Potential benefits from sub-700 MHz spectrum in Pakistan

A report for the GSMA

January 2015

Tim Miller
Val Jervis
John Burns
Sarongrat Wongsaroj
Tim Hogg

About Plum

Plum offers strategic, policy, regulatory and technical advice on problems relating to the use of spectrum and to the telecommunications, online and audio-visual media sectors. A London-based partnership founded in 2007, it works for governments, regulators, service providers and equipment suppliers around the world. Its advice is based on economic analysis and technical knowledge of radio engineering, which it combines with extensive market knowledge of the communications sectors to provide clear and sound analysis.

Plum Consulting, London
T: +44 20 7047 1919, **www.plumconsulting.co.uk**

Table of Contents

1 Introduction

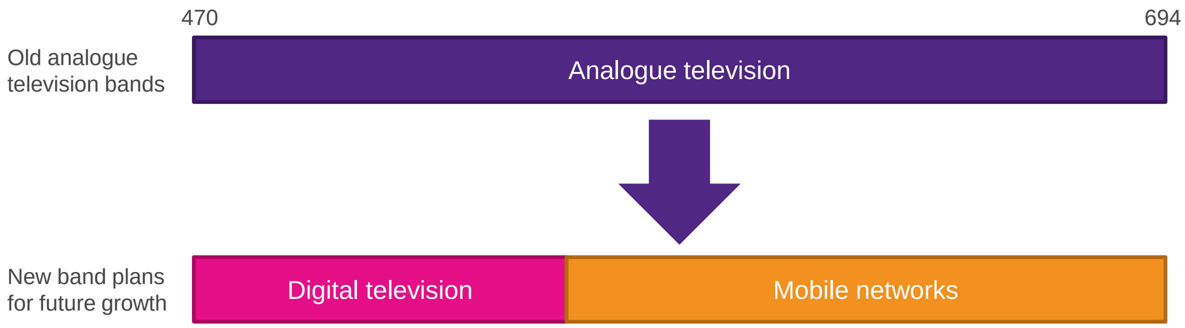
This report has been commissioned by the GSMA to examine the potential benefits of using part of the sub-700 MHz UHF spectrum bands for mobile broadband in Pakistan. These bands are currently used by analogue television, but it is believed that the Pakistani government plans to turn off analogue signals in the near future. It is intended that the analogue television service will be replaced with digital transmissions, which presents a significant opportunity to the country since digital transmission uses a lot less spectrum than analogue for the same amount of content. This newly cleared spectrum can be used to increase the reach and penetration of mobile broadband, which will increase productivity and welfare of the entire country.

However, there has been little movement in Pakistan so far in launching digital transmission, or setting a timetable for switchover. This has the potential to significantly inhibit the launch of mobile broadband as well as denying citizens the benefits of digital television.

1.1 Digital transition

This paper considers two states of the world: before and after the digital transition. Before the transition, all spectrum below 700 MHz will be used by analogue television. After the transition, a portion of this will be available for use by mobile services, with the remainder available for digital television services.

Figure 1-1: Digital transition



In order to examine how this transition will impact Pakistan, there are two questions to be answered:

1. What proportion of the spectrum should be reserved for digital television, and therefore how much spectrum will be available for mobile broadband?
2. How should this transition be handled?

This paper concentrates on the first of these questions, examining the broadcasting market and estimating its future spectrum needs before carrying an economic impact study of an expanded mobile broadband market. However, the second question is also considered at the end of this paper.

1.2 Key working assumptions

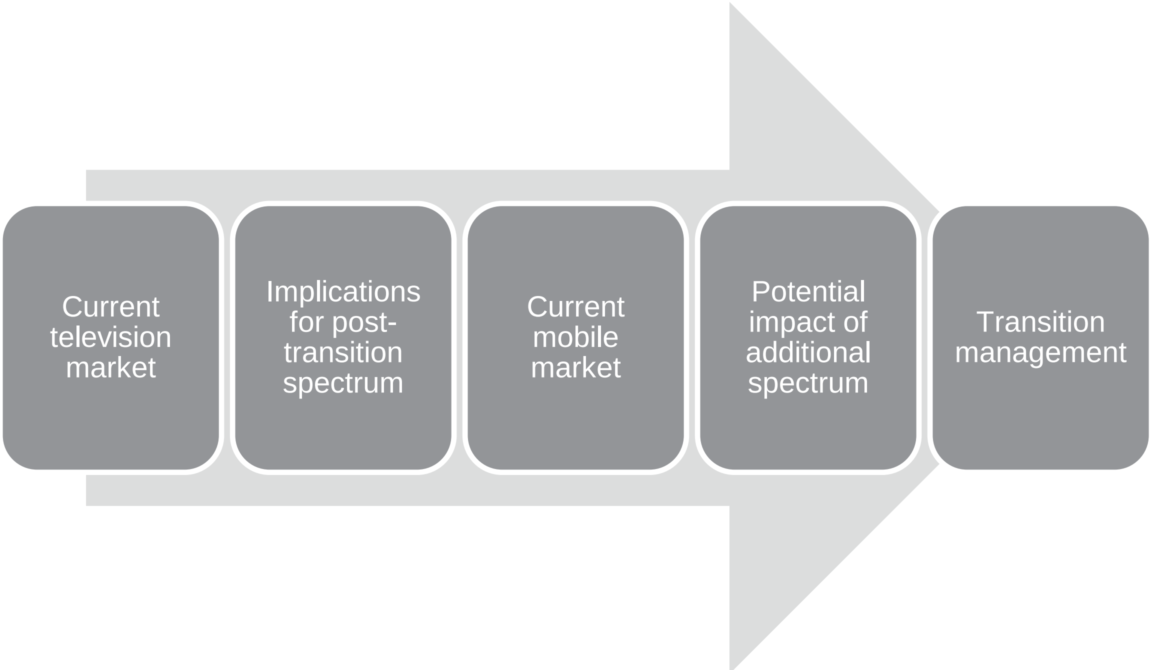
This paper makes a number of assumptions on the broadcasting and mobile communications markets. The most important assumption is that a requirement for digital transition is that all channels currently broadcast over analogue will be broadcast over digital platforms (and the coverage of digital transmissions must be no worse than the coverage of analogue). This means that there is no loss of welfare in terms of television content, although it is possible that there will be significant advantages due to the added capacity for new channels or different types of broadcast.

Assumptions are also made over the amount of spectrum available to mobile operators in the event of no digital transition, market shares, data traffic demand, and so on. These are set out in more detail in Section 5.

1.3 Structure of analysis

Given these methodological assumptions, this paper is structured as shown in Figure 1-2.

Figure 1-2: Structure of analysis



- First, the current television market is examined to see how many channels are broadcast and their ownership structure, whether there are regional variations, the market shares for different delivery platforms, and the overall viewership. This analysis is carried out to establish the minimum requirements for the post-transition market.
- Second, scenarios are run on the broadcasting market looking at how a digital platform could be operated in order to meet these minimum requirements. This results in an estimate for the amount of spectrum that can be released to mobile operators.

- Third, the current mobile market is examined, looking at spectrum holdings, market shares, and trends in device ownership. This overview provides a background to understand how additional spectrum may be used in mobile broadband extension.
- Fourth, an economic impact analysis is carried out to examine how additional spectrum may lead to increased usage of mobile broadband and therefore productivity gains for the economy as a whole.
- Finally, following a conclusion on implications for spectrum policy, the management of transition is considered, looking at how spectrum can be released as quickly and efficiently as possible.

2 The broadcasting market

Pakistan is a country of nearly 190 million people[1] and is urbanising at the fastest rate in South Asia. It is estimated that half the population will live in cities by 2025, up from one-third at present[2]. The Ministry of Planning, Development and Reform in Pakistan publishes an annual plan[3] that looks at the economic performance and prospects for the country, and the section on Mass Media includes data on the TV sector.

Table 2-1: Electronic Media Profile 2012 – 2014

Pakistan TV (PTV) Stations	7
TV Transmitters	110
Number of TV Homes	13 million
Cable Operators (licensed)	2700
Cable Subscribers (official figures)	10 million
Satellite Channels (local)	91 (84 operational)
Landing Rights Permission	26
Multipoint Multi-channel Distribution System (MMDS)	6 (all operational)

Source 2014 – 2015 Annual Plan

It can be seen that cable is a significant means of delivering TV, but in practice even with 13 million TV homes there must be a lot of communal watching, especially in rural areas where terrestrial broadcasts are more likely. This makes it difficult to determine the exact reach (in terms of population) of each of the broadcast platforms. Meanwhile, the number of broadband connections was 3.34 million in January 2014, so alternatives to the traditional (terrestrial, cable and satellite) platforms such as IPTV are unlikely to have little impact currently.

According to the Ministry's annual plan

> "*the entire country is terrestrially covered through TV and radio signals and a significant part has multiple TV and radio viewing and listening choices. Public sector funding is provided for development of infrastructure, upgrading of equipment and provision of TV and radio services to the remote and uncovered areas of the country*."

As stated in Section 1.2, a key assumption of this study is that the broadcasting sector is not left in a worse position than it currently holds with analogue, and this means that it is important that digital terrestrial television retains sufficient spectrum. However, the availability of satellite, and the continued investment in broadcast services, will make this easier by providing coverage in geographic areas where terrestrial TV may no longer be the most efficient or appropriate solution.

[1] According to the latest Pakistan Economic Survey 2013 – 2014 at http://www.finance.gov.pk/survey/chapters_14/Highlights_ES_201314.pdf the urban population has increased to 72.5 million in 2014 from 69.8 million in 2013, while rural population has increased to 115.5 million in 2014 from 114.4 million in 2013.

[2] Source: "Mapping Digital Media: Pakistan" by the Open Society Foundations, June 2013.

[3] For example see http://www.pc.gov.pk/?page_id=2874 for the 2014 – 2015 annual plan.

2.1 Regional viewing penetration

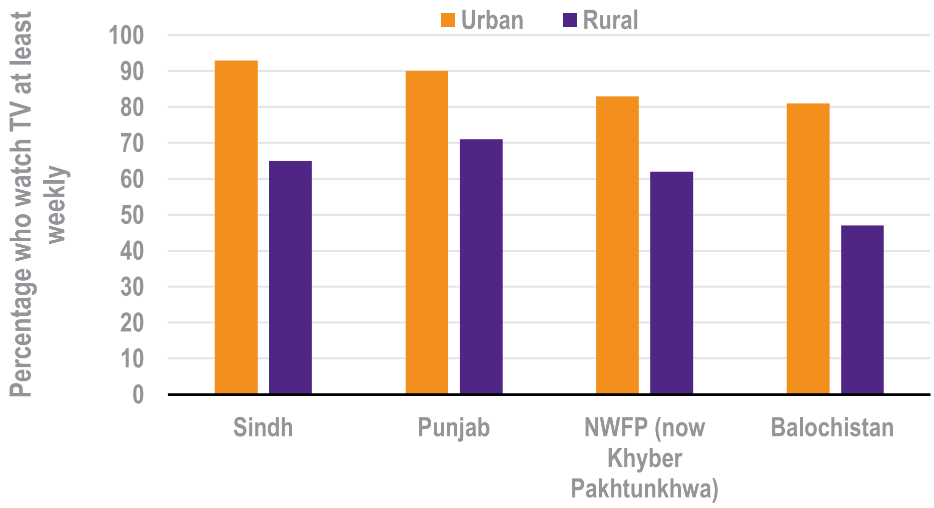
Pakistan is divided into four provinces, each with their own ethno-linguistic identity:

- Sindh,
- Punjab,
- Balochistan, and
- Khyber Pakhtunkhwa (formerly called the North West Frontier Province, NWFP).

In addition there is the Islamabad Capital Territory, the north-western Federally Administered Tribal Areas (FATA), the northern semi-autonomous Gilgit-Baltistan region, and Pakistan-administered Kashmir (known locally as Azad Jammu and Kashmir).

The Pakistan Advertisers Society published an overview of TV in Pakistan[4] which reported that TV was the dominant communication on a national level, but in certain rural regions radio was nearly equally popular and at the time of the survey (2008) it was considered that "TV's reach was limited due to continued high levels of poverty, an inconsistent broadcast signal and lack of reliable electricity infrastructure". The two figures below demonstrate the mix of urban-rural TV viewing in the four provinces at that time and the percentage of viewers with cable or satellite TV access according to income.

