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| **SOUTH ASIAN TELECOMMUNICATIONS REGULATOR’S COUNCIL** **(SATRC)** |  |
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**SATRC REPORT ON**

**SPECTRUM RE-FARMING**

**Prepared by**

**SATRC Working Group on Spectrum**

Adopted by

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**EXECUTIVE SUMMARY**

The telecom sector is one of the most dynamic sectors. With the advent of new technologies and technological advancements, things keep on changing and to be more precise, things keep on getting better, may it be consumer experience, spectrum utilization, development of new services etc. Over the past two decades, there has been a significant advancement in the telecommunications sector which has changed from analog systems carrying only voice, to more robust digital high-speed data to the latest voice over LTE and further advancing towards 5G. All radio communications make use of a highly regulated, scarce and expensive resource - the electromagnetic spectrum. Different portions of the spectrum are allocated for use by different technologies. Agencies typically allocate GSM bands in 800 – 900 MHz and 1800 – 1900 MHz frequencies; UMTS bands are typically within the 1900/2100 MHz frequencies; and LTE is deployed in 700/1900/2100/2400 MHz bands of the spectrum.

To deal with the spectrum scarcity, some countries have changed legislation so that other services can use portions of the spectrum initially allocated to a different service/technology. This is called refarming: repurposing a frequency that was initially allocated to one technology for another one. For example, an operator may have a license to operate on the 900 MHz spectrum for GSM. To better deploy UMTS or LTE, the operator could potentially free some of the GSM capacity and allocate it to LTE or UMTS.

In this domain, the policy and regulatory challenges are enormous and the administration may face a number of difficulties that can complicate, delay and even disrupt the process. The level of difficulty experienced and options of implementations available may subsequently influence an administration’s approach to spectrum refarming. There is a global trend of gradually switching off 2G and 3G Networks with the increase in LTE-based mobile broadband networks. Technology neutrality allows for license holders to evolve the technology deployed and the services delivered as markets develop. Operators are likely to have different technology roadmaps to suit their own consumer portfolios. This allows for license holders to evolve the technology deployed and the services delivered as markets develop. Original mobile licenses (and other spectrum licenses) were technology-specific, some country Regulators have adopted technology neutral principles in those bands. While implementing technology neutrality in traditional technology specific frequency bands, refarming the existing technology specific bands, which were earlier assigned for services like GSM, CDMA, WiMAX etc. is a natural solution for increasing mobile broadband coverage.

This Report aims to provide deeper insight into the theory and practices of spectrum re-farming and as such is expected to be used by administrations in SATRC countries as a source of guidance on this subject.

# Chapter 1: **Introduction**

# Background

* 1. The electromagnetic spectrum can be defined as the range of all possible wavelengths of electromagnetic radiations from high energy gamma rays through visible light and down to low energy radio waves. The radio spectrum is the part of EM Spectrum within the range of about 3 Hz to 300 GHz. Thus, the radio spectrum is a finite resource, but it can be reused. It can benefit each administration by providing a medium to assist communications and economic development, provided it is managed efficiently and effectively.
  2. Radio spectrum is the lifeline of wireless technology. Over the past two decades, there have been significant technological changes/advancements in the telecommunications sector which have changed from analog system carrying only voice, to more robust digital high-speed data to the latest voice over LTE and further advancing towards 5G. These technologies make use of the highly regulated spectrum. With the relentless expansion of wireless services worldwide, all services relying on radio waves are competing for a share of the radio-frequency spectrum to support new applications, growing user numbers and exploding traffic. Since EM Spectrum is finite, Regulatory Agencies in different countries allocate different portions of the spectrum to be used by various mobile services. Therefore, in order to maximize the benefit to each administration, efficient spectrum management is required. Part of efficient and effective spectrum management is planning the development of radio services in advance of their requirement; this may include extending the coverage of existing services, enhancing the performance of existing services and introducing new services.
  3. To improve existing services or introduce new services it may be necessary to move existing users of the radio spectrum to more modern technologies or new frequency bands. The repurposing of spectrum bands to more efficient technologies and/or new services, or as it is otherwise known, spectrum refarming, needs to be planned. Refarming is a strategy where telecom service providers reuse their frequency resources to introduce the latest radio communication technologies to improve spectral efficiency, data throughput and reduce cost. For example, 900 MHz refarming solution is that service providers free about 5 MHz of GSM in 900 MHz band and deploy UMTS or LTE in the 900 MHz band. The reason being the lower the frequency larger the distances it can travel. In terms of cost, the lower propagation loss at 900 MHz means fewer base stations compared to networks using the 2100 MHz core-band 3G spectrum, costs can be 50 to 70% less. Thus, operators can provide less densely populated areas with 3G services more cost-effectively.

# Definition of spectrum refarming

* 1. Spectrum Refarming has been defined by the ITU as under:

The International Telecommunication Union (ITU-T) defines **“***Spectrum refarming (spectrum redeployment) as a combination of administrative, financial and technical measures aimed at removing users or equipment of the existing frequency assignment either completely or partially from a particular frequency band. The frequency band may then be allocated to the same or different service(s). These measures may be implemented in short, medium or long timescales.”*

# Need of spectrum refarming

* 1. More and more users are migrating from feature phones to Smartphones and there has been a substantial rise in bandwidth hungry applications. Further, due to the ongoing Corona Virus Disease 2019 (COVID-19) pandemic situation, with which, the whole world is struggling, the major demand for high speed and high capacity data has emerged from enterprises, industries, educational institutions, manufacturing units, the healthcare sector, retails, housing societies, etc. It is expected that the post-pandemic era will see a change in the ways we live, work and interact. The future life will observe restrictions in the movement of human beings, but at the same time will desire free flow of information, interactions and movements of goods and services. Telecommunications will become a must-have category –high speed connectivity and especially resilient connectivity, is what will be sought. To cater to the increased demand for high-speed broadband, service providers have to use their spectrum efficiently and may require moving towards latest spectrum efficient technologies.
  2. Due to the increased role of telecom, demand for LTE and VoLTE are increasing exponentially, data usage has been growing at a very fast pace. To meet the ever-increasing customer demands, huge spectrum capacity is required. Therefore, for the expansion of LTE network and deployment of latest technologies, such as 5G, spectrum refarming is required to provide more capacity. Each newer generation of mobile network introduces significantly improved radio technology, increasing capacity, data speeds and performance. 4G/LTE can penetrate further indoors than 2G, achieving 100x data rates with high definition voice. There is a global trend of switching off 2G/3G Networks gradually with the increase in mobile broadband networks. Thus, with such a drastic increase in the number of 4G/5G subscribers while downfall in the number of 2G/3G subscribers, telecom service providers may reuse the frequencies spectrum used for 2G/3G services, for ongoing and upcoming newer technologies.



Source: GSMA Intelligence

*Figure 1. Growth of 4G/5G in upcoming years with decreasing number of 2G/3G subscribers.*

* 1. As per GSMA[[1]](#footnote-1), 2100 MHz is the most refarmed band for 5G. Over the last six months, a range of operators shared updates on their spectrum refarming plans. The 2100 MHz band witnessed the most transitions, with 9 operators across six countries refarming spectrum for either 4G or 5G networks. The refarming activity of spectrum used for legacy networks (2G or 3G) for 5G is driven by two factors: the absence of 5G mid-band assignments (e.g. in Denmark and Slovakia) and the need for additional capacity (e.g. in Hong Kong and Germany). Details are given below:



* 1. In order to maximize the benefits to an administration, the radio spectrum needs to be efficiently and effectively managed. Part of efficient and effective spectrum management is planning the development of radio services in advance of their requirement; this may include extending the coverage of existing services, enhancing the performance of existing services planning a spectrum roadmap and introducing new services. The following are the major principles of spectrum management framework:

