIXED, MOBILE, BROADCASTING, BROADCASTING SATELLITE 1492 – 1518 MHz FIXED, MOBILE	Low capacity fixed links, IMT Low capacity fixed links, IMT IMT Low capacity fixed links, IMT	Users of the low capacity links include oil companies and offshore links. Previously DAB
1710 – 1785 / 1805 – 1880 MHz (Band 3)	FIXED, MOBILE	DCS 1800, UMTS / IMT-2000, DECT, LP GSM (1781.7 - 1785 MHz/ 1876.7 – 1880 MHz	1718.8 – 1722.2 MHz radioastronomy on secondary basis
1920 – 1980 / 2110 – 2170 MHz (Band 1)	FIXED, MOBILE	Terrestrial UMTS / IMT-2000	
2300 – 2400 MHz (Band 40)	FIXED, MOBILE, Amateur, Radiolocation	Aeronautical Telemetry Amateur applications Amateur Satellite applications ISM Motion sensors Non-specific SRD / WLAN	
2500 – 2570 / 2620 – 2690 MHz (Band 7) 2570 – 2620 (Band 38)	2500 – 2520 MHz FIXED, MOBILE 2520 – 2670 MHz FIXED, MOBILE, BROADCASTING SATELLITE 2670 - 2690 MHz FIXED, MOBILE	Fixed links, Terrestrial UMTS / IMT-2000 Terrestrial UMTS / IMT-2000, Fixed links 2655 – 2670 MHz Fixed links, Radio astronomy applications, Terrestrial UMTS / IMT-2000, Mobile satellite applications	

Frequency Band	National Allocation	Major Utilisation	Other information
3400 – 3600 MHz (Band 42)	FIXED, FIXED SATELLITE (space to Earth), MOBILE	Fixed links (including point to multipoint), Fixed wireless access, Radars (upper limit 3410 MHz), Mobile applications, IMT-2000	
3600 – 3800 MHz (Band 43)	FIXED, FIXED SATELLITE	Coordinated earth stations in FSS, Medium / high capacity fixed links	

Source: Qatar National Frequency Plan

It is noted that in the ictQATAR's Radio Spectrum Policy v1.0 April 2011, it was intended to identify within the NFAP the spectrum allocated to government users except where information is confidential for security reasons. There is no specific mention in latest version of the NFAP / NFAT of government use.

In Appendix 1 of the National Frequency Allocation Plan there is further information provided on specific assignments in the Kingdom of Qatar and for frequencies covered by the harmonised mobile band plans these are:

Frequency Range (MHz)	Up-link (MHz)	Down-link (MHz)	Applications
450 - 470	450 - 460	460 - 470	PMR / telemetry
457.5375 & 467.5375			UHF on board vessels
790 – 862	790 – 821 (Note 1)	832 - 862	Mobile / LTE
876 - 925	876 - 880	921 - 925	GSM-R
880 - 960	880 - 915	925 - 960	Mobile / E-GSM
1710 - 1880	1710 - 1785	1805 - 1880	Mobile / DCS
1920 - 2170	1920 - 1980	2110 - 2170	Mobile / UMTS
2500 - 2690	2500 - 2570	2620 - 2690	Mobile / LTE
3400 - 3600	3400 - 3500	3500 - 3600	WiMAX

Note 1: This appears to be incorrect as this is the down-link in LTE Band 20 and starts at 791 MHz

We understand that the 400 MHz bands are used extensively by organisations such as the Qatari Armed Forces, Ministry of Interior and Oil companies. The use of the 1400 MHz bands[185] for fixed links will be for narrowband, low capacity links (maximum of 8 Mbps) and are likely to use transmitter powers of 4 watts for the longer links. The 3400 – 3600 MHz band was identified for WiMAX[186] and it is understood that there were at least 2 frequency blocks assigned to Ooredoo (formerly Qtel) – one for WiMAX and the other for NGPMR. There may also be unused frequencies in this band and it is noted in the NFAP it is identified for IMT-2000.

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[185] 1350 – 1375 MHz paired with 1429 – 1517 MHz and 1375 – 1400 MHz paired with 1427 – 1452 MHz.