Figure 2-1: Urban and rural TV viewership by province

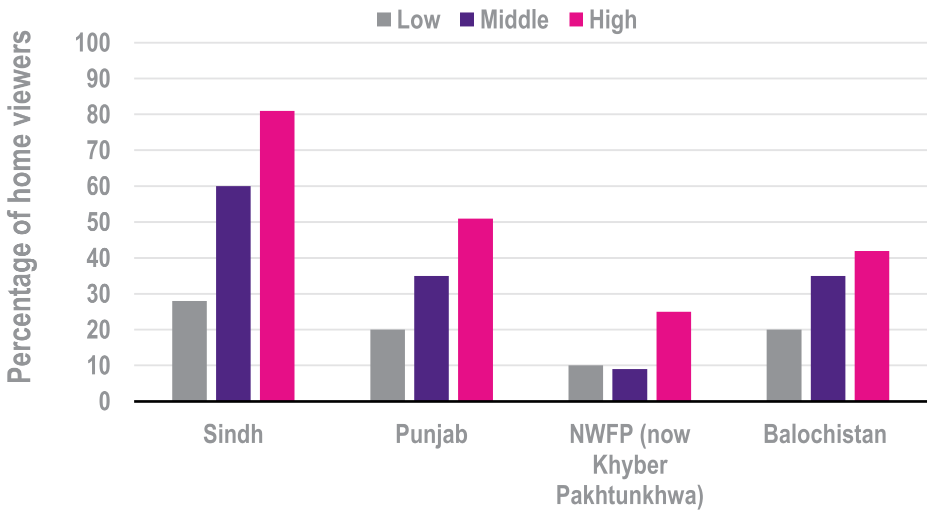


Source: BBC Pakistan 2008 survey of adults

In 2008 PEMRA (Pakistan Electronic Media Regulatory Authority) estimated there were some 8 million households with access to cable TV. However, cost factors limited low-income access to cable or satellite TV, as did the broadcast focus on urban areas. In 2009, Gallup Pakistan, estimated that 48 million people, just over half of all TV viewers, watched terrestrial TV. Gallup Pakistan also estimated that 38 million people aged 10 and over watched cable and satellite TV channels on an average day in 2009 and that only 12 million of these lived in villages.

[4] See: hhttp://www.pas.org.pk/television-in-pakistan-an-overview/

Figure 2-2: Income and cable and satellite TV access by province



Source: BBC Pakistan 2008 survey of adults

2.2 Main broadcasters

State-owned Pakistan TV (PTV) is the main broadcaster. It started its services in November 1994[5], currently operates six channels and is the main provider in rural areas. It delivers over satellite and terrestrial networks and its channels offer news, entertainment and regional language programming as well as the AJK-TV channel.

Whilst analogue terrestrial broadcasting is dominated by PTV, the private sector relies on the satellite and cable delivery platforms for broadcasting the content. There were more than 20 privately owned broadcasters with 89 domestic and 26 foreign channels in 2013. National television viewing was split evenly between terrestrial on the one hand (PTV and ATV), and cable and satellite on the other[6]. The most watched local private channel was Geo News and of the top 10 rated news programs in 2011, six belonged to the Geo TV Network, including four of the top five. PTV News got 3 percent of viewers.

2.3 Platforms

As considered in Section 2.1, the current broadcast market in Pakistan relies on three main platforms, with other technologies starting to enter the market.

[5] See http://www.ptv.com.pk

[6] "Mapping Digital Media: Pakistan" by the Open Society Foundations, June 2013.

2.3.1 Terrestrial TV

There are two analogue terrestrial TV broadcasters: PTV and ATV. PTV is state owned and started its services in November 1964 with two small stations at Lahore and Dhaka[7]. In 1998 there were six production centres (Lahore, Karachi, Quetta, Peshawar, Islamabad I and Islamabad II) and there were 35 re-broadcast stations for PTV-1 and 16 for PTV-2[8]. According to PTV its Home channel covers 89% of the population and its News channel 78%. The costs of network roll-out are subsidised by the Government.

PTV indicates on its website that it operates 10 channels, although some appear not be on air, including the following.

- PTV Home which is provided over terrestrial and satellite but the content is different. This is a 24 hour entertainment channel.
- PTV News which is a 24 hour channel.
- PTV Sports which is a 24 hour sports channel.

It is assumed that all these channels are delivered via terrestrial analogue TV on a national basis. In addition there are some channels that appear to be regional.

- PTV National which, despite its name, carries regional programming for Pakistan's four main provinces.
- PTV Bolan which is a special TV channel for Balochistan.
- AJK TV which is a special channel for Kashmir.

Finally, PTV Global is an international channel broadcast by satellite.

ATV, which is the only other terrestrial television channel operates with 20 stations covering all the major cities and commercial centres in Pakistan and covers over 50% of the population. It is privately owned, but PTV and the Pakistan Broadcasting Corporation (PBC) are majority shareholders.

2.3.2 Cable TV

Cable TV was introduced in Pakistan in the mid-1990s[9] and by 1998 it was available in all the big cities in Pakistan. The attractiveness of cable television was its affordability – it was within the spending range of most households compared with other telecommunications services (such as broadband internet and IPTV) – it relayed satellite TV channels and DVD video channels to those that could not afford pay-per-view channels or DVD players. In 2000 there was a considerable growth in cable television networks after the Government legalised cable television and the Pakistan Telecom Authority (PTA) invited bids for a national terrestrial cable network. In 2010 the results of a survey into spend on CATV[10] showed that 68% of people were spending US$1-2 per month as subscription fees to cable TV with only 10% spending US$5 or more.

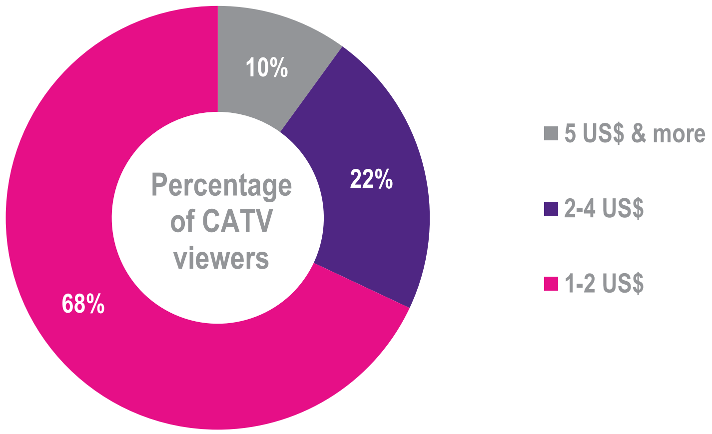
[7] See http://www.ptv.com.pk/Introduction.asp

[8] See http://www.ptv.com.pk

[9] It is understood that it was first deployed in Karachi in the early 1980s but the main introduction was during the 90s.

[10] See "Digital Television Age: A Policy Perspective from Pakistan" by Arzak Khan.

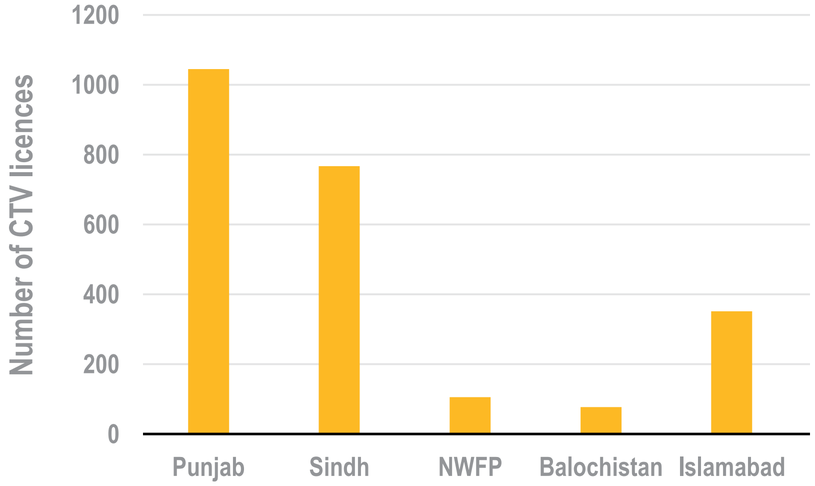
Figure 2-3: Monthly amount spent on access to CATV services



Source: "Digital Television Age: A Policy Perspective from Pakistan", Arzak Khan

According to PEMRA in its annual reports, cable TV is the most popular way of receiving TV signals and it provides access to 74% of the urban population. It was estimated that over 8 million households (equating to around 40 million people assuming a typical house-hold of 5 people) were receiving cable TV services from 2346 registered cable networks across Pakistan.

Figure 2-4: Number of CTV licences issued from 1st July 2002 to end 2009

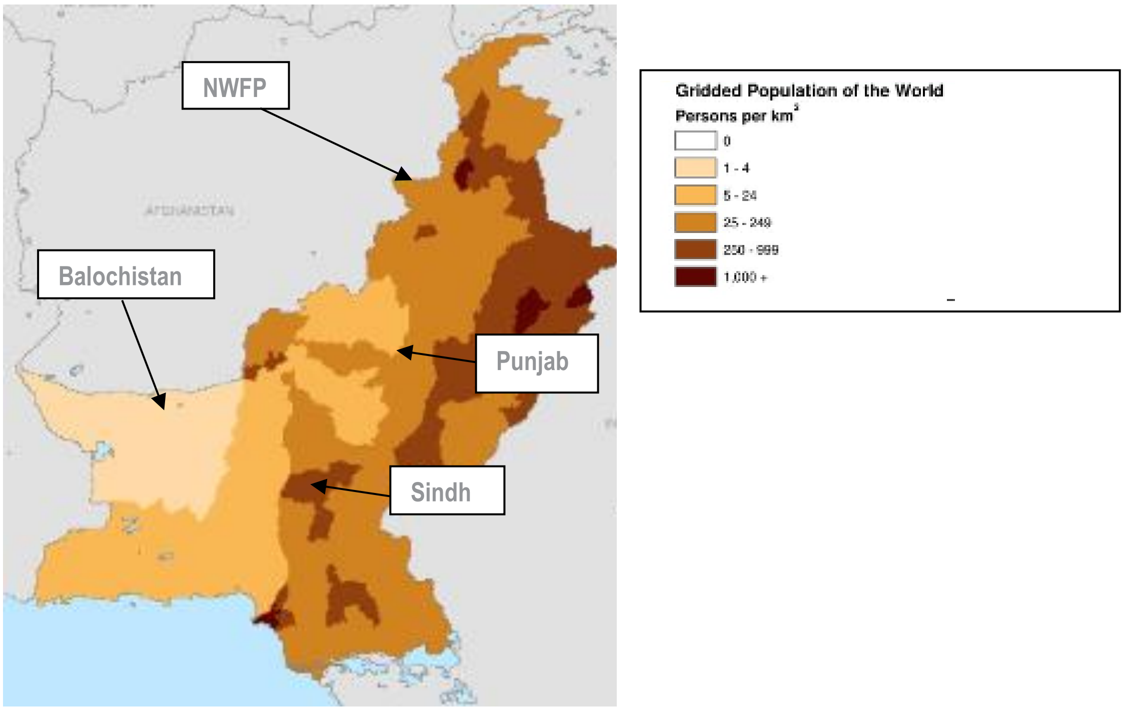


Source: PEMRA

In the 2010 Annual Report it was reported that PEMRA had issued 2500 cable TV licences up to 2010, and in 2012 this number had increased to 2700. PEMRA is encouraging expansion of cable TV services to rural areas and villages and in 2010 issued 206 licences for rural categories.

The number of cable TV licences reflects the population density in the four provinces.

Figure 2-5: Population density in 2000



Source: Gridded Population of the World (GPW), v3

2.3.3 Satellite TV

According to the PEMRA 2010 Annual Report, satellite TV is provided using the C-band and Ku-band, and both local channels and foreign TV channels have seen rapid growth. The foreign channels that relay their transmissions in Pakistan have to obtain landing rights permission and in 2010 there were eleven registered companies that marketed and distributed 26 satellite TV channels. The table below, taken from PEMRA's 2010 Annual Report, shows the growth in satellite TV:

Figure 2-6: Satellite TV licences

Source: PEMRA 2010 Annual Report

2.3.4 MMDS

According to the PEMRA annual report 2009, MMDS networks were operational in Lahore, Karachi, Islamabad, Shaiwal and Okara under licences issued to M/s Southern Networks Ltd and M/s Ranjha Enterprises (Pvt) Ltd. The Frequency Allocation Board (FAB) has indicated the availability of MMDS frequencies for 33 more cities. It was estimated that 70,000 to 80,000 households were connected via MMDS operators.