1. Achieving the highest economic efficiency;
2. Achieving the highest technical efficiency;
3. Increasing social development and satisfaction;
   1. Spectrum refarming is an important step forward to accomplish the principles of spectrum management. For e.g. The new use of released band can make more efficient use of spectrum and can provide services to improve quality of life and generate new business opportunities that can increase employment. Mobile network operators are also required to use the existing spectrum resources from GSM and UMTS to LTE in the most efficient way, so to accommodate new radio technologies by reassigning spectrum resources.
   2. From the above, it can be concluded that spectrum refarming is a spectrum management tool that can be used to satisfy new market demands, increase spectrum efficiency, or to respond to changes in international frequency allocations. Also, to improve existing services or introduce new services, it may be necessary to move existing users of the radio spectrum to more modern technologies or new frequency bands. In many cases, spectrum redeployment is a natural process as existing users change their radio operations based on new technologies.
   3. A study found that refarming spectrum from 2G to 3G accelerates per capita GDP growth. “For a given level of total mobile penetration a 10 percent substitution from 2G to 3G increases per capita GDP by 0.15 percentage points.” The same study also found that the higher data volumes enabled by 3G (and by implication 4G and 5G) have a positive economic impact. “A doubling of mobile data use leads to an increase in the GDP per capita growth rate of 0.5 percentage points.”[[2]](#footnote-2)
   4. The requirement to move existing users of the spectrum can arise for several reasons, for example[[3]](#footnote-3):
4. a spectrum allocation may have been in operation for a considerable period of time and currently no longer matches the demands of users, or the capabilities of modern systems;
5. an allocation within a specific range of frequencies is required for a new radio service and these frequencies are occupied by services with whom the new service cannot share;
6. a decision by a World Radio-communication Conference (WRC) to allocate a currently occupied frequency band to a different service on a regional or global basis.
   1. In order to re-engineer the band to improve spectral efficiency the following can be done:
7. the level of spectrum sharing can be increased;
8. to increase the number of channels, channel bandwidth can be reduced;
9. applying more efficient modulation techniques that permit greater sharing;
10. reducing the frequency reuse distance.
    1. The above options may provide the requirement for starting the spectrum refarming process. This process may not be difficult if the administration is able to move the existing users to an unused frequency band. However, due to changes in the type of equipment used, or changes in frequency allocation, an administration’s flexibility to refarm the spectrum is limited. The extent to which the administration will need to use spectrum refarming will depend on the size of the demand for spectrum and the level of spectrum congestion within the administration.
    2. Refarming does not mean that older technologies are no longer available to serve customers with 2G or 3G handsets. In fact, service continuity and investment certainty are critical for successful refarming. Today’s technology allows ‘graceful refarming’ of spectrum from 2G or 3G to 4G or 4G to 5G. LTE can be introduced in, for example, 1.4 or 3 MHz of 900 MHz spectrum so that 2G or 3G can run simultaneously in the same 5MHz block. Or, for example, if an operator has 2x10 MHz of 700 MHz spectrum, 4G and 5G can run alongside, each in a 2x5MHz block but in the same radio. Assigning spectrum to different technologies is adjusted based on demand. Operators observe the decline in GSM voice traffic and 3G data traffic and the growth in 4G data traffic[[4]](#footnote-4).

# Benefits of spectrum refarming

* 1. Refarming is a cost-effective way to increase capacity for newer technologies such as LTE, 5G, without the need to bid for new spectrum.
  2. Another interesting benefit for operators is that lower frequencies (usually allocated to GSM networks) provide much better coverage. Lower frequencies reach farther and have less penetration loss than higher frequencies, enabling better rural coverage and improved indoor urban coverage. Higher frequencies typically deliver greater capacity, rather than coverage, in urban areas. Thus, by deploying a suitable spectrum band, the operators can provide services in a cost effective manner. Deploying lower spectrum bands for coverage also results in enhanced Quality of Service (QoS) because fewer base stations mean fewer handovers. Considering that the majority of phone calls are initiated indoors, the higher in-building penetration afforded by lower-frequency bands is a significant factor.
  3. Spectrum re-farming allows to free a frequency band from an obsolescent Radio Access Technology (RAT) to re-allocate it to a new RAT and also confining the obsolete RAT in one frequency band just to guarantee coverage for new RAT. Hence it solves QoS issues on sites that were subject to (or close to) congestion.
  4. If spectrum deployment is in line with the globally harmonized bands as identified by ITU, it will also mitigate the cross-country interference issues experienced in border areas.
  5. To sum up, spectrum refarming has the following benefits:
* Refarming is cost-effective
* Alternative source of spectrum
* Increases capacity
* Enhances Quality of Spectrum
* New technologies
* Better interference management

# Objective of this Report

* 1. This Report aims to provide deeper insight into the theory and practices of spectrum refarming and as such is expected to be used by administrations in SATRC countries as a source of guidance on this subject. This report has been prepared as an assigned work item of SATRC Working Group on Spectrum under SATRC Action Plan Phase VII. Spectrum refarming requires careful planning and management to guarantee a smooth transition to mobile broadband networks.
  2. While the Report is intended as guidance on the application of spectrum refarming, it is however realized that the implementation of spectrum refarming process remains a strictly national issue. As such their use depends fully on the legal bases and regulatory practices in the area of spectrum management in a particular country. This Report gives information and guidelines for Administrations to consider now and in the future. It also gives recommendations based on the best practices.

# Chapter 2: Regulatory Aspects of Spectrum Refarming

* 1. Traditionally, the need to change the use of frequency bands (broadly defined as refarming) was not a significant problem in the centrally regulated environment of the Postal, Telegraph and Telephone (PTT) era, when the telecom services were primarily provided by state-owned post and telegraph companies. The appearance of new systems was planned well in advance and necessary spectrum relocation provisions could be made reasonably effortless, usually as a natural migration of technology. However, liberalization of telecom sector, rapid changes in radio technology and increasing digitalization have led to unprecedented growth in the use of telecom services, particularly mobile services. Since the key ingredient for mobile services is spectrum, it has become necessary for the regulators to focus on efficient and effective utilization of spectrum.
  2. Demands for new services and applications, from unobtrusive and ubiquitous short-range devices to sophisticated public mobile telephony and data networks, are ever-growing and spectrum managers have difficulty in deciding which applications and/or services should be granted access to the parts of the radio spectrum most in demand. The resulting congestion of the most attractive parts of radio spectrum and much shorter system life-cycles today often neither allows for finding suitable unused bands for new radiocommunication services nor achieving suitable sharing arrangements with incumbent services. Therefore, the issues of deciding between services competing for the same spectrum and refarming of currently used spectrum for new systems are increasingly faced by the regulators. Market-related considerations, such as ensuring competition and satisfying the customer needs were not always of prime consideration in centrally planned approaches, but in today’s situation, they are of high importance. It is expected that because of these developments in the radiocommunications market, refarming of frequency bands will be a process that countries may have to employ more often in the future. Therefore, spectrum refarming should be included in the administration’s national spectrum strategy together with the mechanism identified to assist the implementation of refarming.
  3. Reallocation of spectrum is one of the biggest challenges faced by the regulators. When frequencies have been used for one purpose, perhaps for decades, it is often difficult to reallocate these frequencies for different use. Spectrum refarming is a national spectrum management tool. Refarming (re-deployment) is a cost-effective way to increase capacity for mobile telecommunication services without the need to auctioning a new spectrum. However, the policy and regulatory challenges are enormous, and the regulator may face a number of difficulties that can complicate, delay and even disrupt the process. The level of difficulty experienced and options of implementations available may subsequently influence a regulator’s approach to spectrum refarming.
  4. Spectrum refarming can be broadly divided into two categories.

1. First category involves a spectrum band, which has been identified by ITU for IMT services, but the country is not currently using it for IMT services. In such cases, the country regulator needs to examine for what purpose the spectrum band is currently used, how efficiently it is being used, what are the alternates for such a service, alternate spectrum bands available and suitable for such service and the cost of redeployment. While considering the cost of redeployment for the incumbent to shift to an alternate band, it needs to be compared with economic benefits (direct and indirect) of redeployment of spectrum. The country regulator needs to perform a study and carve out a plan to vacate a suitable spectrum band for use by IMT services.
2. The second category involves change of technology in IMT spectrum bands already assigned to the telecom operators. Change in technology in a spectrum band involves various challenges, which are described in the following section.

# Challenges in change of technology in already assigned spectrum bands

* 1. Apart from the fact that spectrum refarming could be a time consuming process, it presents certain challenges. The first and most obvious are meeting the prerequisites for it:
* Operators must have sufficient contiguous spectrum to support the simultaneous operation of two or three technologies in a frequency band
* Simultaneous, mixed use of frequency bands presents challenges regarding bandwidth allocation across bands
* The same operator should be using both sides of the spectrum adjacent to the dividing point
* Adjacent channel interference must be dealt with using guard bands
  1. Other challenges include avoiding disruption to existing users on the band/technology being refarmed and encouraging them to migrate to new services. The operator needs to maintain quality of existing service as the process takes place, not compromising customer satisfaction and experience. Avoiding service degradation means understanding traffic patterns and managing how traffic will be served.
  2. Since frequencies in a spectrum band is assigned to different operators based on the then availability of spectrum and provision of guard band, over a period of time, it may lead to dual problem (i) it may result in Spectrum becoming interleaved between operators and (ii) it may result in a situation where the vacant spectrum is available in smaller chunks, making them non-usable. Such a situation may require reconfiguration to avoid fragmentation. This can require considerable coordination and cooperation. After reconfiguration, a full site/cluster audit needs to be carried out to understand new coverage, traffic distribution, and interference/quality.
  3. Some handsets and machine-to-machine devices cannot work with multiple bands or must remain on the old technology. This can be a big challenge when discontinuing the use of a legacy network.
  4. Once the spectrum is made available for use with the target technology, for example, refarming GSM to LTE, the spectrum needs to be cleaned up of external interference often caused by legacy signals left behind.
  5. Technology changes are difficult to predict by themselves, but it may be even more difficult to predict the time scales for commercial deployment of the emerging technologies (e.g. recent delays with the deployment of IMT-2020). This places particularly high pressure on spectrum management because a priori spectrum availability is usually demanded and seen as a necessary guarantee for investing into the development of new technologies. At the same time, the advance freeing up of spectrum may lead to inefficiency, if the new technology gets delayed or does not arrive at all. This once again reinforces the need for inherent flexibility of future spectrum management decisions.