[186] Announcement of second fixed line operator being awarded spectrum to provide WiMAX in 2008 and Qtel having the option of also using this technology http://www.motc.gov.qa/en/news-events/news/wimax-second-fixed-line-operator

E.2 Licensing

The original licences that were awarded were for mobile operating licences that included a list of spectrum licences and related licence obligations, such as coverage[187] and technologies, relevant to the service licence. Vodafone's operating licence was issued for 20 years in 2008[188].

In May 2015 CRA consulted on revising individual licences "to remove radio spectrum provisions to maintain a clear separation between service licenses and spectrum licenses" and "make the revised licences technology-neutral". It was specifically mentioned that as part of the process new licences would be issued.

CRA has put in place terms and conditions for accessing and sharing of civil infrastructure and reported that in 2016 there was a "114% increase in requests for approvals of new mobile sites (92 in 2016 compared to 43 in 2015)"[189].

E.3 Spectrum roadmap

The CRA conducted a public consultation on future spectrum demand in 2014[190]. This public consultation was intended to inform CRA's five-year spectrum outlook which would complement the CRA spectrum management framework. The intention was to update the document every year.

In the 2014 consultation it was noted that:

- Digital broadcasting switchover was planned to be completed by June 30, 2015. Frequencies that had been agreed internationally and regionally for wireless broadband (690 – 790 MHz and 790 – 862 MHz) would not be assigned for digital TV.
- The frequency bands being used by public land mobile systems were:
  - 800 MHz
  - 900 MHz
  - 1800 MHz
  - 2100 MHz, and
  - 2600 MHz.
- Two operators had been assigned spectrum to operate their GSM and UMTS networks.
- The digital dividend bands (690 – 790 MHz and 790 – 862 MHz) were being considered for assignment, subject to availability, to meet the continuous growth in data.

A number of questions were raised in the consultation to inform CRA on future requirements including what bands should be considered a priority for mobile broadband and expected spectrum demand for the following 5 years.

[187] Coverage obligation of 100% geographic and population applied.

[188] http://www.motc.gov.qa/sites/default/files/documents/Vodafone_MobileLicense.pdf

[189] It was also noted that 18 applications were rejected and not passed to relevant government entities for final approval mainly due to sites being available within 500m of the requested new location.

[190] http://www.cra.gov.qa/en/document/public-consultation-future-spectrum-demand-qatar

It is however not clear whether there has been a forward-looking spectrum roadmap developed as a result of this consultation and responses.

E.4 Conclusions and recommendations

The CRA's objectives in regards radio spectrum are set out in the radio spectrum policy that was developed and published in 2010. Amongst a number of objectives the intentions are to:

- Provide a transparent, non-discriminatory, and predictable approach to spectrum management
- Promote economic and societal benefits, and
- Facilitate stakeholder participation in key allocation decisions.

It is clear from the information provided on the CRA's web-site that considerable progress has been made in meeting these objectives.

Also, the CRA has awarded spectrum for mobile broadband in the frequency bands that are widely supported worldwide including the 800 MHz band through timely release of the digital dividend spectrum.

It is recommended that there could be further transparency in the management of spectrum for mobile broadband by providing:

- Information on the spectrum that has already been awarded to the two mobile operators.
- Access to the radio spectrum licences or licence conditions that were set at licence award.
- Information on the responses to the consultation on future spectrum requirements and reflecting this in a regularly updated spectrum roadmap.

There may be the potential to licence further bandwidth within the 2300, 2600 and 3500 MHz bands through further refarming.

Appendix F: Saudi Arabia

CITC (Communications and Information Technology Commission) is responsible for regulating the ICT sector in the Kingdom of Saudi Arabia. CITC was established in 2001 and one of its main objectives is to ensure effective and interference free usage of frequencies. Other objectives include clarity and transparency of procedures, ensure principles of equality and non-discrimination and to promote and encourage fair competition in all fields of telecommunications

According to the CITC's annual report for 2015[191], by the end of the year, the penetration of mobile communications services was approximately 167% with mobile broadband reaching about 106% of the population and the contribution of the ICT sector to GDP was around 6%.