However, in the recent Telecom Policy Stakeholders Consultation[11] it was mentioned that MMDS spectrum may be reallocated either wholly or partly to telecommunications services based on international best practice.

2.3.5 IPTV

The distribution of broadcast content over the “last mile” to end users can be provided using IP. IPTV licences are issued to Local Loop Operators licensed by the PTA. The plan was to issue IPTV licences on a Zonal basis for 14 telecommunication regions. In late 2006 PTCL was awarded the first IPTV licence by PEMRA and in mid-2008 it announced it was launching its Smart TV service. By 2010 the Smart TV services was available in 16 cities across Pakistan.

2.3.6 Mobile TV

Content providers could be licensed to provide broadcasting content to end users via a licensed mobile network operator. It was reported in the 2009 annual plan that two licences had been issued to

[11] Telecommunication Policy Consultation Draft (version 1.4) issued by the Ministry of Information Technology, Islamic Republic of Pakistan in 2014.

M/s Celle Vision (Pvt.) Ltd and M/s Brand Promotion Services (Pvt.) Ltd for providing services to Mobilink and Telenor respectively[12].

[12] These are non-exclusive arrangements.

3 Spectrum use

The Ministry of Planning, Development and Reform has published Vision 2025[13] which defines an agenda for long term development in Pakistan. It identifies digital video broadcasting, digital audio broadcasting, Internet Protocol Television (IPTV), mobile audio and TV, and digital multimedia broadcasting to be the new broadcasting culture.

In the 2014/2015 annual plan the Ministry recognised 2015 as the fixed cut-off date from the ITU (International Telecommunications Union) for complete switch over from analogue to digital broadcasting. It mentioned that the Government was "setting its goals towards conversion of analogue terrestrial broadcasting system to digital terrestrial system for PTV" and that "a feasibility study will be carried out first, in order to determine the best standard of Digital Terrestrial Television Broadcasting (DTTB)".

PEMRA issued a notice to obtain Expressions of Interest in the award of digital cable TV licences for the requisite cities by 6 November 2014 as part of the commitment to digitise Cable TV networks by the end of 2015. Furthermore, a notice was issued regarding commercial satellite television broadcast station licences, requesting applications by 31 October 2014, which stated that "pre-qualified applicant companies shall be invited to participate in the bidding process for the award of the satellite TV broadcast station licence at a date and time given by the Authority".

Similarly, in its annual reports, PEMRA has indicated the intention to introduce digital terrestrial broadcasting at national, provincial and district level, subject to the availability of frequencies. A detailed proposal for the allocation of frequencies has been prepared for the consideration of the Frequency Allocation Board (FAB) which is responsible for the identification of frequencies.

3.1 Terrestrial television use

According to the PEMRA 2006-2009 Annual Report, the VHF and UHF bands are occupied "mostly by Analogue Terrestrial Broadcasting 160 MHz (21 channels), which is the exclusive domain of PTVC and STN[14] (public entities)". In the footnotes to the National Frequency Allocation Table[15] the following use of the spectrum is identified in Pakistan:

- PAK 08: 61-68 MHz can be considered for terrestrial TV broadcasting
- PAK 12: 174-230 MHz is for analogue terrestrial TV
- PAK 13: TV channels 5-12 (174-230 MHz) will be considered for terrestrial DAB (Digital Audio Broadcasting)
- PAK 14: For terrestrial digital video broadcasting TV channels 25-36[16] in UHF range 470-960 MHz will be considered on a case to case basis.
- PAK 15: TV channels 26, 28, 30, 32 are allocated for Mobile TV transmitters (Outside Broadcast Operation).

[13] See http://www.pc.gov.pk/?page_id=73

[14] Now ATV

[15] See http://www.fab.gov.pk/images/pdf/pakistantable.pdf

[16] Channels 25 – 36 are in UHF Band IV

3.2 Other services

In the footnotes to the National Frequency Allocation Table[17] the following use of the spectrum is identified in Pakistan:

- PAK 16: The frequency ranges 485-490 and 495-500 MHz[18], and 806-811 and 851-856 MHz[19] are identified for Radio Trunking Service. Both 12.5 kHz and 25 kHz channel spacing will be considered on case to case basis.
- PAK 17: 608-614 MHz also allocated to radio astronomy service on a secondary basis.

The FAB website (under Spectrum Refarmation for IMT bands) mentions that the 700 MHz band may be made available through the reformation and redeployment mechanism[20]. However, no plans for this are known and it is uncertain when this may be released.

3.3 Digital switch-over

No information has been identified in regards of digital switch over (DSO) for terrestrial TV in Pakistan. There have been indications in PEMRA annual reports that the digital switch over would be completed by 2015 and that a digital terrestrial TV frequency plan had been submitted to the FAB for approval. Also, the recent Telecommunication Policy Stakeholders Consultation stated that

> "*FAB will determine the degree to which spectrum may be reallocated either wholly or part to telecommunications services in order to achieve a digital dividend and to accelerate provision of broadband services to rural communities which is enabled by better coverage characteristics of this spectrum*."

In a recent presentation by Rumana Haque of the Bangladesh Telecommunication Regulatory Commission[21] it was said that Pakistan was still to decide on the standard and the switchover process.

3.3.1 Choice of standard

Although there is no publicly available information on the DTT standard it is assumed that Pakistan will take advantage of migrating from analogue to the latest digital standards and will therefore deploy DVB-T2, as this will provide economies of scale and low receiver prices as well as supporting SD (standard definition), HD (high definition), UHD (ultra high definition), mobile TV or any combination of these.

According to the DVB organisation[22], DVB-T is the most widely adopted DTT standard which has been deployed in over 70 countries worldwide and its successor, DVB-T2, has been adopted or deployed in 69 countries.

---

[17] See http://www.fab.gov.pk/images/pdf/pakistantable.pdf

[18] UHF Band IV

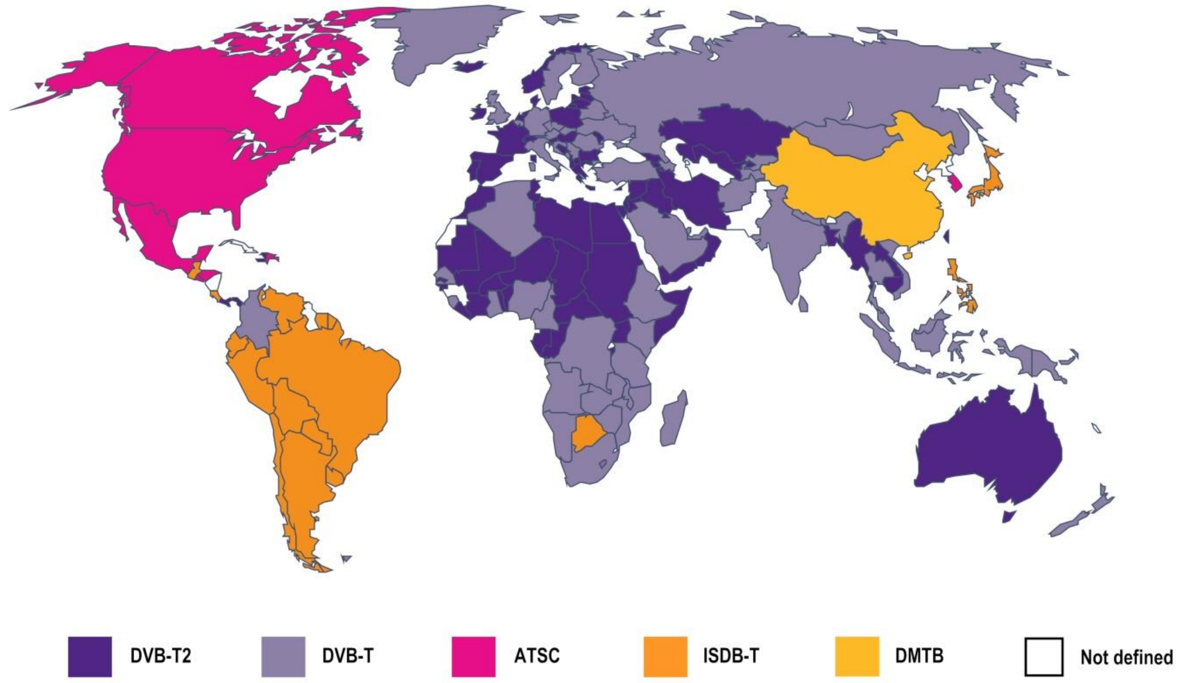
[19] These channels are in UHF Band V

[20] See http://www.fab.gov.pk/article/future-plans-for-spectrum-refarmation.html

[21] Study on Digital Switchover in SATRC Countries at the 2nd SATRC Spectrum WG Meeting in March 2014.

[22] See https://www.dvb.org/ and specifically https://www.dvb.org/standards/dvb-t2

Figure 3-1: DTT standards deployment



Source: The DVB Project, December 2014

3.3.2 Frequency and network planning

The DVB-T2 standard offers a large choice of OFDM parameters and – depending on how the modulation scheme, FFT[23] sizes and guard intervals are combined – SFN (single frequency) and MFN (multi frequency) networks can be designed for different applications; ranging from low bit rate robust mobile reception to high bit rate fixed reception. As per this study's key assumption, the requirement will be to achieve at least the same level of TV coverage as the existing terrestrial analogue network and make use of the existing domestic receiving antennas and transmission infrastructure (transmitter sites). This implies the possible use of VHF and UHF frequency bands.

In planning any DVB-T2 network the first consideration is whether the network is required to support rooftop reception or, for example, portable outdoor reception. This will define the DVB-T2 equipment parameters and the resulting coverage and capacity. In the case of national channels there is the possibility of deploying a single frequency network (SFN) but this requires the largest guard intervals and robust modulation schemes to avoid situations where coverage is severely limited by self-interference and this requirement for greater robustness reduces the capacity. However, assuming SISO (single input, single output) operation of DVB-T2, whereby each transmitter emits the same signal, and a channel bandwidth of 8 MHz, the maximum transmitter distance can be around 150km in the UHF bands. This will support around 12 to 14 standard definition programmes as shown in the table below:

[23] Fast Fourier Transform

Table 3-1: Comparison of capacity for a DVB-T2 SFN

	Fixed reception	Portable reception
Modulation	64 QAM	64 QAM
FFT size	32k	16 k
Guard interval	19 / 128	1 / 4
Maximum transmitter distance	159.6 km	132.4 km
Code rate	2 / 3	2 / 3
Carrier mode	Extended	Extended
Capacity	24.5 Mbit/s	22.4 Mbit/s
Number of programmes (MPEG4)	14 SD / 2 HD	12 SD / 2 HD

Source: LS Telecom based on planning in Europe

Another consideration is the frequencies that should be used. It is noted that in the GE-06 Agreement, which applies to Region 1, there was a single DVB-T coverage layer identified for each country in VHF Band III[24]. Further frequencies are normally identified in the UHF bands.

There are potentially 14 or 15 eight MHz bandwidth channels in UHF Band IV (470-582 or 470-590 MHz). In terms of frequency utilisation it is possible for adjacent channels to be used so long as the Muxes are radiated from the same site. It has even been possible for transmitters serving directly adjacent area to be co-channel based on the receiver aerial discrimination at the border of the two areas.

It is also important to recognise that digital terrestrial will rarely, if ever, provide end to end distribution for broadcast services because of the costs associated with deploying a network with 100% geographic coverage. Instead it is usual for DTT to provide the final link between transmission sites and viewers at a national or regional level. The primary distribution is provided via satellite, IP over fibre and microwave or a combination of these. Clearly satellite is likely to provide the most efficient solution in areas which are sparsely populated and there is little or no IP fibre.

3.3.3 Spectrum requirements

Currently there are around seven channels delivered over analogue terrestrial TV and most multi-channel viewing is via cable or satellite with cable TV services being encouraged and rolled-out in rural areas.

If the current split of delivery mechanisms was maintained[25], the existing national terrestrial TV channels could be supported, in standard definition format, by a single DVB-T2 Multiplex and a single

[24] Band III is suitable for mobile services as its Doppler performance is up to 4 times better than UHF Band IV.