# Different approaches for spectrum refarming[[5]](#footnote-5)

* 1. Spectrum redeployment may be used in several different ways but there are only two basic types: voluntary spectrum redeployment and regulatory spectrum redeployment.
     1. **Voluntary Spectrum Refarming**
  2. In this approach of spectrum refarming, the administration decides to implement spectrum refarming using methods that encourage an existing spectrum user to voluntarily decide to return the frequencies used to the spectrum manager for re-assignment. This process is done when an existing user determines that the benefits, they are gaining from using the spectrum are less than the costs of continuing to use it. If the spectrum needs to be recovered quickly, this method may not be suitable as it is likely to take time. Typically, voluntary spectrum refarming occurs when there may be an increase in license fees or an increase in license fees to coincide with the existing equipment needing to be serviced or replaced, or a new technology appearing that provides a better service than the existing equipment.
  3. An administration may decide to implement voluntary spectrum refarming for many reasons, including the monitoring of statistics on the use of a frequency band, e.g. if the number of users in a frequency band are decreasing nationally, or possibly regionally, or if there is a rapid turnover of users in the band. Such changes in the number of users may indicate that the existing service is either no longer desirable or there are problems of operation with that particular service. Noting that spectrum users may vacate a frequency band for many reasons and that in some frequency bands there may be only a limited number of users (either due to a large operating bandwidth or individual users having access to multiple frequency assignments in the band), the decision by a single user to leave a band may create an opportunity for the administration to consider future usage. If a frequency band became vacant, without any action by the administration, good spectrum management practice should mean the automatic reconsideration of the frequency band’s usage.
  4. When this spectrum refarming method is to be used as part of an identified administrative policy then it may need to be linked to a charging mechanism, e.g. license fees. To provide the greatest flexibility the charging mechanism also needs to be flexible. Hence this spectrum refarming method may be suitable for charging mechanisms like spectrum pricing, where the cost of the license can be linked to a wide variety of factors, e.g. coverage area, the extent of sharing, bandwidth, and hours of operation.
  5. Regulator could indirectly push existing occupants to initiate redeployment by raising spectrum price. This method may not be suitable if the spectrum needs to be recovered quickly. This method is a good way for technology improvement with aim of a better service than the existing equipment could provide. Since it is a voluntary refarming, an in-built advantage is that there is no expectation of governmental compensation by the spectrum users.
  6. One important factor influencing voluntary spectrum refarming is the adoption of technology-neutral approach (i.e. the telecom operator is free to decide the technology to be deployed in a spectrum band) for the assigned spectrum. Technology neutrality allows for license holders to evolve the technology deployed and the services delivered as markets develop. Many Regulators have adopted technology neutral principles. While implementing technology neutral approach in traditional technology specific frequency bands, refarming dying technology specific bands like GSM, CDMA, WiMAX etc. is a natural solution for mobile broadband coverage. If a country has adopted technology neutral approach, it becomes easier for the telecom operators to plan for migration from one technology to another. However, if the spectrum is not technology neutral, the telecom operators will have to come back to the regulator to redefine the technology for that particular spectrum band, which may result in delays and there is always some amount of uncertainty for the telecom operators. Thus, the telecom operator may not be able to deploy the spectrum for newer technology as per the market demand i.e. there could be a delay. Needless to mention, the newer wireless technologies are capable of having a strong positive impact on the economic growth of the country; thus, any delay in the launch of new technology also delays the economic development of the nation.
     1. **Regulatory Spectrum Refarming**
  7. This approach is most associated with an administrative policy to refarm spectrum. This method basically consists of the administration either terminating the license or refusing to renew the license. Early notification/publicity of the administration’s plans for the frequency band is essential to ensure that those affected will have the maximum time to plan alternative arrangements. There are three main categories under this refarming method, these are explained below.
* Spectrum refarming at the expiration of the current license
* Spectrum refarming at the end of the equipment’s lifetime or before the expiration of the license
* Refarming of spectrum in license-exempt bands

1. Spectrum Refarming at the Expiration of the Current License
   1. This approach currently appears to be the most common way of achieving spectrum refarming. The difficulty faced by the administration in applying the policy will depend on the length of the license term and the speed with which the administration wishes to recover the frequency band. If the period of the license is short (e.g. one or two years) or the administration knows sufficiently far in advance that it requires this spectrum, then recovering the spectrum may not be a problem. However, if the administration wants to recover the spectrum quickly, it may face claims for compensation depending on the terms and conditions of the licence, if:

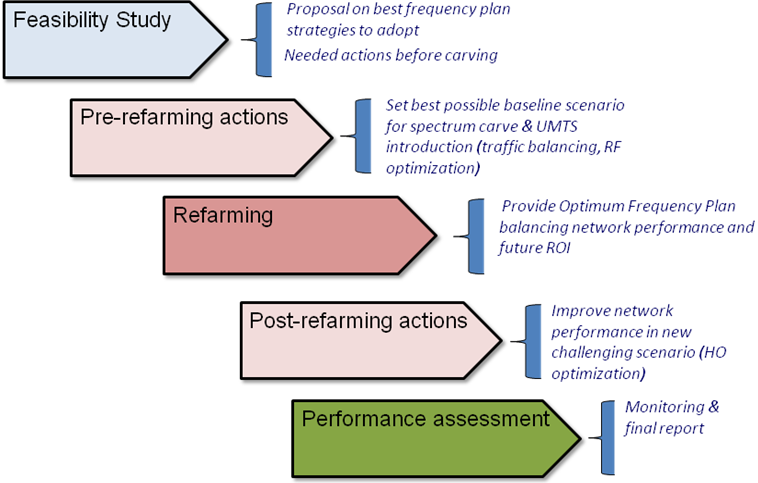
* the existing licence period is long (e.g. 10-15 years); or
* the licensee has purchased radio equipment based on an understanding that, even though the licence period is short, the licence will be renewed automatically.

1. Spectrum refarming at the end of the equipment’s lifetime or before the expiration of the licence
   1. This approach requires that the administration announce its intentions to redeploy the spectrum sufficiently far in advance of the date on which they propose to reclaim the frequency band. To minimize difficulties, the administration could wait until the end of the equipment’s lifetime. However, the lifetime of equipment differs from service to service and for some systems, such as military equipment, updating technologies are used which further prolong the lifetime of equipment. For cases where the operational lifetime of the equipment is unacceptable, compared to the period the administration has set to recover the spectrum, it may be necessary for the administration to agree with the users a fixed lifetime for the equipment or impose a cut-off date; potentially giving rise to claims for compensation.

* Administration: Far advance announcement of redeployment.
* Due to non-certainty in lifetime of equipment, a fixed lifetime shall be set and then compensation may get necessary

1. Refarming of spectrum in license-exempt bands
   1. By definition there are no records of users and their application of services used in license-exempt bands. It would be impossible to contact all users to notify them of refarming bands, and this prevents the band from being emptied of incumbent users.
   2. Considerations for new assignments or allocations of license-exempt bands should take account of the legacy from assigning license-exempt services if the bands are later to be the subject of refarming plans.

# Spectrum Refarming Framework



*Figure..Spectrum migration solution overview*

* 1. **Feasibility study:** The main target of this phase is to evaluate if the migration can be done within the acceptance criteria (i.e. agreed KPI levels for amount of spectrum to be released). The first task is to define the required spectrum reduction, typically dependent on the following factors:
* Operator restrictions
* Maturity of the network
* Expected traffic growth
* Network evolution
  1. **Pre-refarming actions:** In this phase, using output from the feasibility study, a complete set of actions will be proposed in order to establish the best baseline scenario for the implementation of a new frequency plan after the spectrum carving. These actions typically include RF optimization and RRM optimization. There are several functions that can be used to aid in the achievement of the objectives (capacity, interference and traffic management). These functions will reduce the interference levels or improve the network’s ability to cope with the increased interference.
  2. **Frequency plan elaboration & implementation:** In this phase, the final frequency will be implemented guided by the strategies defined in the previous phase. This phase includes the following parts:
* Frequency plan
* Updated neighbour list
* Fall-back plan
  + Fall back to the previous frequency plan
  + A fast-reactive process to identify & troubleshoot the worst performing sectors
  1. **Post-refarming actions:** The second round of optimization actions may be proposed after the implementation of the re-farmed frequency plan. In order to understand the real scope of this phase, a performance analysis must be carried for two main reasons:
* Ensure no severe degradation is present post-re-farming. If this is the case, then a fall-back plan will be auctioned.
* Acknowledge the necessary actions to be carried out in order to meet the agreed acceptance criteria.
  1. **Performance assessment:** After implementation, the network will be monitored mainly through the OSS-based tool. Other tools may be also utilized for specific monitoring tasks.

# Possible Technical Methods to Re-Arrange Existing Technology Specific Spectrum Bands[[6]](#footnote-6) and support the migration

* 1. This section discusses the different technical methods that can be used to change the re-arrange existing technology specific spectrum.

1. **Multi-RAT frequency resource allocation**
   1. Two frequency allocation modes are available, depending on the operator’s spectrum resource usage: edge frequency allocation and sandwich frequency allocation. These schemes are depicted in Figure shown below.