F.1 Services operating in bands identified for mobile

The current National Frequency Plan was approved by the decision of the Council of Minister No. 61 on 02/03/1429H and came into force on 2/5/1429H (May 2008). Whilst there is currently no publicly available updated Plan, it still provides an indication of those services that might be deployed in the bands identified for mobile broadband and the applicable national allocations that apply.

Table F-1: Allocations and use of mobile frequency bands in Saudi Arabia

Frequency Band	National Allocation	User Category (Note 1)	Other information
452.5 – 457.5 / 462.5 – 467.5 MHz (Band 31)	FIXED, MOBILE	COM	Major utilisation is PMR in 450 – 470 MHz for civil & government use According to the CDG[192] there may be a CDMA network operating in the 450 MHz band provided by Saudi Telecom company.[193]
703 – 733 / 758 – 788 MHz (Band 28)	BROADCASTING	CIV	
832 – 862 / 791 – 821 MHz (Band 20)	FIXED, MOBILE, BROADCASTING	COM	
880 – 915 / 925 – 960 MHz (Band 8)	FIXED, MOBILE	COM	
1427 – 1518 MHz	1452 – 1492 MHz FIXED, MOBILE, BROADCASTING, BROADCASTING SATELLITE	COM / CIV	1427 – 1452 MHz & 1452 – 1492 MHz used for fixed low capacity links – government use.

191 http://www.citc.gov.sa/en/mediacenter/annualreport/Documents/PR_REP_011Eng.pdf

192 http://www.cdg.org/about/index.asp

193 http://www.cdg.org/worldwide/index.asp

Frequency Band	National Allocation	User Category (Note 1)	Other information
1710 – 1785 / 1805 – 1880 MHz (Band 3)	FIXED, MOBILE	COM	
1920 – 1980 / 2110 – 2170 MHz (Band 1)	FIXED, MOBILE	COM	2110 – 2120 MHz also allocated to SPACE OPERATIONS
2300 – 2400 MHz (Band 40)	FIXED, MOBILE	COM	STC is deploying LTE
2500 – 2570 / 2620 – 2690 MHz (Band 7) 2570 – 2620 (Band 38)	2500 – 2520 MHz FIXED, MOBILE, MOBILE SATELLITE 2520 – 2690 MHz FIXED, MOBILE, BROADCASTING SATELLITE	COM	Used for Fixed Wireless Access. Use highly fragmented with a mix of FDD and TDD, though mainly TDD, and different bandwidths. STC, Mobily, Bayanat, ITC and Atheeb all have access to this band. Also some governmental use.
3400 – 3600 MHz (Band 42)	FIXED, FIXED SATELLITE	COM	Used for Fixed Wireless Access. STC has paired 2×35 MHz and also there are paired assignments to ITC, Bayanat and Atheeb
3600 – 3800 MHz (Band 43)	FIXED, FIXED SATELLITE	COM / CIV	

Note 1: In the National Frequency Plan there are 3 different user categories:

GOV: Governmental category that includes the National Guard, Ministry of Defence and Aviation, Ministry of Interior and General Presidency of Intelligence.

CIV: Civil category that includes users of all governmental entities, enterprises excluding those covered by the commercial category, non-commercial organisations etc. as well as private users.

COM: Commercial category licensed to provide telecommunications services.

Saudi Telecom used WiMAX in the 3.5 GHz band based on 802.16e[194]. It is understood that WiMAX technology is no longer among the services marketed by STC on its web-site[195] and that potentially it may have been refarmed for LTE technology. Mobily was reported as working to migrate their 2.5 GHz WiMAX networks to LTE / WiMAX in 2013 and that they were looking to use TD-LTE in the 3.5 GHz spectrum[196].

[194] https://www.telegeography.com/products/commsupdate/articles/2008/07/22/stc-completes-first-phase-of-wimax-rollout/

[195] Page 10 https://www.telegeography.com/page_attachments/products/website/research-services/globalcomms-database-service/0005/5890/gcd-saudi-telecom-company-stc.pdf

[196] Heavy Reading report 20-12-2013 "WiMAX Advanced to Harmonise with TD-LTE in the 2.3, 2.5 and 3.5 GHz Bands. Opportunities and Challenges for WiMAX".