[25] In fact, this analysis is not overly sensitive to this assumption. Since there are relatively few channels carried over terrestrial platforms, and the assumptions used in our analysis are conservative, the number of channels that could be carried over terrestrial platforms could increase significantly before there is any impact on the analysis. Furthermore, even if fewer subscribers use terrestrial in the future (preferring to move to satellite or cable), this will not impact on the spectrum demands for terrestrial as this is reliant only on the number of channels, not the number of viewers.

frequency network. It would also be possible to include a number of national commercial channels and in the longer term, post switchover, this Multiplex could be accommodated in Band III. If the aim is to provide some high definition channels these could be supported by a further Multiplex.

There is also a requirement to support provincial content and these could each be supported by a single Multiplex using a provincial SFN. Again there would be spare capacity for further channels (commercial or mobile TV).

Whilst trunked radio systems potentially have access to part of UHF Band IV, even if these frequencies are used across all of Pakistan there still remain around ten 8 MHz channels (assuming channel 21 and channels 26-34 can be used for DTT). Further, it is possible that white-space spectrum can be used to carry outside broadcast traffic or it can be moved to higher spectrum (above 2 GHz[26]), meaning that no additional spectrum would be required for this service.

It is therefore assumed that these ten channels will be more than sufficient to support at least two Multiplexes for each province after switch-over. This would allow the entirety of UHF Band V to be released to mobile. In the future, it may be possible to consolidate digital television into Band III, freeing up the entirety of the UHF spectrum for mobile. The Pakistan authorities should consider whether this is a realistic goal at the outset.

A similar report for India[27] has concluded that it should also be possible to release the entirety of Band V in India for mobile. This should provide significant benefits in managing the potential for cross-border interference compared with the scenario of high power TV broadcasting transmitters being deployed in one country and mobile in the other. In this instance there could be significant geographic areas near the border where it would not be possible to deploy mobile networks in the same band.

The release of the same spectrum would also facilitate the adoption of common channel plans and such an approach should be encouraged in other neighbouring countries.

Therefore, to be conservative, this study considers that the entirety of Band V will be released to mobile providing the potential of 80 MHz of spectrum. The impacts of this are discussed in Section 5.

3.3.4 Further benefits of digital switch-over

As well as the benefits that may arise from mobile use of freed-up spectrum, there are additional benefits that arise from use of digital transmission for terrestrial television. These are not quantified in this paper, but the potential benefits should not be underestimated.

- A greater selection of channels can be delivered to the poorest sections of society, without the need for pay-TV subscriptions or satellite equipment. This can allow increases in educational content and local cultural content.
- Additional technologies such as subtitles and supplementary text which extend accessibility and can provide viewers with more information and interactivity.
- Digital EPGs ensure that viewers are able to track when programmes are being shown, and potentially set alerts.
- Encryption allows pay-TV channels, which will allow the platform to carry more profitable content.

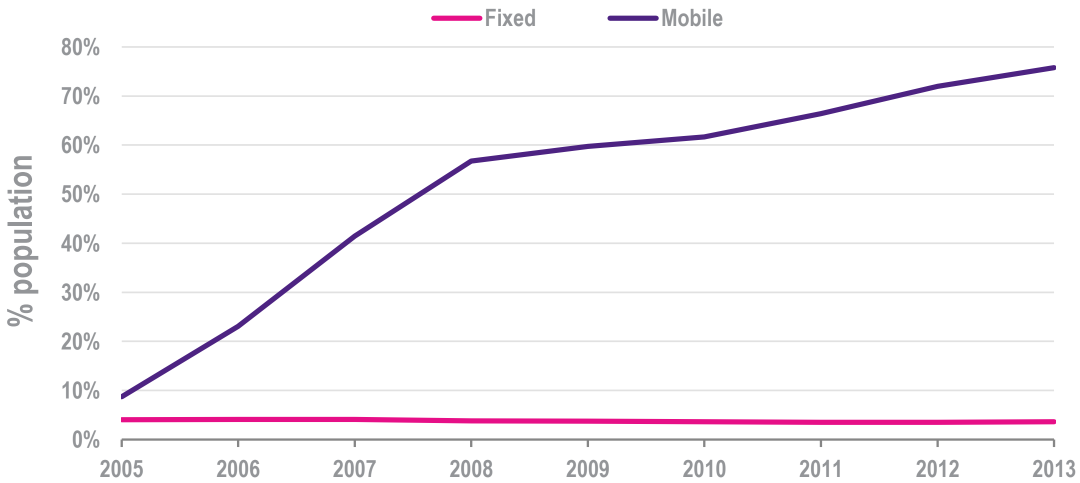
[26] It is common practice to use frequency bands above 2 GHz for video applications. Radio microphones generally use white space spectrum.

[27] Plum Consulting for the GSMA, ‘Potential benefits from sub-700 MHz spectrum in India’, January 2015

4 The telecommunications market

The Pakistan mobile market has undergone significant growth over the past decade; at the turn of the century there was one mobile operator (the incumbent, Mobilink) with under half a million subscriptions. There are currently six operators competing in a vibrant market with over 120 million subscriptions; mobile penetration is over 70% and is continuing to grow. In contrast to this rapid growth, the penetration of fixed lines has remained stagnant.

Figure 4-1: Fixed telephone line vs. mobile penetration



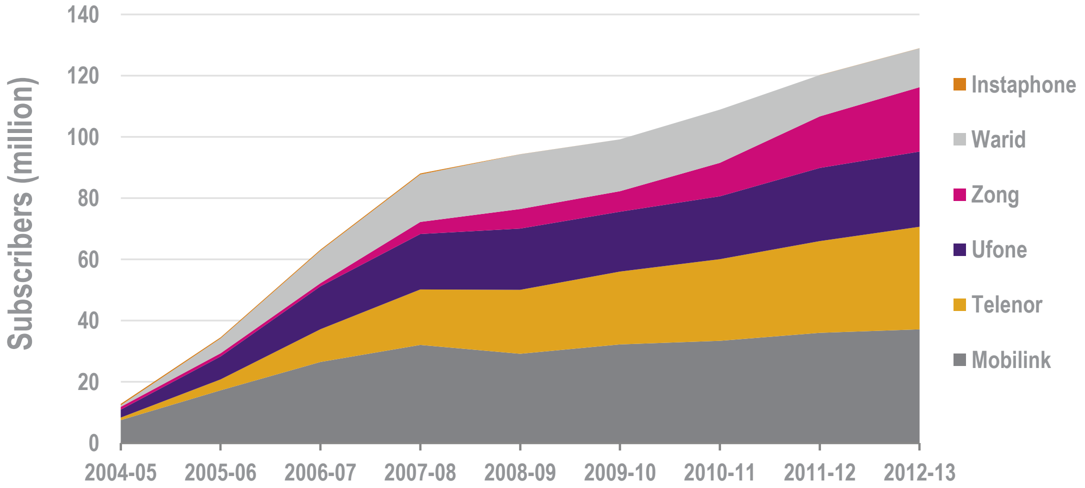
Source: Plum Consulting, PTA, World Bank

The growth of the mobile market accelerated in 2005 when two new operators, Warid Telecom and Telenor Pakistan, entered the market. As shown in Figure 4-2, there is strong competition in the market, with the incumbent Mobilink's market share falling form 58% in 2005 to 29% in 2013. Paktel was reinvigorated after China Mobile bought it 2007 and rebranded it as Zong in 2008. Following the privatisation of Pakistan Telecommunications Co. Ltd (PTCL) Ufone became part of Etisalat in 2006, while Instaphone exited the market in 2009.

However, mobile market growth slowed in 2009 and has since remained at a lower level. This is likely to be in part because of the global economic climate; foreign direct investment in Pakistani telecommunications fell from US$1,439 million in 2008 to US$79 million in 2011[28] (although this is a faster rate of reduction than the rest of the Pakistan economy has experienced). The lower growth rate is also likely to be due to market saturation in urban areas; it typically takes more investment for operators to reach less profitable rural subscribers.

[28] BuddeComm, 2013

Figure 4-2: Mobile subscribers by operator



Source: Plum Consulting, PTA

Nevertheless, the rural market is an important one; 62% of the population of Pakistan lives in rural areas[29]. In 2006 the Ministry of Information Technology (MoIT) formed the universal service fund (USF), funded by a 1.5% tax on operator income, to specifically support telecommunications in rural areas. The stagnation of fixed lines and the significant growth of mobile point to mobile as the best way for rural areas to gain access to basic telecommunications services, as well as broadband.

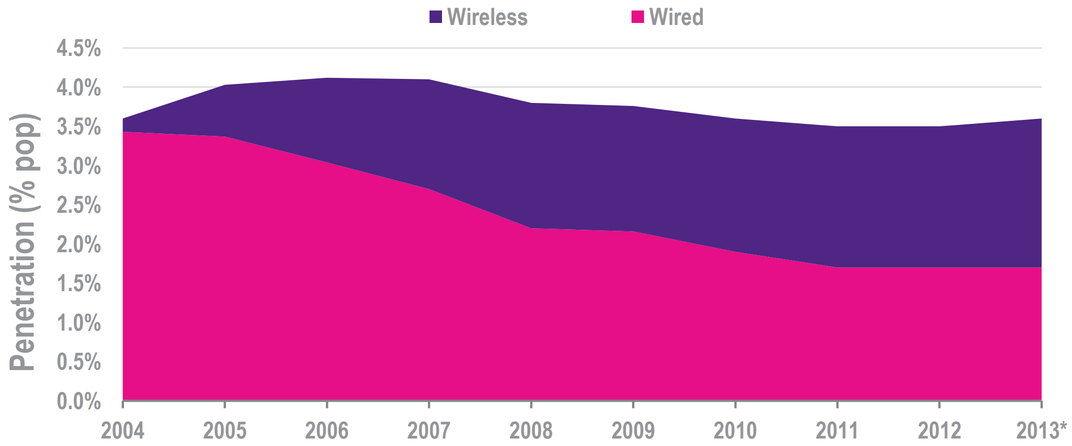
4.1 Fixed line penetration

Fixed lines in Pakistan are provided using wired and wireless technology, with the proportion of wired fixed lines falling over the last ten years. The incumbent PTCL has the vast majority of fixed telephone subscribers (95% in June 2012)[30], with the rest of the market split between a number of smaller, some regional, firms.

[29] World Bank, 2013

[30] BuddeComm, 2013

Figure 4-3: Fixed telephone line penetration

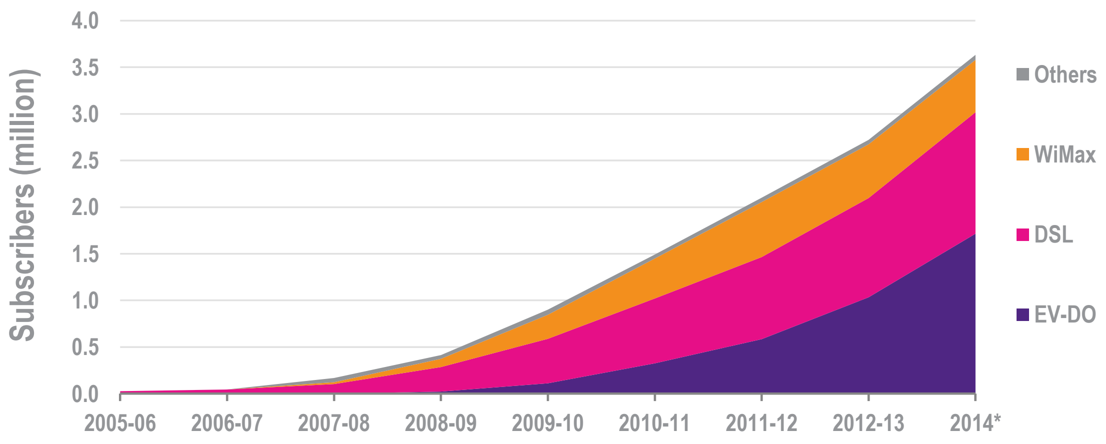


Source: Plum Consulting, PTA
*September

4.2 Use of broadband

Broadband penetration in Pakistan is low but growing fast, with take-up of wireless technologies (in this case EV-DO and WiMax) again driving growth. The rapid expansion of wireless telecommunications in Pakistan points to the role that mobile broadband will have in connecting urban and rural consumers in the near future. The large rural population of Pakistan is a key reason why mobile broadband is the optimal way to drive broadband penetration in Pakistan.