**UMTS**

**GSM**

**GSM**

**Other**

**Operator**

GSM BCCH

UMTS

GSM non-BCCH

**UMTS**

**GSM**

**Other**

**Operator**

*Figure. Multi-RAT frequency allocations*

Edge frequency allocation

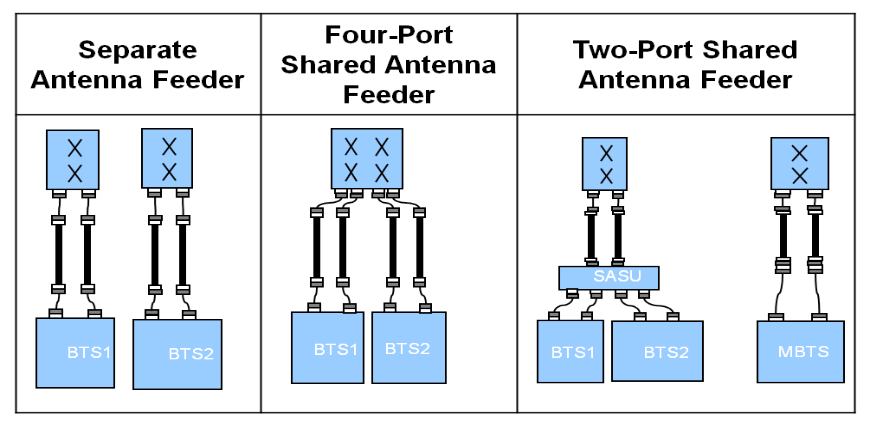
* 1. The UMTS/LTE and GSM systems are arranged side-by-side and maintain standard central frequency separation from the UMTS/LTE and GSM of other operators.

Sandwich frequency allocation

* 1. Within the frequency band of an operator, the UMTS/LTE is arranged in the middle with the GSM on both sides. If the operator has abundant frequency resources, it may allocate a second UMTS carrier or bigger bandwidth LTE as network services expand. At this point, the UMTS/LTE can be arranged at one side of the operator's frequency band for asymmetric sandwich allocation. The GSM spectrum at the other side is as wide as possible, and thus the UMTS/LTE planned does not require adjustment, which facilitates smooth capacity expansion.
  2. For the single sided method, only one additional guard band is needed while in the sandwich allocation two additional guard bands are needed. The sandwich allocation does not require the consideration of interference with the systems of other operators.

1. **Bufferzone solution**
   1. In the case of GSM and UMTS/LTE co-channel interference, a space separation is required to reduce the co-channel interference. Areas with UMTS/LTE networks deployed and their peripheral areas form a band-type area. In this area, GSM networks cannot use frequencies overlapped in UMTS/LTE frequency spectrums and therefore GSM network capacity decreases. A large space separation for co-channel interference decreases impacts of GSM and UMTS/LTE co-channel interference on network performance. For space separation for co-channel interference, buffer zone planning solution is based on emulation and onsite traffic statistics to accommodate different scenarios.
2. **Multi-RAT antenna solution**
   1. After GSM re-farming, UMTS/LTE networks deployed may use three antenna feeder solutions, as shown below:

* Separate antenna feeder solution
* Four-port shared antenna feeder solution
* Two-port shared antenna feeder solution



*Figure: GSM and UMTS/LTE antenna feeder solutions*

* 1. The three antenna feeder solutions are different in deployment scenarios and requirements for investment and performance. Here BTS1 and BTS2 are employed different RATs, and MBTS is the MSR BTS.
  2. More and more operators would like to use multi-port and multi-band antenna, there will be only one antenna in one cell.
  3. It could be better to modernization of the hardware if refarming is performed. i.e. use multi-standard products able to operate in mixed mode, which can both improve receiver sensitivity at the BTS and remove the need for combiners, reducing the signal loss.

1. **Power sharing between GSM/UMTS or GSM/LTE**
   1. With mixed mode GSM/UMTS or GSM/LTE base station, UMTS High Speed Downlink Packet Access (HSDPA)/LTE cells can share the idle carrier power provided by the GSM cells. Thanks to the intelligent power management, GSM power control features and behavior of GSM traffic bursts, the GSM cells can be configured with more total power than what is nominally available, without degrading KPIs. This means that UMTS/LTE can be configured to a higher power level, thereby letting GSM have a smaller portion of the total available power, while still keeping the GSM coverage and capacity. The power sharing and retrieval help improve the power usage efficiency and the UMTS/LTE network quality when busy hours of the GSM and UMTS/LTE networks fall in different periods or different positions.
2. **Spectrum sharing** 
   1. In areas with both GSM and UMTS/LTE coverage, the spectral resources can be shared with GSM network and the UMTS/LTE network based on the service load on both networks. This sharing mechanism improves spectral efficiency. Some of the idle GSM spectral resources can be shared with the UMTS/LTE network when the service load on the GSM network is below a specific threshold. When the service load on the GSM network is above a specific threshold, the GSM network reclaims the shared spectral resources. UMTS/LTE has higher spectral efficiency than GSM. Therefore, the network throughput can be increased and the composite costs of data services can be reduced with spectrum sharing between GSM/UMTS or GSM/LTE.
   2. With latest wireless iteration of wireless technology i.e. 5G coming in, dynamic spectrum sharing can be used to achieve gradual refarming also termed as soft refarming from LTE to 5G. For the telecom operators already offering LTE services, dynamic spectrum sharing is the best proposition. Dynamic Spectrum Sharing is a spectrum sharing technique that can be used for the deployment of 5G technology in a band in which the existing 4G technology is already deployed. In this method, the entire spectrum is used jointly by both the technologies and the spectrum is allocated dynamically to 4G (LTE) and 5G (NR) based on instantaneous traffic in the cell. By this method, we can introduce 5G in the existing 4G bands without any hard/static refarming of spectrum. In this way, the Dynamic Spectrum Sharing will allow “soft re-farming” to 5G New Radio with minimal impact on LTE performance. It results in better spectral efficiency also.
3. **Tight frequency reuse**
   1. The 1/1 or 1/3 RF hopping solution can be adopted to achieve a tighter frequency reuse. In this case, interference suppression technology should be applied in conjunction with conventional power control and DTX. Interference planning based on network synchronization can also be utilized.

# Compensation for Frequency Band Redeployment

* 1. The radio spectrum is an asset that belongs to the country and not to individual groups of spectrum users. Payment of compensation should not be de facto policy, but if it is to be provided it is advised that administrations have the appropriate policies for compensation and competition restrictions that comply with national legislation and international bodies like the World Trade Organization (WTO). Compensation does not only have to be given in the form of a direct financial payment; for example it could take the form of licensing assistance (trial licenses) or equipment subsidies. The correct level of any compensation and how it should be provided can be a difficult task depending on:
  + the spectrum rights provided by the administration when they issued the license;
  + the spectrum rights retained by the administration;
  + the time-scales for completion of spectrum redeployment;
  + the proposed method of compensation.
  1. Potential Sources of Compensation could be

**Compensation by New Entrant**: The administration does not have to fund any compensation. It can speed up the release of spectrum only when the new entrant requires it. One way of its implementation could be through spectrum trading. The new entrants may have to pay less or more than the market value for the spectrum. However, for transparency, a clear mechanism for trading or handling payments, the process should be defined.

**Redeployment Fund**: It may facilitate for implementing redeployment in a shorter time-scale than waiting for the expiry of a license. Sources for redeployment fund could be entry fee paid by the telecom operators, license fee, spectrum pricing fee, etc. It is necessary to clearly identify the conditions under which any compensation may be paid. However, redeployment funds may not be sufficiently strong to pay for redeployment in other than limited cases. Further, it may raise political and judicial issues.

# Consequences of Spectrum Refarming

* Spectrum refarming cause varying of spectrum plan and associated frequency plan.
* It may cost existing users to move operation to new spectrum or change of radio units (RU).
* End-users of migrating old networks may need to change terminals.
* Considerable amount of evacuated bandwidth may remain unused if new network delay in spectrum utilization.
* Subscribers of delaying operator may move to the new network of re-farmed operator in a competitive market.
* Quality of delivered services by the network under re-farming may degrade and consequently the number of subscribers of operators may drop.

# Summing-up

* 1. The radio spectrum is a finite, but a reusable resource that can benefit each administration by providing a medium to assist communications and economic development. In order to maximize the benefits to an administration, the radio spectrum needs to be efficiently and effectively managed. Part of efficient and effective spectrum management is planning the development of radio services in advance of their requirement; this may include extending the coverage of existing services, enhancing the performance of existing services and introducing new services.
  2. Mobile network operators are required to use the existing spectrum resources from GSM and UMTS to LTE in the most efficient way, so to accommodate new radio technologies by reassigning spectrum resources.
  3. Spectrum refarming should be included in the administration’s national spectrum strategy together with the mechanism identified to assist implementation of refarming. It should be considered equally with all other options, i.e. sharing, removing restrictions, and not as a last resort.
  4. Adopting the right approach to spectrum refarming is important to enable smooth implementation of a new spectrum plan.
  5. Spectrum used for one purpose/technology, need to be used for other Services, Technology, Users. Adoption of technology neutral approach allows for license holders to refarm spectrum bands as needed.
  6. Regulators should facilitate clearing of globally harmonized IMT bands well ahead of market needs to provide certainty to CSPs who need to identify strong business cases, seek appropriate funding from internal governance processes, and award contracts to vendors and service partners.