In Annex 2 to the National Frequency Plan, 2008[197] the following potential mobile broadband bands were identified for refarming / reassignment. The refarming / reassignment plans may not all necessarily be to release spectrum for mobile and may instead be to change user category.

Frequency band	Proposed reassignment / refarming and timeframes[198] (Note 1)
450 – 470 MHz	Refarming / reassignment within 3 years
470 – 860 MHz	Routine reassignment process in accordance with NFP to be completed in a 5-year period
806 – 824 MHz / 851 – 869 MHz	Refarming / reassignment within 3 years
880 – 890 MHz / 925 – 935 MHz	Refarming / reassignment within 3 years
890 – 915 MHz / 935 – 960 MHz	Refarming / reassignment within 2 years
1710 – 1785 MHz / 1805 – 1880 MHz	Refarming / reassignment within 2 years
1920 – 1980 MHz / 2110 – 2170 MHz	Refarming / reassignment within 3 years
2170 – 2400 MHz	Routine reassignment process in accordance with NFP to be completed in a 5-year period
2500 – 2690 MHz	Refarming / reassignment within 3 years (starting 2009)
3400 – 3800 MHz	Refarming / reassignment within 2 years

Note 1: In the case of refarming the start date was 2007 unless an alternative date is indicated.

In the 2015 Annual Report (1436 – 1437) the progress was reported on as shown below. It is clear that progress is slower than anticipated. Detailed breakdown was not available by frequency band:

[197] http://www.citc.gov.sa/en/RulesandSystems/RegulatoryDocuments/FrequencySpectrum/Documents/SM%20002%20E-NFP.pdf

[198] In some instances, such as the 450 – 470 MHz band, it is understood that the aim is to move both CIV and GOV users to alternative frequency bands to be able to define sub-bands for GOV and CIV users.

Frequencies to be vacated within two years

Specific locations	City-wide	Province-wide	Kingdom-wide	Assignment level
97.01%	96.87%	26.57%	45.41%	Clearance by end of 2014
98.74%	97.49%	28.95%	45.41%	Clearance by end of 2015

Frequencies to be vacated within three years

Specific locations	City-wide	Province-wide	Kingdom-wide	Assignment level
14.55%	27.39%	97.95%	0.87%	Clearance by end of 2014
14.83%	27.82%	91.65%	0.87%	Clearance by end of 2015

Frequencies to be vacated within five years

Specific locations	City-wide	Province-wide	Kingdom-wide	Assignment level
19.15%	21%	23.59%	15.78%	Clearance by end of 2014
19.24%	21.04%	23.63%	15.81%	Clearance by end of 2015

Source: CITC 2015 Annual Report

F.2 Licensing

In February 2017, CITC issued unified concessions to Mobily and Zain allowing them to offer the same services as STC – mobile, fixed telephony and broadband services. The licences previously awarded were for the provision of services and included the necessary radio spectrum frequencies and licence conditions. Under the new licensing regime, the service licences are separated from the spectrum licences[199]. Saudi Arabia is the first country in Middle East region to adopt service and technology neutrality for spectrum licenses. As part of the new concessions the service licences were extended by 15 years.

CITC held its first spectrum auction in June 2017 and allocated licenses for 15 years in the 700 MHz and 1800 MHz bands. This makes KSA the first Middle Eastern country to award the entire 700 MHz band but UAE is also understood to have awarded a combination of the 700 MHz and 800 MHz bands[200]. One of the key objectives of the auction was to release and provide larger contiguous blocks of spectrum for provision of mobile broadband services. The auction resulted in the 1800 MHz band being fully assigned, with band replanning to align the new and existing spectrum assignments. CITC reported that the spectrum awarded at the auction increased existing spectrum for wireless

[199] According to the 2015 annual report the global trend towards unified licensing has been studied to determine the best approach to adopt a unified licensing approach in Saudi Arabia. It is considered that it will be necessary to have “a transitional phase for existing licensees before the entry of new investments and alliances”.
[200] Mobile World Live, 13 May 2013, “UAE makes mobile broadband breakthrough in 700 MHz band”. Available at: https://www.mobileworldlive.com/featured-content/top-three/uae-makes-mobile-broadband-breakthough-in-700-mhz-band/

communications services by more than 35%[201]. Reports indicate that the new licenses were technology-neutral.