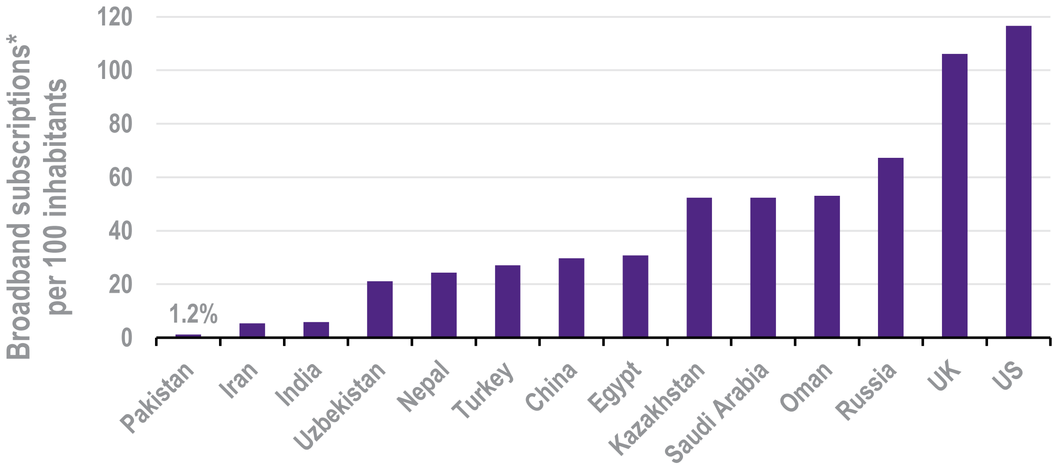
Figure 4-4: Broadband subscribers by platform



Source: Plum Consulting, PTA
*April

However, the growth of mobile broadband appears to be constrained by its reliance on old technologies. Both EV-DO and WiMax have significant limitations when compared to the newer technologies available such as LTE and even HSPDA, and the relatively high cost of EV-DO networks is likely to prevent a general mass-market rollout. Pakistan's broadband penetration is significantly below that of other similar countries, as can be seen in Figure 4-5.

Figure 4-5: Broadband penetration (2012)



Source: Plum Consulting, ITU
*The ITU defines broadband as 256 kbit/s

This study believes that it is important that the Government acts quickly to open the market to more advanced wireless technologies. However, these require large amounts of spectrum, and rural mobile broadband rollout is best enabled through the releasing of low frequency spectrum. Although mobile broadband rollout could be achieved with limited additional spectrum through significant network investment, however, it is unlikely that operators will find it profitable to do so on a large scale. Average monthly revenue per mobile user (ARPU) in Pakistan has decreased substantially in recent years; from US$19.2 in 2002[31] to US$2.2 in 2013[32]. This is partly because the percentage of subscriptions that are post-paid has fallen; 5.9% in 2005, 1.7% in 2011[33].

In April 2014 the PTA held a spectrum auction which sold 30 MHz in the 2100 MHz band and 10 MHz in the 1800 MHz band[34]. The winner of the 1800 MHz spectrum (Zong) is licensed to use LTE in the band; for the first time mobile broadband can be utilised in Pakistan. The 2100 MHz spectrum is licensed for 3G usage – also the first time 3G has been used in Pakistan. While the April auction enabled mobile broadband, it did not provide the market with what is needed for mobile broadband to take off – that is, a large quantity of low frequency spectrum.

As discussed in Section 3, there is an opportunity for the Government to use spectrum freed up from the digital transition (often termed "digital dividend spectrum") to enable mobile broadband growth. The next section considers the benefit that could be expected if 80 MHz of spectrum was awarded to mobile operators.

[31] BuddeComm, 2013

[32] The Nation, '*Cellular operators invest $452m despite drop in ARPU*', 31st January 2014 http://nation.com.pk/business/31-Jan-2014/cellular-operators-invest-452m-despite-drop-in-arpu

[33] BuddeComm, 2013

[34] The remaining, unsold 10 MHz in the 1800 MHz band is to be auctioned again at a later date.

5 Economic impact of released spectrum

When operators have additional spectrum, it can be used to expand mobile network capacity. In particular, the increased frequency bandwidth can be used to extend mobile broadband service to those who may have previously been priced out. An increase in deployment of mobile broadband, leading to an increase in broadband service take-up, can have significant impacts on GDP through two key channels.

- The first is the direct injection of funds into the economy as operators deploy new infrastructure. This can support the creation of new jobs, and multipliers, such as the creation of and consumption broadband-based or online services, in the economy lead to further rises in GDP.
- The second is the adoption of broadband by businesses and consumers. The adoption of broadband by enterprises can enhance multifactor productivity, which contributes to GDP growth. Similarly, households which use broadband will have better access to information and services which could help to improve its members' job prospect and labour productivity and increase household income.

5.1 Benefit estimation methodology

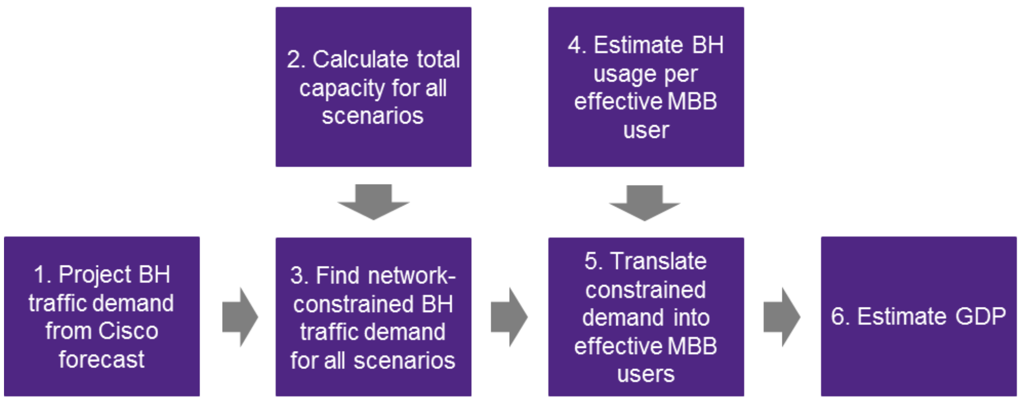
The methodology for estimating the economic impact of an increase in spectrum availability in this report is based on the observed positive correlations between broadband penetration and GDP growth. There is extensive literature which confirms this relationship, and a comprehensive review of the relevant studies can be found in Plum's study for the GSMA on Egypt[35].

The model is driven by the understanding that by having access to additional spectrum, mobile operators will expand their network capacity more rapidly since they can do this at a relatively low cost compared to rolling out new base station sites. This will enable extra demand for mobile broadband to be met, and there will be more mobile broadband users contributing to an overall increase in the country's broadband penetration. This means that where there is greater spectrum availability, there will be more broadband users than under a scenario where no additional spectrum is made available in future.

Figure 5-1 is a flow diagram of the steps that the model follows to derive the economic impact of new spectrum release for mobile broadband in GDP terms. This process is repeated for each scenario to be modelled. The GDP estimates for different spectrum release scenarios are then computed, and the difference between these represents the change in GDP when one spectrum scenario is implemented over another.

[35] Available at http://www.plumconsulting.co.uk/pdfs/Plum_Sep14_The_Impact_of_Mobile_Broadband_in_Egypt.pdf

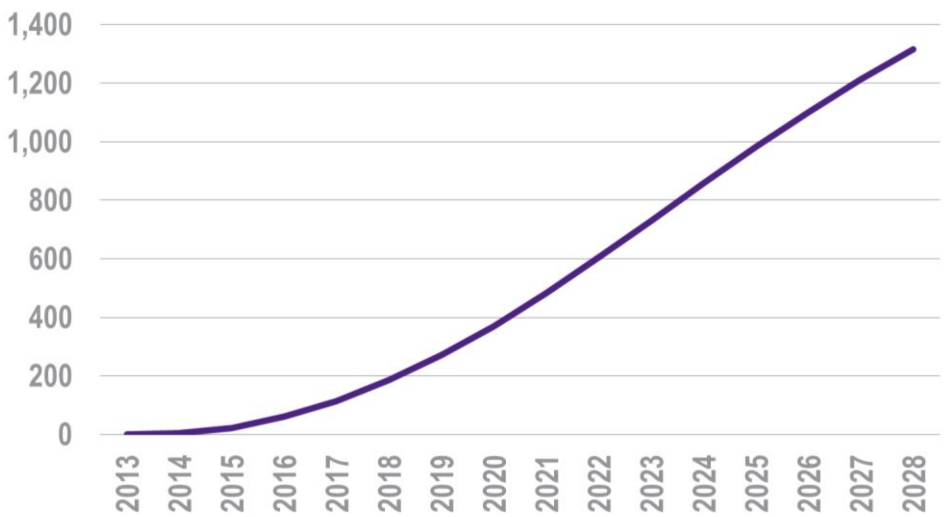
Figure 5-1: Flow diagram of steps for GDP calculation



Data to populate the model has been derived from a number of public sources and confidential data provided by Pakistani operators. Where assumptions have been made, these have been presented to operators so that they may be sense checked. However, limited data has been provided directly by operators and so where assumptions have been made this has been done in a conservative way.

First, the total mobile data demand in the market in the absence of supply-side constraints has been derived based on Cisco VNI 2014 forecasts, adjusted based on input from operators and other experience of similar markets. This is shown in Figure 5-2. The assumptions over data growth are shown in Appendix A.

Figure 5-2: Unconstrained mobile traffic in Pakistan (PB)



Source: Cisco VNI 2014, Plum Consulting

Next, the total capacity in the network is calculated based on technical parameters and the spectrum holdings expected for the operators. These data inputs are set out in Appendix A, and have been computed from public sources and data provided by operators. When network capacity falls below the level set out in Figure 5-2, demand is said to be constrained. It is this constrained demand that determines the number of mobile broadband users that can be accommodated in the market. This will differ from scenario to scenario, depending on how much additional spectrum is released and how it is distributed amongst operators.

The constrained demand computed through Step 1 to Step 3 is converted into the number of effective mobile broadband users that there could be in the market in the absence of supply-side constraints. To do this monthly usage per subscriber has been estimated based on operator's data on traffic per mobile broadband subscriber in the market, traffic volumes for mobile band compatible devices from Cisco VNI 2014, and estimates used in previous studies[36] for similar developing economies. The constrained demand expressed as the number of mobile broadband users allows the model to calculate the change in broadband penetration[37] for each scenario.

To estimate the effect of mobile broadband on GDP growth under each scenario, the model makes use of the relationships in established studies[38] between the increase in broadband penetration and the change in GDP or the change in GDP growth. For this study, the model uses a conservative estimate of an increase of 0.5 percentage points in annual GDP growth rate for a rise of 10 percentage points in broadband penetration. This enables the model to produce a time series of GDP for the modelling period for each spectrum release scenario. Once the GDP time series for each spectrum scenario including the base case is obtained, the change in GDP between the base case (without additional spectrum) and the alternate scenario for each year can be computed.

5.1.1 The base case

As mentioned in Section 5.1, the benefit in GDP terms that accrues to each scenario is represented by the change in GDP from the base case. In this base case, it is assumed that no spectrum in the 600 MHz band is released. Only spectrum in the 850 MHz, 900 MHz, 1800 MHz and 2100 MHz bands are available for use in providing mobile broadband services. Figure 5-3 shows the total amount of spectrum assumed to be available and used by operators to offer mobile broadband service during the modelling period.

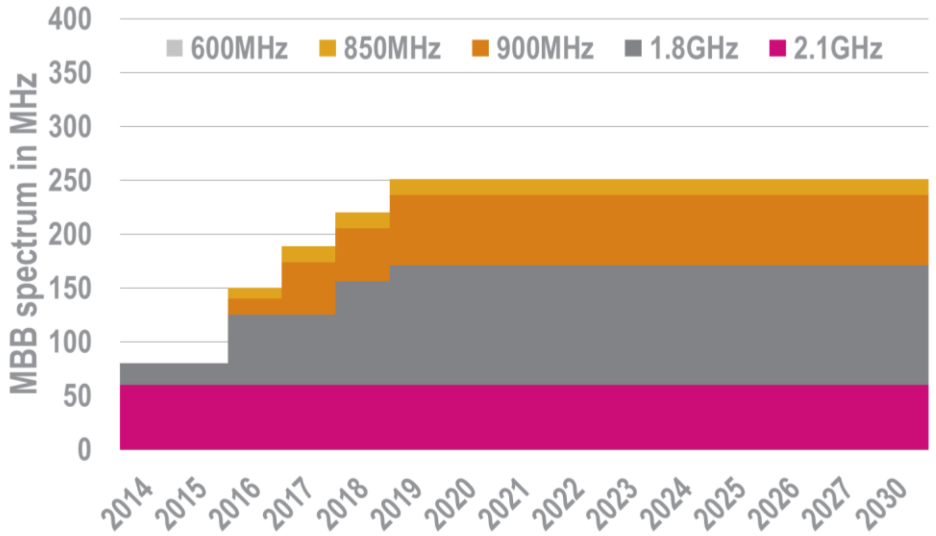
It should be noted that this base case does not include any award of 700 MHz spectrum to mobile operators. While, as mentioned in Section 3.2, the Pakistani authorities have indicated their intention to follow international guidelines and release the 700 MHz spectrum to IMT, there are no published plans for when this may occur. Therefore, this study does not speculate on this award and it is not considered in the base case.