# Chapter 3: Case Studies of Successful Re-Farming

# FRANCE

1. The 900 MHz and 1800 MHz bands in France have historically been used for providing2G mobile services using GSM technology. As 2G networks approach the end of their natural life, France – in common with all European countries –considered options for refarming these frequency bands for new mobile technologies.
2. France presented a success story of operator-driven refarming of the 900/1800 MHz[[7]](#footnote-7). The refarming process that emerged subsequently has a number of notable features:

* Refarming in France is operator driven i.e. all existing 2G spectrum licenses were renewed which were scheduled to expire in 2006.  Operators decide when to apply to have their licenses changed to allow for deployment of new technologies. ARCEP-French NRA launched a public consultation in July 2003 to initiate the renewal process.
* ARCEP has a policy of promoting equitable spectrum holdings across operators, and this is reflected in the refarming processes.  Once an operator applies to refarm spectrum in a 2G band, this triggers a formal review of spectrum holdings in that band, which may result in redistribution of spectrum between operators.   Reflecting this policy, the process of refarming has been closely linked to the licensing of a fourth mobile operator, a process that was completed in January 2010 with the entry of Illiad Free Mobile.
* ARCEP levied fee plus tax on sales for renewal on the new 3G licensees. Renewal applied for 15 years from March 2006. License obligation and rollout were imposed for renewal (NERA, 2011).
* The refarming process was not technology neutral.  All decisions prior to 2009 focused on reuse of 2G spectrum for 3G (UMTS) services. Refarming in the 1800MHz band was not implemented as none of the incumbent operators requested at that time. Following the adoption of the 2009 EC Directive and Decision and its 2011 modification into French law, the existing framework allows for the introduction of LTE in the 900 MHz and 1800 MHz bands.

1. In 2013, ARCEP made two decisions. Firstly, authorizing its mobile operators SFR (Société française du radiotéléphone) and Orange France for refarming the 1800MHz[[8]](#footnote-8) band for LTE use from 25 May 2016, if they give some of the spectrum to smaller operator -Free Mobile. Another decision is allowing Bouygues Telecom to start offering 1800MHz LTE from 1 October 2013, while the 5MHz of spectrum it returned was awarded to Free Mobile in December 2014. ARCEP processed this refarming to ensure equality between operators and the conditions for effective competition in the mobile market. At the end, three largest operators (Orange, SFR and Bouygues Telecom) each holds 20 MHz, while smaller rival Free Mobile has 15 MHz.

**Redeployment fund**

1. The concept of a redeployment fund to compensate spectrum users for having to hand back spectrum was introduced in France. This approach provides several possibilities for implementing redeployment in a shorter time-scale than waiting for the expiry of a license. A re-deployment fund can be funded from several different sources for example: a) the new entrants could pay into the fund collectively, b) all license holders could pay via part of the license fee, c) spectrum pricing fees could be transferred to the redeployment fund or d) fees from auctioning of licenses or frequency bands could be transferred to the redeployment fund. While a redeployment fund can provide a convenient means to speed up the spectrum redeployment process, it is not a universal remedy. Redeployment funds may not be sufficiently strong to pay for refarming in other than limited cases. The fund will need to be managed and there may be concerns over transparency. Therefore, evaluation of the various cost elements and redeployment principles; a schedule for the redeployment operation; the supervision of the procedure and managing the redeployment fund are the important tasks which need to be carried out by NRA (ITU-R SM.1603-2, 2014)

**Spectrum refarming procedure for decision-making[[9]](#footnote-9)**

1. In France, the spectrum refarming procedure involves evaluating the cost of the refarming operations and the management of a fund needed to finance these operations. The approach is pro-active since it requires the participation of all parties concerned for modifying the assignment of frequencies or the allocation of services.
2. State plays the role of intermediary by financing out of its own budget for the refarming work and may require subsequent reimbursement of the sums advanced from the new users once they have obtained their frequencies. The intermediary role played by the State makes it possible to anticipate the move.
3. Refarming enables the spectrum manager to meet demands in the radio sector and to observe the timetable laid down for the availability of frequencies to newcomers. Its costs are broadly offset by the increase in the community surplus. Thus, refarming emerges as a dynamic method of spectrum management that aims to maximize the welfare
4. The community as a whole must derive sufficient benefit from a refarming of radio frequency bands to merit the granting of authorization. This benefit is reflected, in economic terms, through a maximization of the community surplus. In other words, one must reach an equilibrium point such that no other use of the spectrum can improve the community surplus
5. In seeking this equilibrium point it is useful to compare the preferences (utilities) of the various players involved. Their utility functions are expressed in terms of private value and social value for the community. The private value corresponds to the profits they can derive from the use of the frequency bands, whereas the social value corresponds to the importance of the service to society at large. The calculation of private value is fairly simple, whereas quantifying the social value is relatively complex. It is possible to call on the notion of "opportunity" in trying to evaluate the social value of the service, in other words by calculating what the absence of the service would cost the community.
6. As regards the process of spectrum refarming, it is necessary to compare the utilities in terms of private value and social value of the agent being asked to relinquish the frequency bands and of the incoming agent.
7. Let Uoutgoer and Uincomer denote the respective utilities (comprising the private and social values) of the operator leaving the spectrum and the operator who replaces him. Let Cremoval denote the spectrum refarming cost for the outgoer

If Uincomer>Uoutgoer + Cremoval>> the removal is socially and economically optimal

If Uincomer<Uoutgoer>> the removal is not socially and economically optimal

If Uoutgoer<Uincomer<Uoutgoer + Cremoval>> a choice has to be made

# GERMANY

1. Refarming the 800MHz[[10]](#footnote-10) band in Germany was aimed at using the spectrum as a means of providing universal broadband access across the rural areas of Germany which was driven by the government broadband strategy. However, the refarming process was complicated due to the separation of regulatory responsibility between the broadcasting, which is undertaken by Federal States (Bundesländer), and licensing of spectrum for electronic communications services, which is undertaken by the national government and the NRA-BNetzA.
2. In June 2009, the Federal States adopted the national government’s proposals. The 800 MHz band was awarded in May 2010 in a combined auction with spectrum in the 1800MHz, 2.1GHz and 2.6GHz bands, resulting in a total of 360MHz of spectrum being auctioned together. A significant coverage obligation is one key aspect of the license for 800MHz spectrum which had to be met by 2016. The mandated coverage was specified in rural areas of each Federal State, prior to the deployment of such services in the main cities to ensure that the citizens in these rural regions had access to high-speed Internet services. The auction revenue of 800 MHz band was counted as over 80 percent of the total auction revenue. As illustrated by the bidding price, it is considered that 800MHz is an important frequency band for mobile services. Some of auction revenues were divided to the Federal States which reflected as a compensation fee for refarming.
3. The 1800 MHz band is allocated to cellular services. For years, GSM technology is deployed in this band but nowadays Mobile Network Operators (MNO) are refarming their 1800 MHz[[11]](#footnote-11) frequencies to launch 4G LTE. T-Mobile Germany covers the rural areas with LTE800 and the populated areas with LTE1800. The spectrogram from Munich shows how T-Mobile refarmed their GSM frequencies and deploys a LTE network with a 20 MHz bandwidth.

# AUSTRALIA

1. In Australia[[12]](#footnote-12), the Radiocommunications (Spectrum re-allocation) declarations (Declaration No.1 of 2011 and No.2 of 2011) related to the 700 MHz band and 2.5 GHz were proposed by Australian Communications and Media Authority (ACMA).
2. Both bands were allocated for issuing a spectrum license. However, there were several different licenses actively operating in these frequency bands. The mechanism used to clear the services in each band depended on the type of license.
3. The 700 MHz band was occupied by the commercial, national or community television broadcasting and low interference potential devices. ACMA made alternative bands available for the apparatus license in 2.5GHz to relocate to. Cancelling all the licensees made the spectrum free for new uses, especially wireless access services.
4. ACMA auctioned spectrum in the 700 MHz and the 2.5 GHz band to new licensees using a combinatorial clock auction (CCA) format in April 2013. Four applicants (Optus, Telstra, TPG Internet and Vodafone Hutchinson Australia (VHA) applied to participate in the auction. However, VHA withdrew before the auction. The residual 700 MHz band spectrum from the 2013 digital dividend auction was auctioned in 2017. All lots were sold to two successful bidders which are TPG and Vodafone Hutchinson Australia (VHA).
5. In November 2015[[13]](#footnote-13), the ACMA released its Long-term strategy for the 803–960 MHz band decision paper, signalling an end to the review of this band and commencement of a long-term implementation plan to put those decisions into effect. One of the key decisions arising from the review was that 2 x 15 MHz of 4G-standardised spectrum will be made available for new mobile broadband services from 2024. This spectrum is known as the 850 MHz ‘expansion band’, which is lower adjacent to the current 850 MHz 3G band used by Telstra and Vodafone Hutchison Australia. In September 2019[[14]](#footnote-14), ACMA released its Five-year spectrum outlook for the period 2019–23 and in the replanning stage, it is mentioned that the 850 MHz expansion band (809–824 MHz and 854–869 MHz) is being cleared progressively. The ACMA continues to consider options for optimising its use. Allocation timeframes are tied to those of the 900 MHz band.