The operators have been able to refarm spectrum to more efficient technologies. Zain has refarmed some of their 900 MHz frequencies from 2G to 4G technology and all three operators have refarmed some of their 1800 MHz spectrum[202]. LTE technology has also been deployed in the 2600 MHz spectrum held by STC and Zain and in the 2300 MHz band by STC.

Zain has launched LTE-A using carrier aggregation of the 1800 and 2100 MHz bands and the 900, 1800 and 2100 MHz bands[203].

F.3 Spectrum roadmap

There appears to be no publicly available information on CITC's plans for future release and award of spectrum.

F.4 Conclusions and recommendations

The mobile operators are using 4G technologies and carrier aggregation to support higher broadband data speeds. There is also use of the 2300 MHz and 2600 MHz bands to support LTE although this spectrum does not appear to have been specifically released for mobile broadband and was originally licensed for FWA. In the 900 MHz, 1800 MHz and 2100 MHz bands the spectrum blocks are contiguous and based on multiples of 5 MHz that makes them ideal for future migration to the latest technologies from 2G and 3G. Recently the unassigned 1800 MHz spectrum has been awarded and the band reconfigured to provide contiguous assignments.

It is recommended that:

- CITC release further spectrum, as soon as possible, in the un-paired 2300 MHz band and make the assignments contiguous.
- CITC aligns the 2600 MHz band and make the assignments contiguous.
- Make the 2600 MHz and 3500 MHz bands available for mobile broadband through refarming or reallocation.
- Award spectrum (800 MHz) to provide additional frequencies suitable for provision of coverage once spectrum released from legacy technologies.
- CITC develop a forward-looking spectrum roadmap that identifies the priority bands that will be released and those planned for later release and the associated timescales.
- CITC adopt both technology- and service-neutral spectrum policy for all new released bands for mobile industry.
- CITC should develop a strategy spectrum road map for 5G.

[201] http://www.citc.gov.sa/en/mediacenter/pressreleases/Pages/2017060601.aspx

[202] https://en.wikipedia.org/wiki/List_of_LTE_networks#Middle_East

[203] https://www.telegeography.com/products/commsupdate/articles/2015/06/25/zain-saudi-launches-lte-a-using-ca-in-1800mhz-and-2100mhz-bands/ and https://www.telegeography.com/products/commsupdate/articles/2016/05/12/zain-saudi-launches-tri-band-lte-a-in-jeddah/

Appendix G: United Arab Emirates (UAE)

The Telecommunications Regulatory Authority (TRA) of the United Arab Emirates (UAE) was established in 2003 and is responsible for the management of every aspect of the telecommunications and information technology industries in the UAE.

Mobile penetration in the UAE is among the highest in the world at 209.8% in 2015 with 19.94 million subscribers[204] and has 78% smartphone penetration[205]. In comparison the penetration rate for fixed line subscriptions is 26.4% with 2.26 million subscribers.

Mobile operators in Dubai "are launching advanced services around initiatives such as smart cities, the Internet of Things (IoT) and digital identity"[206].

G.1 Services operating in bands identified for mobile

The current National Frequency Plan is available in electronic format on the TRA web-site. It is not clear when it was last updated but all bands that can potentially be used to deploy mobile services are identified through the Footnote UAE15.