[36] For example, http://www.plumconsulting.co.uk/pdfs/Plum_Sep14_The_Impact_of_Mobile_Broadband_in_Egypt.pdf and Plum Consulting for the GSMA, 'Potential benefits from sub-700 MHz spectrum in India', January 2015

[37] Existing fixed broadband connections and included and their growth is extrapolated into the future in all cases to ensure that the effect of the increase in broadband penetration due to greater availability of mobile broadband is accurately captured.

[38] As summarised in http://www.plumconsulting.co.uk/pdfs/Plum_Sep14_The_Impact_of_Mobile_Broadband_in_Egypt.pdf

Figure 5-3: Total spectrum used for mobile broadband in the base case

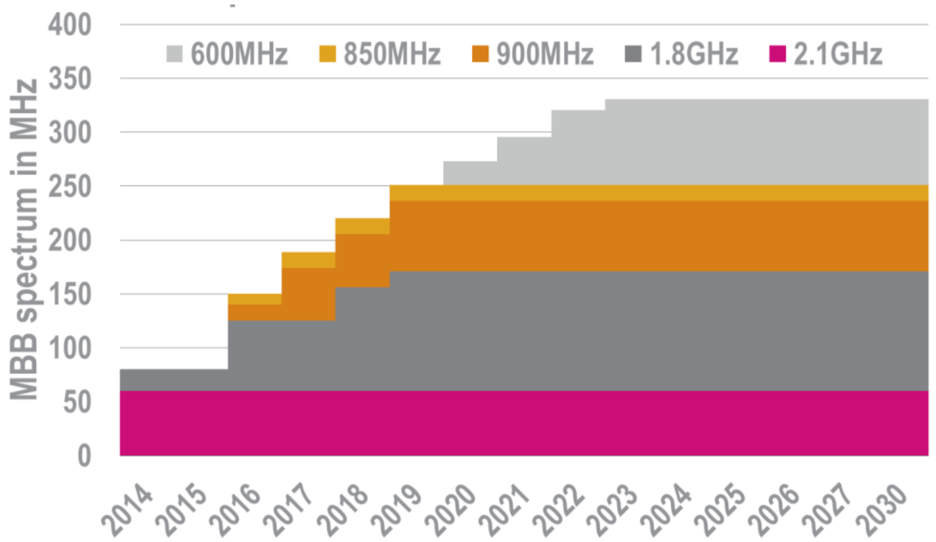


Source: PTA, Plum Analysis

5.1.2 Alternate scenario

In the alternate scenario, it is assumed that 80 MHz of spectrum in the 600 MHz UHF band (that is, the entirety of Band V, as described in Section 3.3.3) is allocated to mobile services and assigned to operators to provide mobile broadband services from 2020, in addition to bandwidths in the 850 MHz, 900 MHz, 1800 MHz and 2100 MHz bands. When released, the 600 MHz UHF band is assumed to be used in supplemental-downlink mode, which allows the entire bandwidth to be used for expanding downlink capacity. This is more efficient than a paired configuration given that downlink traffic is expected to continue to account for more than 70% of total mobile data traffic and there will be sufficient uplink capacity in other bands to accommodate all uplink traffic. Figure 5-4 shows the total amount of spectrum that is assumed to be available and used by operators for the provision of mobile broadband services during the modelling period under the alternate scenario.

Figure 5-4: Total spectrum used for mobile broadband in the alternate case



Source: PTA, Plum Analysis

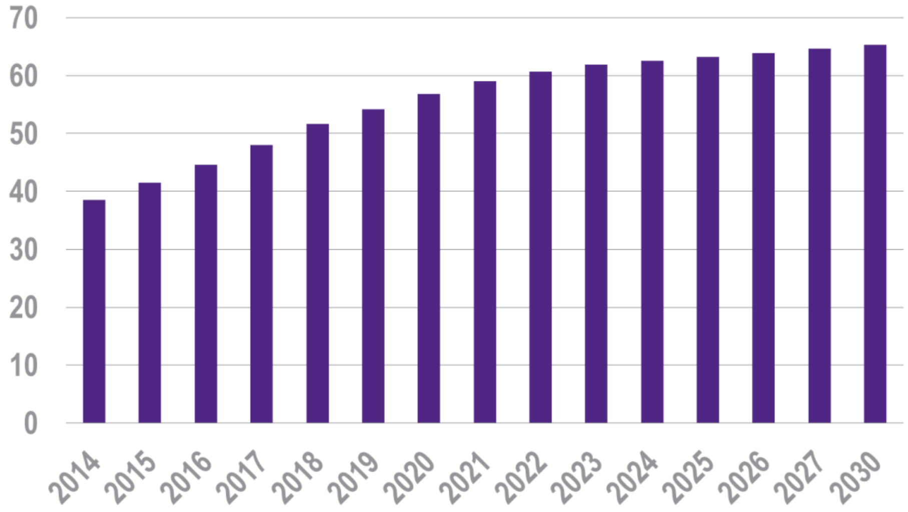
It is assumed that the additional spectrum will start to be used in 2020, following clearance of analogue television and the potential movement of digital television. However, it will take a few years for operators to use all spectrum effectively, and so full capacity is not reached until 2023.

This delay in the use of released spectrum is a common issue with regulatory spectrum awards. It is important that spectrum is released well in advance of capacity constraints being felt, so that operators are able to invest in time. Given this, it is crucial that the Pakistani Government acts as soon as possible to release the UHF spectrum to mobile operators to overcome current capacity shortages. If spectrum were made available before 2020, the potential benefits would be greater than estimated in this paper.

5.1.3 Other assumptions

The number of sites is assumed to be identical in the base case and the alternate scenario. The time series of site count is shown in Figure 5-5.

Figure 5-5: Projected total number of unique sites in Pakistan



Source: PTA, Operator sources, Plum Analysis

Table 2 summarises the key assumptions that are used in the base case and the alternate scenario.

Table 2: Comparison of assumptions for the base case and alternate scenario

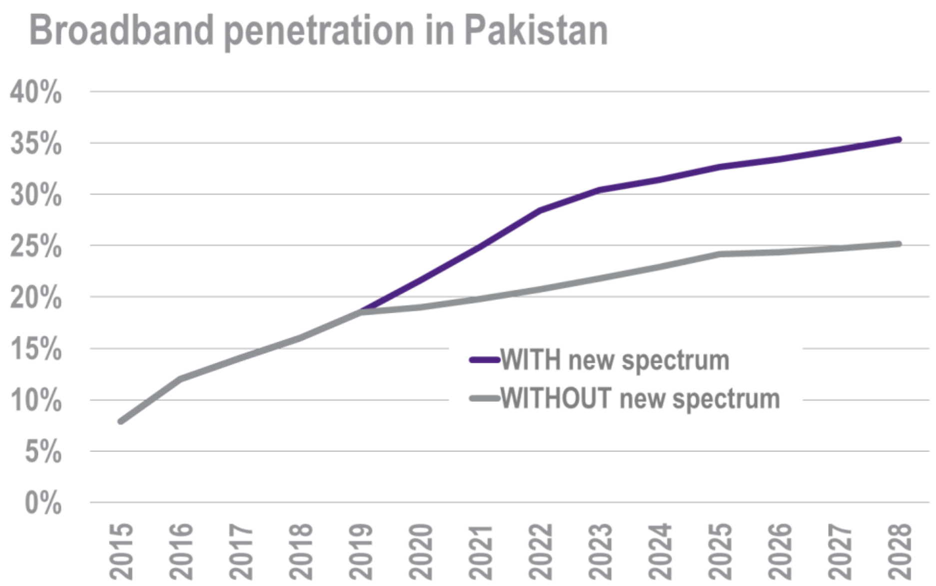
Assumption	Value assumed for the scenario	
	Base case	Alternate scenario
Number of operators	5	5
600MHz spectrum release date	N/A	2020
600MHz mobile broadband service deployment date	N/A	2020
Additional combined spectrum released in the 600MHz band	0MHz	80MHz

Other assumptions are the same under all scenarios and can be found in Appendix A.

5.2 Quantitative results

The model shows that given the amount of spectrum and the network infrastructure available for mobile broadband service, there will be a capacity constraint throughout the modelling period. However, the capacity shortfall can be alleviated with the release of 80 MHz of the 600 MHz UHF spectrum in 2020. This allows take-up of mobile broadband service to increase contributing to an increase in broadband penetration in the alternate scenario compared to the base case. Figure 5-6 shows the levels of broadband penetration that are achievable under the base case and the alternate scenario.

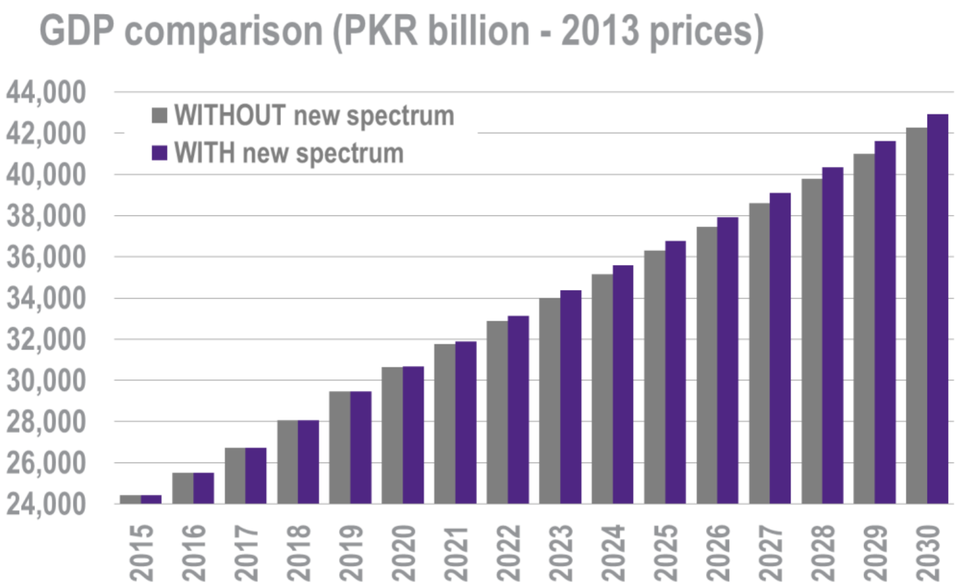
Figure 5-6: Broadband penetration under base case and the alternate scenario



Source: Plum Consulting

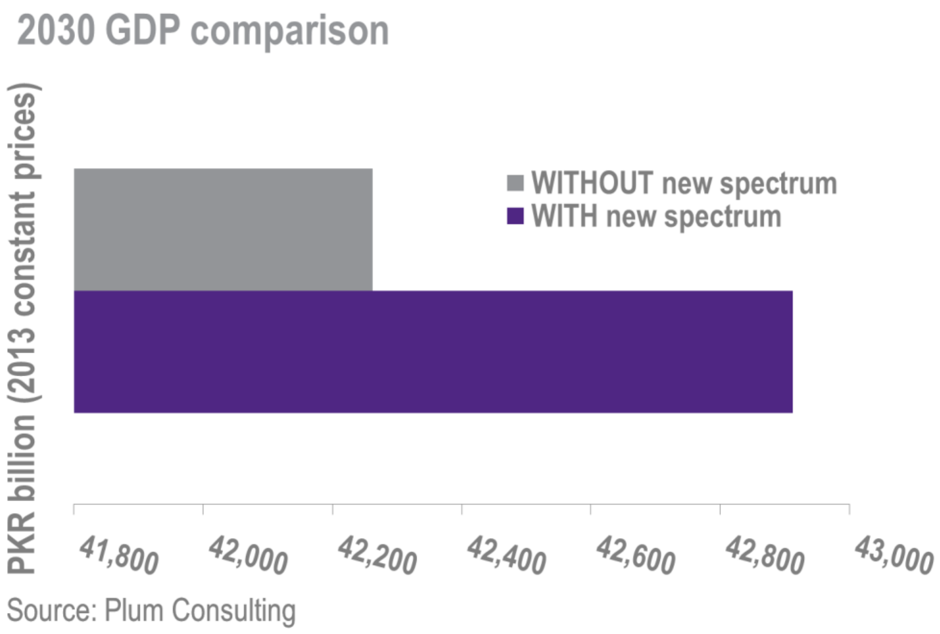
Figure 5-7 shows the time series of GDP that would be realised under the base case without 600MHz UHF spectrum and the alternate scenario with 600 MHz UHF spectrum. By 2030, the GDP in the alternate scenario is 1.5% higher than the base-line GDP in the base case. A snapshot of the GDP in 2030 for the base case and the alternate scenario is shown in Figure 5-8.