# SWEDEN

**900 MHz band**

1. The first phase of the Swedish 900 MHz band restructuring process was about renewingincumbent’s licenses and granting them some additional bandwidth. Assignment of some additional bandwidth were possible after the band was expanded from 2X30 MHz to 2X35 MHz. PTS (Swedish Post and Telecom Authority) concluded continued use for securing GSM services being offered and renewing the incumbent’s licenses were the most efficient use of the 900 MHz band resources[[15]](#footnote-15).
2. The second phase of the Swedish 900 MHz band restructuring process was about two incumbent operators each transferring 2X2.5 MHz of spectrum to the mobile operator without access to 900 MHz band spectrum and then the five 900 MHz band licensees engaging in swapping spectrum to reconfigure the band for contiguous spectrum for each licensee based on the band being divided into seven blocks of 2X5 MHz. HI3G became the fifth 900 MHz band licensee controlling 2X5 MHz of bandwidth through the secondary market transaction. The transaction was given approval of the PTS after they had concluded that the transaction was likely to enhance competition in the Swedish market. In the process of reconfiguring the 2X35 MHz 900 MHz band all four incumbents had to move spectrally and consequently engage in adjusting their existing networks etc.
3. The third phase of the Swedish 900 MHz band restructuring process was to lift the GSM technology restrictions simultaneously when the reconfiguration of the band was finalized.
4. From 24 May 2011 technology choices and the incumbents timing for implementing their technology upgrades are commercial decisions subject to the requirements on coordinating with the spectral neighbours to manage interference risks
5. Probably the most unique component of the Swedish 900 MHz band restructuring process was the initiative of the four incumbents and the existing mobile operator without 900 MHz band spectrum when they discussed and developed a consensus proposal, used for submitting a joint application to the PTS, for the four incumbents to renew their licenses and for two of them to engage in the spectrum trading transaction which introduced the fifth 900MHz band licensee in Sweden. PTS encouraging the mobile operators to engage in developing consensus and using voluntary approaches and market-based tools is also something that characterizes the Swedish 900 MHz band restructuring process between 2008 and 2011.

**1800 MHz band**

1. The Swedish 1800 MHz[[16]](#footnote-16) band restructuring process comprised prolonging the existing 1800MHz band licenses for a couple of years allowing the incumbents to adjust to changes, renewal of incumbents licenses but with reduced bandwidth per licensee and an auction of2X35 MHz bandwidth that was supposed to be vacant. The renewed licenses and the licenses sold in the 2011auction entered into force by 1 January 2013 and at the same day the usage rights became more technology neutral so 1800 MHz band licensees can deploy mobile technologies that can technically co‐exist (with the existing GSM deployments).
2. The renewal of the incumbents 1800 MHz band licenses did mean 2x40 MHz of 1800 MHz spectrum was being vacant by 1 January 2013. Since publishing its consultation on renewing the incumbents licenses in December 2009, PTS had made their intention to auction off the vacant spectrum known to the public. In parallel, with the renewal of licenses process, PTS prepared and consulted all interested parties on the upcoming 1800 MHz band auction.
3. In August 2011 PTS approved a secondary market transaction of two of the three incumbent licensees who had received a renewed license transferring their licenses effective from 1 January 2013 to a commonly owned network company they had established. This transaction paved the way for this commonly owned company also being the registered bidder in the 1800 MHz band auction a couple of months later.
4. The terms and conditions of the renewed licenses and of the terms and conditions attached to the licenses sold in the auction were based on a more technology neutral approach and a service neutral approach. The licenses entering into force effective 1 January 2013 allowed for deployment of mobile technologies that can co‐exist with the existing GSM deployments. Consequently, the Swedish 1800 MHz band licensees were permitted to use their usage rights for deploying e.g. GSM/EDGE/GPRS, UMTS/HSPA and LTE from 1 January 2013.

# DENMARK

1. The National IT and Telecom Agency (NITA) carried out the Danish 900 MHz and 1800 MHz band refarming in the same process and by using the open and transparent approach of public meetings, publicly available information notes, public consultation and making its final decision documents public.
2. The Danish 900 MHz and 1800 MHz band refarming process consisted of redistribution of spectrum to accommodate new entry licensees in both bands, reshuffling of existing licensees meaning all operators had to spectrally move their current operations, lifting technology restrictions and adjusting to a more technology neutral approach to license design and adjusting expiry dates of existing licenses.
3. In the 900 MHz band NITA basically made no changes to the total bandwidth of the operators - TDC and Telenor, while Telia’s bandwidth was reduced leaving the three existing licensees with 2x9 MHz contiguous bandwidth for TDC and Telenor and2x11.8 MHz contiguous bandwidth for Telia. All existing licensees were spectrally moved. Existing licenses were expiring in 2011 or 2012 prior to the refarming decision but NITA did prolong and synchronize the duration so that all existing licenses expire by end of 2019 and NITA made it clear that there will be no renewals and only new awards when prolonged licenses expire by end 2019. NITA also decided to remove existing guard bands between licensees (but not guard bands at the edges of the 900 MHz band) and ended up with freeing up 2x5 MHz contiguous bandwidth for a new license to be auctioned off.
4. In the 1800 MHz band NITA made no change to bandwidth of operator Telenor while operators Telia and TDC’s bandwidth was reduced leaving the three existing licensees with2x19.4 MHz contiguous bandwidth, 2x23.6 MHz contiguous bandwidth and 2x21.8 MHz contiguous bandwidth respectively. All existing licensees were spectrally moved. Existing expiry date was basically not changed; licenses would have been expired by June 2017 and NITA made it clear that it will be no renewals and only new awards when licenses expire by 2017. NITA ended up with freeing up 2x10 MHz contiguous bandwidth for a new license to be auctioned off.
5. Existing licensees were given approximately one year to carry out their re‐planning and accomplishing the process of spectrally moving transmitters. The GSM only technology restrictions were lifted and replaced with conditions on deployment of GSM and technologies than can coexist with GSM, e.g. UMTS/HSPA and LTE can be deployed. NITA implemented rules on timing of the lifting of the technology restrictions aiming at creating competitive playing level field for all licensees, existing licensees and the new entry licensees into the bands, regarding when new technologies can be deployed[[17]](#footnote-17).

# THE UNITED STATES

1. In the United States, regulatory responsibility for the radio spectrum is divided between the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA). The FCC, which is an independent regulatory agency, administers spectrum for non-Federal use (i.e., state, local government, commercial, private internal business, and personal use) and the NTIA, which is an operating unit of the Department of Commerce, administers spectrum for Federal use (e.g., use by the Army, the FAA, and the FBI). Within the FCC, the Office of Engineering and Technology (OET) provides advice on technical and policy issues pertaining to spectrum allocation and use[[18]](#footnote-18).
2. Major refarming[[19]](#footnote-19) in the US can be categorized into two events. First is the relocation of 1710-1755 MHz band for commercial use. The FCC discussed reallocating several bands for new advanced mobile and fixed communications services, including the 1710-1755 MHz band, which had been identified for transfer from Federal Government to mixed use in 1995, paired with the 2110-2150/2160-2165 MHz bands, which had been identified for reallocation by the Commission under its Emerging Technologies proceeding since 2001 (FCC, 2001a).
3. The main users of 1710-1755 MHz band were the government agencies. The relocation process started from March 2007 to December 2014. According to the Commercial Spectrum Enhancement Act (CSEA), the Spectrum Relocation Fund (SRF) provides a funding mechanism for relocation cost and authorizes it to be auctioned for commercial purposes. The Office of Management and Budget (OMB) were responsible for transferring relocation expenses from the SRF to agencies (OMB, 2007). United States Government Accountability Office (GAO) was directly involved for reviewing the costs to relocate federal spectrum users and revenues from spectrum auctions in order to ensure that auction revenues will be exceeded relocation costs and relocation cost estimation is a sustainable approach (GAO, 2013). In 2002, FCC designated the spectrum for Advanced Wireless Services (AWS) and the auction held in 2006 and 2008. The auction revenue was deposited back in the SRF in accordance with the CSEA (Prizker& Strickling, 2015). A portion of the auction proceeds was used to facilitate relocation of FCC systems.
4. Second refarming event is the relocation of 700 MHz band. In 2002, FCC re-allocated the 698-746 MHz band (Lower 700 MHz band) that was originally used by TV Channels 52-59. The upper band was for TV Channels 60-69 (FCC, 2001b). The lower band is 48 MHz while upper band is 60 MHz. Of the total 60 MHz, 24 MHz of the spectrum is reserved for public safety, while rest has beeen auctioned off. The U.S. House of Representatives approved a budget for analog switch-off in 2006. In March 2008, the FCC auctioned spectrum in the 700 MHz block, known as Auction 73, which had previously been allocated to analog television. Auction generated $19.6 billion in revenue, nearly double prior estimates and the highest amount for any U.S. spectrum auction (Eisenach, 2011).
5. During the relocation process, the FCC placed rules on public safety for auction (FCC, 2017) and introduced legislation to reallocate the spectrum from commercial to public safety use and to use the proceeds from and provide funding to support an interoperable public safety network.[[20]](#footnote-20)

Refarming of mid band spectrum for 5G[[21]](#footnote-21)