Table G-1: Allocations and use of mobile frequency bands in UAE

Frequency Band	National Allocation	References and Notes
452.5 – 457.5 / 462.5 – 467.5 MHz (Band 31)	450 – 470 MHz FIXED, MOBILE	434.79 – 470 MHz identified for PMR in TRA Private Mobile Radio Regulations. 450 – 470 MHz identified for Public Safety (Governmental use). 450 – 456 MHz and 459 – 460 MHz shown as having a preference for Public Protection Use.
703 – 733 / 758 – 788 MHz (Band 28)	694 – 790 MHz MOBILE	Mobile. Portion of the band can be allocated for PPDR. 470 – 694 MHz PMSE frequency range
832 – 862 / 791 – 821 MHz (Band 20)	790 – 862 MHz MOBILE	Mobile
880 – 915 / 925 – 960 MHz (Band 8)	880 – 960 MHz MOBILE	Mobile

[204] Annual UAE Telecommunications Sector Review, 2012 – 2015. https://www.tra.gov.ae/en/media-hub/press-releases/2016/12/29/the-tra-releases-the-seventh-annual-uae-telecommunications-sector-review.aspx

[205] http://www.tradearabia.com/news/IT_304663.html

[206] https://www.gsmaintelligence.com/research/?file=9246bbe14813f73dd85b97a90738c860&download

Frequency Band	National Allocation	References and Notes
1427 – 1518 MHz	1427 – 1429 MHz NONE SPECIFIED 1429 – 1452 MHz FIXED, MOBILE 1452 – 1492 MHz FIXED, MOBILE, BROADCASTING, BROADCASTING SATELLITE 1492 – 1518 MHz FIXED, MOBILE	1427 – 1518 MHz – use for mobile must protect MSS in adjacent bands
1710 – 1785 / 1805 – 1880 MHz (Band 3)	FIXED, MOBILE	Mobile usage, includes on-board aircraft
1920 – 1980 / 2110 – 2170 MHz (Band 1)	FIXED, MOBILE	Mobile usage, includes on-board aircraft
2300 – 2400 MHz (Band 40)	FIXED, MOBILE	Mobile (Public safety)
2500 – 2570 / 2620 – 2690 MHz (Band 7) 2570 – 2620 (Band 38)	2500 – 2520 MHz FIXED, MOBILE 2520 – 2670 MHz FIXED, MOBILE, BROADCASTING SATELLITE 2670 - 2690 MHz FIXED, MOBILE	Mobile
3400 – 3600 MHz (Band 42)	FIXED, FIXED SATELLITE (space to Earth), MOBILE	Mobile (Protect FSS)
3600 – 3800 MHz (Band 43)	FIXED, FIXED SATELLITE	

Apart for the 450 – 470 MHz and 2300 MHz bands there is the potential for public mobile broadband in all the other currently identified mobile broadband bands.

G.2 Licensing

The public telecommunications licences (operating licences) outline that spectrum is granted by TRA following written request from operator with justification of application for use of spectrum (see article 14.1 of license). The licence also outlines that duration of license is 20 years and any network technology can be permitted provided that the technology is approved in advance by the TRA (that is, technology-neutral so long as TRA consent to the technology deployed), see article 13.5 of license.[207]

G.3 Spectrum roadmap

UAE is aiming for early 5G deployment before 2020 and is focusing on identifying 5G spectrum; the UAE is considered to be one of the seven countries, along with the US, UK, China, Korea, Germany and Japan, driving the 5G technology[208].

G.4 Conclusions and recommendations

All of the 800, 900 and 1800 MHz spectrum has been divided between the two mobile operators in the UAE which means higher bandwidths can be supported in all frequency bands.

Not all the 2100 MHz band is currently licensed and apart for the 3500 MHz band, which is licensed for fixed wireless access.

The TRA has also been considering the potential requirements of spectrum for 5G and it is expected that UAE will be one of the first countries where 5G networks are launched.

It is recommended that:

- TRA consider the potential for release of the 2300 MHz band for mobile broadband
- TRA continue to be active in the 5G discussions and identify what further frequency bands (for example, millimetric frequencies) may need refarming and timescales for release.
- TRA publish a clear spectrum roadmap to enable its operators to stay at the forefront of technology roll-out and new service deployment.

[207] Du and Etisalat operator licenses, assigned in 2006 and available at: http://www.tra.gov.ae/en/services-and-activities/licensing/details.aspx#pages-32703

[208] For example, see Samena Trends, Volume 05, March 2017