Figure 5-7: GDP time series for the base case and the alternate scenario (PKR bn, 2013 prices)



Source: Plum Consulting

Figure 5-8: Comparison of 2030 GDP between the base case and the alternate scenario



Discounting the time series of the GDP between 2015 and 2030 back to 2015 yields an NPV of GDP of:

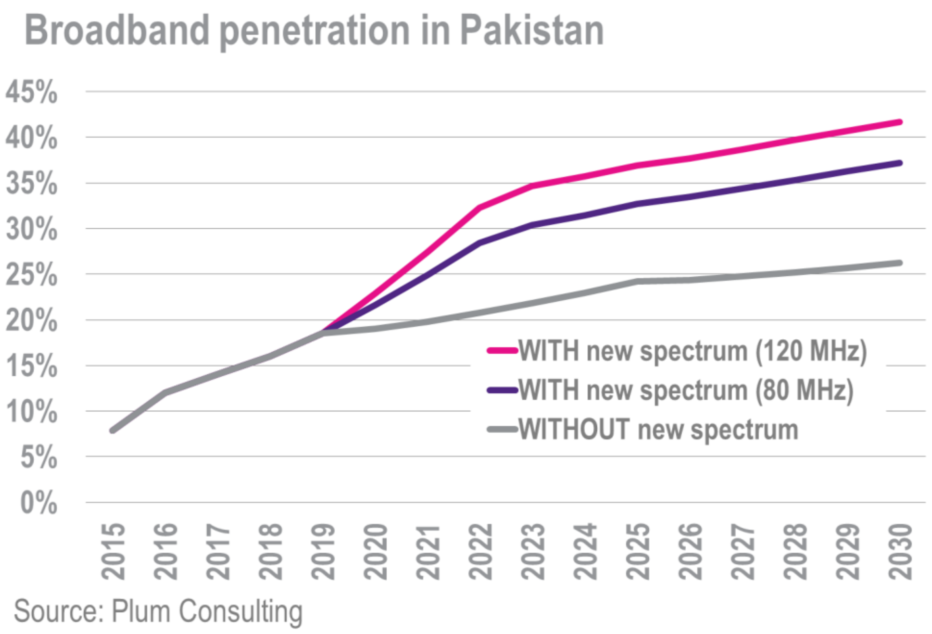
- PKR446,425bn (USD4,483bn) for the base case, and
- PKR449,885bn (USD4,517bn) for alternate case

This means that the total economic benefit in terms of additional GDP in NPV terms could be up to **PKR3,460bn** (USD34bn) if 80 MHz of UHF spectrum (that is, the entirety of Band V) is allocated to mobile service. However, any delay in awarding spectrum will lead to a lower benefit being felt.

5.2.1 The impact of releasing more spectrum

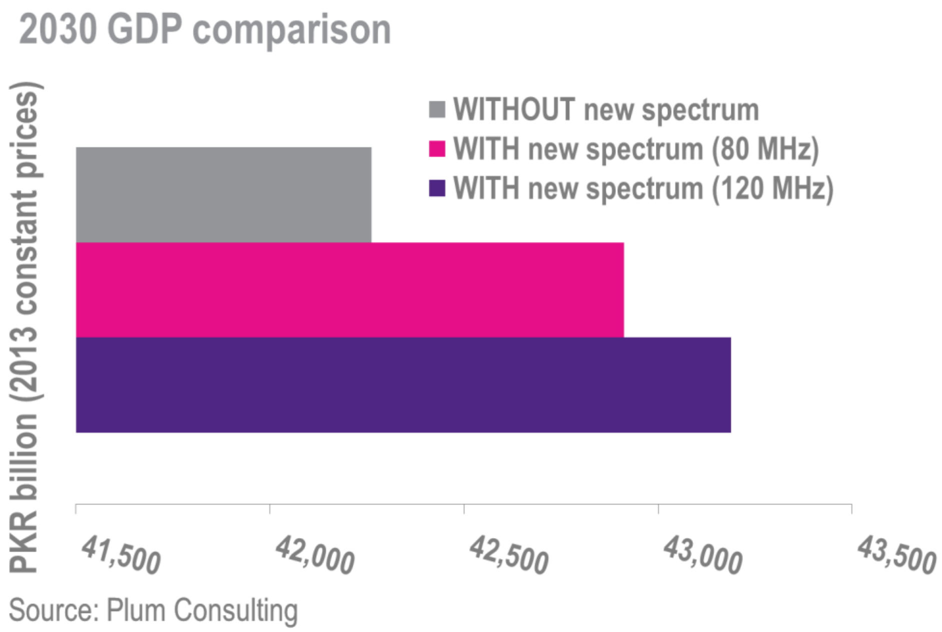
As mentioned in Section 3.3.3, it may be possible to release more than 80 MHz of spectrum. In order to quantify the impact of this, a sensitivity analysis has been conducted. If a total of 120 MHz can be released for use by mobile operators instead of 80 MHz, then there would be an increase in broadband penetration of 16 percentage points rather than 11 percentage points. This is show in Figure 5-9.

Figure 5-9: Broadband penetration under base case and the alternate scenarios



Similarly the GDP in 2030 would also be 2.2% higher rather than 1.5% higher. Figure 5-10 compares the GDP figures in 2030 for the different spectrum scenarios.

Figure 5-10: Comparison of 2030 GDP between the base case and the alternate scenarios



For the whole modelling period, the NPV of GDP would be PKR451,520bn (USD4,534bn). This means that the additional GDP in NPV terms would be PKR5,095bn (USD51bn), compared to PKR3,460bn (USD34bn) in the case where 80 MHz is made available.

6 Implications for spectrum policy

This report has shown that there are significant potential benefits from moving terrestrial television services from the current analogue platforms to digital transmission, both in terms of expanding the television services available and also releasing spectrum that can be used to expand mobile broadband services. Indeed, it is estimated that the latter could grow the Pakistani economy by up to 1.5% by 2030.

The Government of Pakistan should act to ensure that this transition can take place as soon as possible, particularly given the current lack of digital broadcasting. The mobile broadband market is already significantly constrained, with consumers reliant on less efficient technologies. Broadband penetration is low and given the low penetration of fixed line telecommunications, mobile broadband is crucial to improving this. The length of the wait before the transition will determine the size of the benefits; the sooner it occurs the larger the benefits.

Therefore, the sooner the Government can release spectrum to mobile operators, the sooner these benefits will be realised.

Spectrum release

The exact amount of spectrum that can be released is unclear, but this study believes that at least 80 MHz would be made available after the digital transition due to the low number of analogue channels currently broadcast, which would theoretically be able to all be carried on a limited number of multiplexes in UHF Band IV. However, the Government may be able to consolidate terrestrial broadcasting further to release more spectrum for mobile broadband, by:

- Defining multiplexes for DTT which do not use the whole of Band IV, or
- Potentially using VHF spectrum (Band III) for DTT, therefore releasing the whole of Band IV.

In making this decision, the Government must take account of decisions made by neighbouring countries. If Pakistan were to allocate spectrum in a different way to India, for example, there would be significant areas of the country in which the new mobile broadband spectrum would be rendered unusable due to interference.

Timing of release

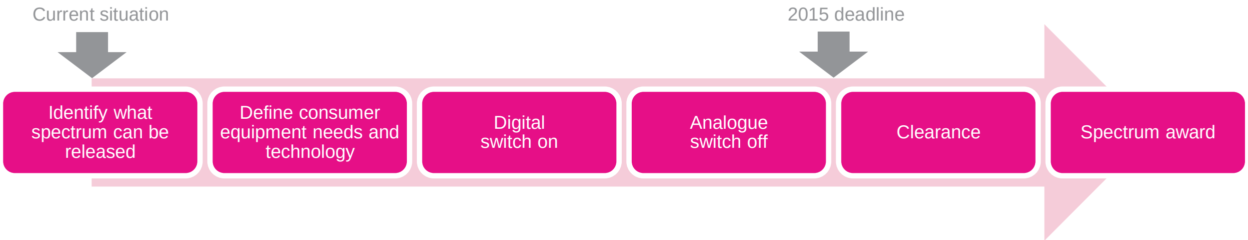
It has been assumed throughout this study that new spectrum will be available for mobile from 2020. This release date directly impacts on the size of the benefits that can be expected, since these are accrued in each year. If the spectrum is released later than this date, then benefits over the study period will necessarily be reduced, while if spectrum is made available sooner there would be a significant increase in benefit (especially as networks are already spectrum constrained).

7 Transition management

This report has demonstrated that there are significant benefits that may be realised if the Pakistani authorities act to release sub-700MHz UHF spectrum to mobile broadband in the near future. This will be achieved by completing the digital transition for terrestrial television services. However, information on Pakistan's current progress towards digital transition is unclear and it does not appear that any decisions have been made on the digital technology to be used.

The digital transition requires six steps, as shown in Figure 7-1. This study has identified that spectrum will be able to be released, and has made some assumptions over the technologies to be used. However, without very quick action over the introduction of digital transmission, the Government will be unable to make progress towards analogue switch-off which was planned for later in 2015.

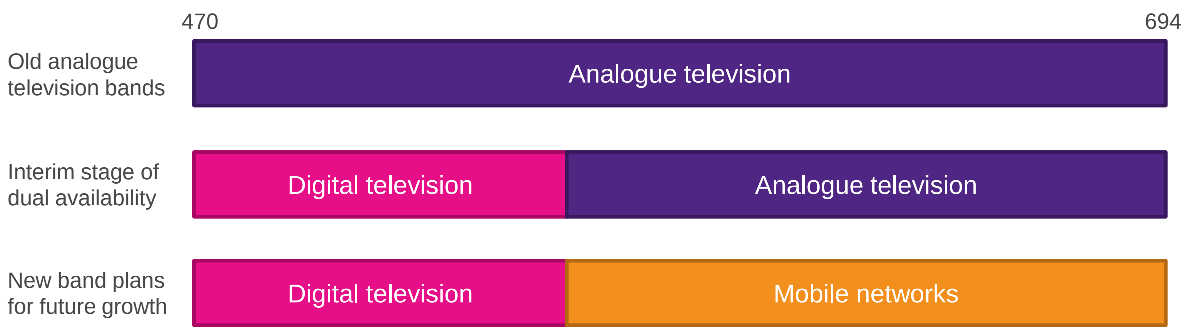
Figure 7-1: Digital transition



Prior to starting digital transmission, the telecommunications and broadcasting regulators must establish which bands are actually being used by analogue television and the best way to run simultaneous analogue and digital broadcasts.