1. Considering that the lower 3 GHz band and the 3450 MHz to 3550 MHz portion of the band is emerging as spectrum to support 5G world over, in the year 2018, the federal government of the United States passed the Fiscal Year 2018 omnibus spending bill, which directed the National Telecommunications and Information Administration (NTIA) to work with the Commission on identifying sharing opportunities in the 3.1-3.55 GHz band and submit a report on the feasibility of “allowing commercial wireless service, licensed or unlicensed, to share use of the frequencies between 3100 MHz and 3550 MHz by March 2020.
2. NTIA announced that it had identified the 3.45-3.55 GHz band for study for potential repurposing to spur commercial wireless innovation. NTIA identified the top 100 megahertz in the 3.1-3.55 GHz band as the most promising portion for sharing in the near term, but it confirmed in July 2019 that it was conducting an assessment, in collaboration with the Department of Defense (DoD), on the feasibility of sharing in the entire 3.1-3.55 GHz band.
3. This band was being allocated on a primary basis for federal used such as radiolocation services, aeronautical radionavigation services. However, on secondary basis, there were non-federal radiolocation service allocations in 3.3-3.55 GHz as well as non-federal amateur allocations in the 3.3-3.5 GHz band.
4. In light of the NTIA’s ongoing study of the band for sharing, the Wireless Telecommunications Bureau in February 2019 imposed a freeze on accepting and processing applications for non-federal Radiolocation Service operations in the 3.1-3.55 GHz. The freeze was implemented to “maintain a stable spectral environment in a band that is under active consideration for possible alternative use.”
5. In December 2019, the Commission adopted a Notice of Proposed Rulemaking that proposed to clear non-federal secondary allocations from the 3.3-3.5 GHz band as a preliminary step toward potential future shared use between federal incumbents and commercial users of the band. It also sought comment on what alternative spectrum would be available for those non-federal incumbents’ future operations, what transition mechanisms would be appropriate, what the cost of relocating those secondary operations might be, if and how relocating operations should be compensated, and whether their secondary status should affect the extent or nature of their compensation for relocation. A large number of stakeholders filed comments supporting the proposal to remove the non-federal secondary allocations and operations from at least the upper portion of the 3.1-3.55 GHz band, including the radiolocation services licensees whose operations would be impacted. Many commenters also supported removing the allocations from the lower portion of the band. Several amateur radio operators opposed the removal of the secondary amateur allocation from the band. It was found that removing the existing secondary non-federal allocations from the 3.3-3.55 GHz band and clearing these non-federal operations from the band is in the public interest, and therefore this proposal was adopted.
6. NTIA released this feasibility study in January 2020, in which it found that, while commercial operations would impact incumbent federal systems, spectrum sharing that provides both sufficient protection to incumbent operations and attractive opportunities for commercial business is possible, subject to further analysis. In April 2020, NTIA’s research laboratory, the Institute for Telecommunications Sciences, published a summary report that presented data collected from a two-year effort to measure spectrum occupancy in the 3450-3650 MHz range. It was observed that at the locations with military presence, the measured occupancy of the 3450-3550 MHz band varied from 9% to 25% on an annualized basis. At the sites without significant military presence, occupancy averaged below 1%.
7. In 2020, the White House and the DoD formed America’s Mid-Band Initiative Team (AMBIT) with the goal of making 100 megahertz of contiguous mid-band spectrum available in the 3.45-3.55 GHz band for full commercial use. Under the agreement that was reached as part of the AMBIT study process, the DoD expects to enable commercial 5G systems to operate at full power throughout almost all the contiguous United States by (1) adjusting its concept of operations within the band; (2) coordinating network planning with new commercial operators in certain areas near the DoD’s operations; (3) periodically coordinating with new commercial operators for use of the spectrum during certain discrete time periods in specific areas; (4) relocating certain airborne systems out of the band; and (5) developing and deploying a supplemental radar capability which operates outside the band. The DoD would also require access to the spectrum during times of national emergency.
8. In June 2021[[22]](#footnote-22), the Commission adopted changes to its rules to make 100 megahertz of mid-band spectrum in the 3.45-3.55 GHz band available for flexible use. It allocated the 3.45 GHz band to add a co-primary non-Federal fixed and mobile (except aeronautical mobile) allocation and adopted technical, licensing, and competitive bidding rules for this service largely consistent with its rules for other flexible-use wireless spectrum bands. While the majority of incumbent Federal operations in this band will be relocated to alternate spectrum, some operations will continue and must be protected from harmful interference through a system of coordination in specific Cooperative Planning Areas and Periodic Use Areas, described in the Second Report and Order. In addition, the Commission requires non-Federal radiolocation operations in the band to sunset operations within 180 days after the grant of new flexible-use licenses and provides for reimbursement of reasonable relocation costs. Further, the Commission requires amateur operators in the band to cease operations within 90 days of the public notice announcing the close of the auction, while allowing these amateur operations to continue in the 3.3-3.45 GHz band pending future Commission action in that spectrum.
9. Adoption of the new Rules would allocate the 3.45-3.55 GHz spectrum band for flexible-use service, provide for coordination of federal and non-federal users and relocate non-federal radio-location use to 2.9-3.0 GHz and eventually end amateur use of 3.3-3.5 GHz.

# Chapter 4: Inputs from SATRC Member Countries

* 1. Before analysing and considering of refarming of spectrum bands in the SATRC member countries, it is important to know the spectrum bands currently being utilised for specific use. In order to carry out the study, a questionnaire was prepared and circulated to all the expert members of the SATRC Working Group on Spectrum for their inputs. The questionnaire aimed to seek the information and details about the various spectrum bands adopted for IMT services, spectrum assignment methodologies, plans for allocating new bands for IMT including 5G and details about adoption of spectrum re-farming in the country. The inputs received from the SATRC Member countries are analysed in this chapter. A copy of the questionnaire is placed at Annexure-I.