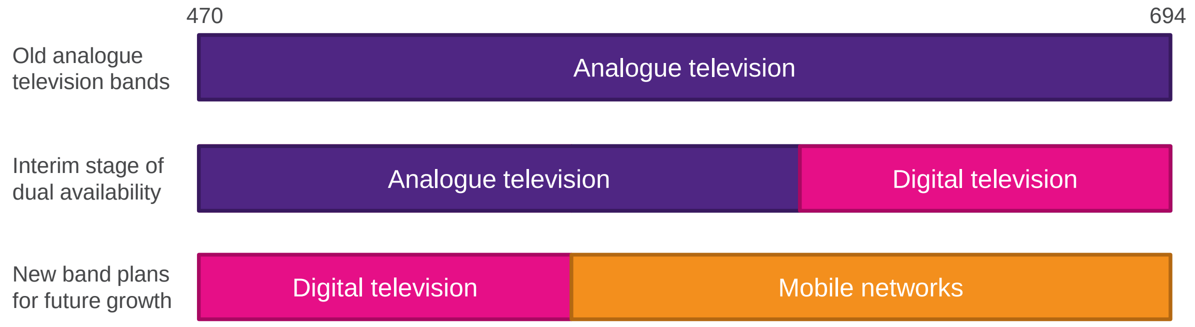
It is likely that given the historical development of broadcasting in Pakistan, analogue broadcasts will be spread out across the existing spectrum, and there will need to be some movement of channels to allow for the initial digital transmissions. Where analogue transmissions are moved to will depend on the type of consumer antennae equipment prevalent in Pakistan. If full-band antennae are generally used, so that transmissions can be received over the entire UHF band, it would make sense to introduce digital television at the lower end of the band where it will ultimately lie, to prevent a retuning exercise.

Figure 7-2: Preferred transition sequence



However, if antennae are typically configured only for part of the band, it may be that analogue transmissions will need to stay at the lower end of the band, with digital transmission only available initially to those with more capable equipment. After analogue switch-off, digital can then move to its permanent home.

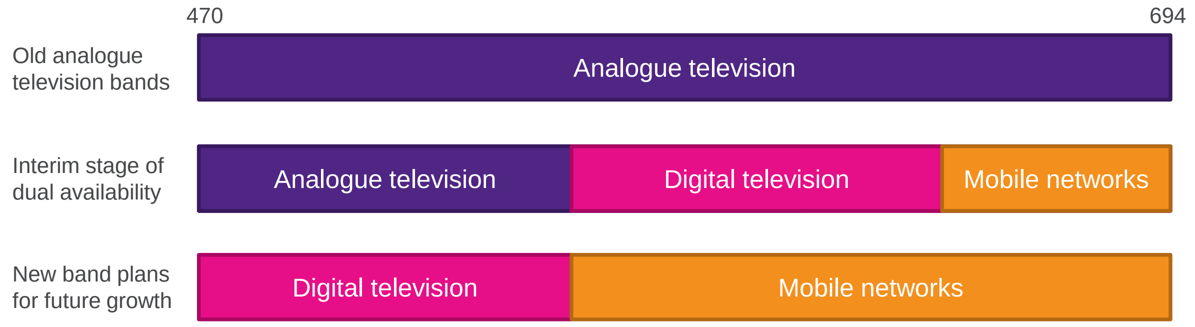
Figure 7-3: Alternative transition sequence



The government must establish the best path to reach its end goals based on the existing markets, taking care when referring to international examples. In many cases regulators have required multiple movements of services within the UHF band in order to reach a fixed end point, incurring additional cost for broadcasters and inconvenience for users.

In fact, in an ideal situation, all existing analogue broadcasts will already be in a restricted frequency range, which would allow both digital broadcasts and mobile networks to be set up immediately, as shown in Figure 7-4.

Figure 7-4: Transition sequence with immediate mobile capability



Further, it may be possible to rearrange the location of analogue and digital transmission during the interim stage to prevent the need for a retuning exercise. Without comprehensive study of the national broadcasting frequencies, however, it is impossible to determine the optimum path.

Appendix A: Modelling assumptions

The following tables contain values for inputs to the economic impact model. The information sources are listed alongside the values.

The majority of this data has been derived from public sources and assumptions based on Plum's previous experience. Where assumptions have been made they tend to be made in a conservative way (that is, reducing the estimated benefits).

A.1 Demographic assumptions

Parameter	Value used	Source
Population (million)		Plum's projection based on statistics from the World Urbanization Prospects: 2014 Revision
2013	182	
2015	188	
2020	203	
2025	218	
2030	232	
Urban population percentage		Plum's projection based on statistics from the World Urbanization Prospects: 2014 Revision
2013	38%	
2015	39%	
2020	41%	
2025	44%	
2030	47%	
Average number of people per household		Estimated based on ITU Yearbook's statistics to between 2003 and 2012
2013 - 2023	7	
2024 - 2030	6.5	
Maximum % of urban population that can afford mobile broadband service	100%	Plum's estimate assuming that there is no affordability constraint – i.e. the market is competitive and prices are sufficiently low when there is no supply constraint

A.2 Market and traffic demand assumptions

Parameter	Value used	Source
Number of operators	5	PTA
Mobile population coverage (2013-2025)		Plum's estimate
Urban	100%	
Rural	92% - 94%	
Blended	92% - 94%	

Parameter	Value used	Source
Country's monthly mobile data usage volume		Estimated based on pro-rating Plum's Gompertz-curve projection of Cisco VNI 2014 forecasts for India and information from operator sources in Pakistan
2014	3.7 PB	
2015	20.2 PB	
2020	370.1 PB	
2025	983.1 PB	
2030	1,494.3 PB	
Monthly data usage volume per effective mobile broadband subscriber		Plum's estimates based on previous socioeconomic study on Pakistan and Cisco VNI's reported usage for tablets, smartphones and computers in 2013 for MEA and information from operator sources in Pakistan
2014	0.5 GB	
2015	1.5 GB	
2020	5.6 GB	
2025	7.2 GB	
2030	8.3 GB	
Number of fixed broadband subscriptions (million)		Estimated based on a straight-line extrapolation of the PTA's statistics for fixed and wireless broadband lines from their website (excluding EV-DO connections)
2013	1.8	
2015	2.4	
2020	3.9	
2025	5.4	
2030	6.9	

A.3 Network assumptions

Parameter	Value used	Source
% of traffic from occasional users		Plum's estimate
2013	15%	
2015	11%	
2020	5%	
2025	0%	
2030	0%	
% traffic in busy hour	10%	Plum study for Qualcomm[39]
% traffic in downlink	90%	Plum study for Qualcomm
% utilisation of capacity for reasonable quality of service for end user	60%	Plum study for Qualcomm
Downlink:Uplink timeslot ratio for TDD band	2:1	Plum study for Qualcomm
Sectors per BTS	3	

[39] http://www.plumconsulting.co.uk/pdfs/Plum_Aug2013_Pakistan_3G.pdf

Parameter	Value used	Source
Spectrum efficiency (bps/Hz)		Plum's estimate based on discussion with equipment vendors as used in Plum's study for Qualcomm on LSA in 2.3 GHz band[40]
2013	0.45	
2015	0.65	
2020	1.10	
2025	1.35	
2030	1.60	
Year on year change in spectrum efficiency (bps/Hz)	0.05 – 0.10	Plum's estimate based on discussion with equipment vendors
Number of base stations at end-2013		Estimated based on historical statistics from PTA's webite and annual reports
Mobilink	9,117	
Telenor	7,977	
Ufone	7,203	
Zong	6,416	
Warid	5,175	
Growth rate of site count		Plum's estimate based on international trends
Urban areas	1% - 8%	
Rural areas	2%	
Ratio of urban site count to rural site count	45:55	Plum's estimate based on data from a previous Plum's economic impact studies for other developing countries
% of rural sites that are mobile-broadband ready[41]		Plum's estimate
2013	0%	
2015	20%	
2020	50%	
2025	50%	
2030	50%	

[40] http://www.plumconsulting.co.uk/pdfs/Plum_Dec2013_Economic_benefits_of_LSA_2.3_GHz_in_Europe.pdf

[41] This is defined as a site that has a backhaul link capable of high-speed data transmission.

A.4 Economic assumptions for GDP growth model

Parameter	Value used	Source
Boost to GDP growth rate per additional 10pp broadband penetration	0.5 percentage points	Plum study for GSMA[42]
Duration for which the growth rate boost persists	3 years	Plum study for GSMA
Discount rate	2%[43]	Estimated based on World Bank's reported real interest rate for the country between 2004 and 2013
GDP at 2013 constant prices (PKR billion)		IMF World Economic Outlook database April 2014 edition
2013	22,489	
2016	25,502	
2019	29,446	
15-year base-line GDP yearly growth rate[44]	3.0%	Plum's estimate based on IMF's near-term projection
Tax as a percentage of GDP for the modelling period	6%	Estimated based on averages calculated using information on GDP and tax available from Asian Development Bank's website[45]

A.5 Spectrum assumptions

It is assumed that, in future, all new GSM 900 and 1800 devices will be UMTS-compatible (given the current trend) and 1800 MHz LTE handsets will affordable, so that operators can gradually re-farm their 900 MHz and 1800 MHz spectrum for use with mobile broadband from 2015. However, where 1800 MHz spectrum has been awarded for 4G, it will be used to offer 4G service immediately. The assumptions below are made based on the total quantum of spectrum available to operators that Plum is aware of and possible release dates of new spectrum in the press. The same amount of spectrum is assumed to be made available for mobile broadband (3G or more advanced technologies) for all circles.

[42] http://www.plumconsulting.co.uk/pdfs/Plum_Aug2013_Pakistan_3G.pdf

[43] This is based on average interest rates and rates of return in Pakistan. This is lower than most international benchmarks, and to analyse the impact of this sensitivity analysis was carried out in the model using a 5% discount rate. This leads to a fall in the NPV of benefits by approximately 30%.

[44] The rate at which GDP is expected to grow in the absence of contribution from broadband

[45] http://www.adb.org/publications/key-indicators-asia-and-pacific-2014

A.5.1 Total mobile broadband spectrum available if no UHF spectrum is released

It should be noted that the bandwidth in each row of the tables below refers to the total bandwidth in each spectrum band that is available **for mobile broadband service**. It is assumed that the 900 MHz and 1800MHz bands will be re-farmed gradually from 2G services from 2015.

A.5.1.1 Urban areas

Band	2013	2015	2020	2025	2030
600MHz	0 MHz	0 MHz	0 MHz	0 MHz	0 MHz
850MHz	0 MHz	0 MHz	14.8 MHz	14.8 MHz	14.8 MHz
900MHz	0 MHz	0 MHz	64.8 MHz	64.8 MHz	64.8 MHz
1800MHz	0 MHz	20 MHz	111.2 MHz	111.2 MHz	111.2 MHz
2100MHz	0 MHz	60 MHz	60 MHz	60 MHz	60 MHz
Total	**0 MHz**	**80 MHz**	**250.8 MHz**	**250.8 MHz**	**250.8 MHz**

A.5.1.2 Rural areas

Band	2013	2015	2020	2025	2030
600MHz	0 MHz	0 MHz	0 MHz	0 MHz	0 MHz
850MHz	0 MHz	0 MHz	14.8 MHz	14.8 MHz	14.8 MHz
900MHz	0 MHz	0 MHz	64.8 MHz	64.8 MHz	64.8 MHz
1800MHz	0 MHz	20 MHz	111.2 MHz	111.2 MHz	111.2 MHz
2100MHz	0 MHz	60 MHz	60 MHz	60 MHz	60 MHz
Total	**0 MHz**	**80 MHz**	**250.8 MHz**	**250.8 MHz**	**250.8 MHz**

A.5.2 Total mobile broadband spectrum available if UHF spectrum is released

A.5.2.1 Urban areas

Band	2013	2015	2020	2025	2030
600MHz	0 MHz	0 MHz	30 MHz	80 MHz	80 MHz
850MHz	0 MHz	0 MHz	14.8 MHz	14.8 MHz	14.8 MHz
900MHz	0 MHz	0 MHz	64.8 MHz	64.8 MHz	64.8 MHz
1800MHz	0 MHz	20 MHz	111.2 MHz	111.2 MHz	111.2 MHz
2100MHz	0 MHz	60 MHz	60 MHz	60 MHz	60 MHz
Total	**0 MHz**	**80 MHz**	**280.8 MHz**	**330.8 MHz**	**330.8 MHz**

A.5.2.2 Rural areas

Band	2013	2015	2020	2025	2030
600MHz	0 MHz	0 MHz	30 MHz	80 MHz	80 MHz
850MHz	0 MHz	0 MHz	14.8 MHz	14.8 MHz	14.8 MHz
900MHz	0 MHz	0 MHz	64.8 MHz	64.8 MHz	64.8 MHz
1800MHz	0 MHz	20 MHz	111.2 MHz	111.2 MHz	111.2 MHz
2100MHz	0 MHz	60 MHz	60 MHz	60 MHz	60 MHz
Total	**0 MHz**	**80 MHz**	**280.8 MHz**	**330.8 MHz**	**330.8 MHz**