# Bands identified by ITU for IMT services

* 1. From the list of various bands identified by ITU for IMT services, the SATRC countries were requested to specify the bands adopted for IMT services. They were also to requested to specify if the assignment is made for services other than IMT services.
  2. The bands identified by ITU for IMT services are adopted majorly for IMT but different countries use them for different services. For example:
* Pakistan uses 2500-2570MHz (uplink), 2620-2690MHz (downlink) and 2496-2690MHz bands for Broad-casting. 703-748MHz (uplink) and 758-803MHz (downlink) are under re-farming. 3400 – 3600MHz is currently used for WLL. 24.25-27.5GHz and 37-40GHz bands are currently used for Backhaul but are identified for IMT 2020 as per decision of WRC 19.
* Afghanistan uses 824-849MHz (uplink) and 869-894MHz (downlink) for CDMA.663-693MHz (uplink) and 617-652MHz (downlink) is used for Analog TV Broadcasting. 26.5-29.5GHz, 24.25-27.5GHz, 37-40GHz bands are used for Fixed (P-to-P) links.
* Bangladesh uses 1850-1910MHz (uplink) and 1930-1990MHz (downlink) for IMT along with CDMA-WLL. 1695-1710MHz (uplink) and 1995-2020MHz (downlink) is used for Meteorological Aids along with Terrestrial and Satellite Component of IMT Band. 3300-4200MHz band is used for TD-IMT along with Satellite and other services.
* Bhutan uses 2500-2570MHz (uplink) and 2620-2690MHz (downlink), 2570-2620MHz, 2496-2690MHz for Fixed wireless. 4400-5000MHz, 26.5-29.5GHz, 24.25-27.5GHz, 37-40GHz are still undecided.
* Maldives uses 880-912MHz (uplink) and 925-960MHz (downlink) bands for providing 2G services. 2500-2570MHz (uplink) and 2620-2690MHz (downlink) is used presently for 4G and is being re-farmed for 5G. 1850-1910MHz (uplink), 1930-1990MHz (downlink) and 1920-1980MHz (uplink) is used for 4G/IMT. 3300-3800MHz has been allocated for 5G.
* Nepal uses 824-834MHz paired with 869-879 MHz for CDMA. 3400-4200 MHz has been allocated to Fixed Satellite Service however partially 3300 to 3800 MHz has been allotted to IMT. 37-39.5GHz is used for Microwave.
* India uses 806-824 MHz (uplink), 851-869 MHz (downlink) partly for radio trunking. 663-693MHz (uplink) and 617-652MHz (downlink) is used for non-IMT (DTT). 24.25-27.5 GHz is under consideration for IMT-2020.
* Iran uses lower part of 824-834MHz paired with 869-879 MHz for TV Broadcasting and higher for IMT. 832-862MHz (uplink), 791-821MHz (downlink) is currently used by TV Broadcasting on a primary basis, and partially for IMT on a secondly basis in rural areas.
* Sri Lanka and Iran use 703-748MHz (uplink) and 758-803MHz (downlink) for TV Broadcasting. 1695-1710MHz (uplink) and 1995-2020MHz (downlink) is used by fixed service. Currently 3400-3600 MHz band is used by FWA IMT and the rest is used by P2P links and FSS ES.
  1. The responses from the SATRC member countries received are tabulated below:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Uplink (MHz)** | **Downlink (MHz)** | **Duplex Mode** | **Purpose** | | | | |
| **Pakistan** | **Afghanistan** | **Bangladesh** | **Bhutan** | **Maldives** |
| 824 – 849 | 869 – 894 | FDD | IMT | CDMA | IMT |  |  |
| 880 – 915 | 925– 960 | FDD | IMT | IMT | IMT |  | 2G Service |
| 832 – 862 | 791– 821 | FDD |  |  |  |  |  |
| 703 – 748 | 758– 803 | FDD | Under Refarming |  | IMT |  |  |
| 663 – 698 | 617– 652 | FDD |  | Analog TV Broadcasting | IMT |  |  |
| 1920 – 1980 | 2110– 2170 | FDD | IMT | IMT | IMT |  | 4G/ IMT |
| 1850– 1910 | 1930– 1990 | FDD |  |  | IMT along with CDMA-WLL |  | 4G/IMT |
| 1710– 1785 | 1805– 1880 | FDD | IMT | IMT | IMT |  | IMT |
| 2500– 2570 | 2620– 2690 | FDD | Broadcasting | IMT | IMT | Fixed Wireless | Present 4G/ Refarming 5G |
| 2570 – 2620 | | TDD |  | IMT | IMT | Fixed Wireless |  |
| 2496 – 2690 | | TDD | Currently Broadcasting, however, identified for IMT |  |  | Fixed Wireless |  |
| 1432 – 1517 | | TDD |  |  | The band is designated to IMT systems under fixed and/ or mobile service.  Existing operations would be continued only until the band allocated for IMT purpose. |  |  |
| 1427– 1432 | | TDD |  |  |  |  |  |
| 1710 – 1780 | 2110 – 2200 | FDD | IMT |  | FD-IMT in the band 1710 – 1785 MHz paired with 1805 – 1880 MHz and 1920 – 1980 MHz paired with 2110 – 2170 MHz |  | IMT |
| 1695 – 1710 | 1995 – 2020 | FDD |  |  | Meteorological Aids along with Terrestrial and Satellite Component of IMT Band |  |  |
| 1427 – 1470 | 1475 – 1518 | FDD |  |  | The band is designated to IMT systems under fixed and/or mobile service.  Existing operations would be continued only until the band allocated for IMT purpose. |  |  |
| N/A | 1432– 1517 | SDL |  |  |  |  |  |
| N/A | 1427– 1432 | SDL |  |  |  |  |  |
| 3300– 4200 | | TDD | 3400 – 3600 currently WLL, however identified for IMT 2020 |  | TD-IMT along with Satellite and other services. |  |  |
| 3300– 3800 | | TDD |  |  |  |  | Allocated for 5G |
| 4400– 5000 | | TDD |  |  |  | Undecided |  |
| 1710– 1785 | N/A | SUL |  |  |  |  |  |
| 1920– 1980 | N/A | SUL |  |  |  |  |  |
| 26.5 GHz – 29.5 GHz | | TDD |  | Fixed (P-to-P) Links |  | Undecided |  |
| 24.25 GHz – 27.5 GHz | | TDD | Currently Backhaul but being identified for IMT 2020 as per decision of WRC 19 | Fixed (P-to-P) Links |  | Undecided |  |
| 37 GHz – 40 GHz | | TDD | As above | Fixed(P-to-P) Links |  | Undecided |  |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Uplink (MHz)** | **Downlink (MHz)** | **Duplex Mode** | **Purpose** | | | |
| **Nepal** | **India\*** | **Iran** | **Sri Lanka** |
| 824 – 849  824 – 840.5 | 869 – 894  869 – 887.5 | FDD | CDMA for 824-834MHz paired with 869-879 MHz | IMT | The lower part used by TV BC and higher part has overlap with row 2 below | IMT(LTE) |
| 880 – 915  880 – 915 | 925– 960  935 – 960 | FDD | IMT | IMT | adopted for IMT | IMT(GSM/LTE) |
| 832 – 862 | 791– 821 | FDD | IMT for 811-821 MHz paired with 852-862 MHz | Partly for radio trunking | Currently used by TV BC on a primary basis, and partially for IMT on a secondly basis in rural areas | - |
| 703 – 748 | 758– 803 | FDD | IMT | IMT | Currently used by TV BC | Broadcasting TV (Analog) |
| 663 – 698 | 617– 652 | FDD |  | Non-IMT use (DTT) | Currently used by TV BC | Broadcasting TV (Analog) |
| 1920 – 1980 | 2110– 2170 | FDD | IMT | IMT | adopted for IMT | IMT(3G/4G) |
| 1850– 1910 | 1930– 1990 | FDD |  |  | Not adopted | - |
| 1710– 1785 | 1805– 1880 | FDD | IMT | IMT | adopted for IMT | IMT(2G/4G) |
| 2500– 2570 | 2620– 2690 | FDD | IMT for 2300-2400 MHz | IMT | adopted for IMT | - |
| 2570 – 2620 | | TDD | IMT for 2500 - 2570 paired with 2620 -2690 MHz FDD, 2570-2620 MHz TDD |  | adopted for IMT |  |
| 2496 – 2690 | | TDD |  | Rows 9& 10 used | IMT(4G) |
| 1432 – 1517 | | TDD | 1525 MHz -1559 MHz paired with 1610 MHz-1660 MHz for GMPCS Services |  | Under re-farming |  |
| 1427– 1432 | | TDD |  | under re-farming |  |
| 1710 – 1780 | 2110 – 2200 | FDD | IMT for 1710-1785 MHz paired with 1805-1880 MHz in 1800 MHz Band and 1920-1980 paired with 2110-2170 MHz in 2100 MHz Band. |  | Rows 6 & 8 used | - |
| 1695 – 1710 | 1995 – 2020 | FDD |  |  | Used by fixed service | - |
| 1427 – 1470 | 1475 – 1518 | FDD |  |  | under re-farming | - |
| N/A | 1432– 1517 | SDL |  |  | under re-farming | - |
| N/A | 1427– 1432 | SDL |  |  | under re-farming | - |
| 3300– 4200 | | TDD | 3400-4200 MHz has been Allocated to Fixed Satellite Service However partially 3300 to 3800 MHz has been allotted to IMT. |  | Currently 3400-3600 MHz band used by FWA IMT. Rest of the band are used by P2P links and FSS ES |  |
| 3300– 3800 | | TDD | IMT | 3300-3600 MHz for IMT 2020 |  |  |
| 4400– 5000 | | TDD |  |  |  |  |
| 1710– 1785 | N/A | SUL |  |  | Row 8 used. | - |
| 1920– 1980 | N/A | SUL |  |  | Row 6 used. | - |
| 26.5 GHz – 29.5 GHz | | TDD |  |  | 27.5-29.5 GHz used by Fixed radio services (see below) |  |
| 24.25 GHz – 27.5 GHz | | TDD |  | Under consideration for IMT -2020 | 24.25-26.5 GHz used by P2P links and 26.5-27.5 GHz would be adopted for IMT |  |
| 37 GHz – 40 GHz | | TDD | Microwave (37-39.5GHz) |  | 37-39.5 GHz used by P2P links |  |

\*Access spectrum assigned through Auction process is technologically neutral. However, the TSP decides the technology to be used based on their requirement and eco-system development. The deployment status by the TSPs is mentioned above. Besides above, 2300-2400 MHz – TDD – being used for IMT (LTE deployment)

# Details of the bands allocated for IMT services in the SATRC countries.

* 1. The details of the bands allocated for IMT services as provided by the experts from the SATRC member countries are summarized in the table below:

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Country** | **Band**  **(MHz)** | **Uplink Frequency**  **(MHz)** | | **Downlink frequency (MHz)** | | **Band Plan (MHz)** | | **Which technology is currently deployed using this band** |
|  | **Afghanistan** | 900 MHz | 880-915 | | 925-960 | | 2x25 | | IMT- GSM |
| 1800 MHz | 1710-1785 | | 1805-1880 | | 2x75 | |
| 2100 MHz | 1920-1980 | | 2110-2170 | | 2x60 | | IMT2000-3G/UMTS |
| 2600 MHz | 2500– 2570 | | 2620 – 2690 | | 2x70 | | IMT-4G/LTE |
|  | **Bangladesh** | 880 – 915/  925 – 960 | 888.40-890.00 | | 933.4–935.0 | | 2x1.6 | | IMT-Technology Neutral |
|  | 890.00-895.20 | | 935.0–940.2 | | 2x5.2 | |
|  | 895.20-900.20 | | 940.2-945.2 | | 2x5.2 | |
|  | 900.20-907.60 | | 945.2-952.6 | | 2x7 | |
|  | 907.60-915.00 | | 952.6-960.0 | | 2x7.4 | |
| 1710 – 1785/ 1805 –1880 | 1710.0-1720.0 | | 1805.0–1815.0 | | 2x10 | |
|  | 1720.0-1737.4 | | 1815.0-1832.4 | | 2x17.4 | |
|  | 1737.4-1752.0 | | 1832.4-1847.0 | | 2x14.6 | |
|  | 1752.0-1767.6 | | 1847.0-1862.6 | | 2x15.6 | |
|  | 1767.6-1772.6 | | 1862.6-1867.6 | | 2x5 | |
| 1920-1960/  2110-2150 | 1925.0-1935.0 | | 2115.0-2125.0 | | 2x10 | |
|  | 1935.0-1945.0 | | 2125.0-2135.0 | | 2x10 | |
|  | 1945.0-1955.0 | | 2135.0-2145.0 | | 2x10 | |
|  | 1960.0-1970.0 | | 2150.0-2160.0 | | 2x10 | |
| 2300 | 2330-2365 | | | | 35 | | TDD-IMT |
| 2500 | 2510-2530 | | 2630-2650 | | 20 | | FDD-IMT |
|  | 2585-2620 | | | | 35 | | TDD-IMT |
|  | **Bhutan** | 900MHz |  | |  | |  | | GSM |
| 700MHz |  | |  | |  | | 4G LTE |
| 1800MHz |  | |  | |  | | 3G and 4G LTE |
| 2100MHz |  | |  | |  | | 3G |
|  | **India** | 700 MHz | 703 -748 MHz | | 758-803 MHz | | 28 | | Technology neutral band for all IMT technologies. Not yet sold. |
| (35 MHz has been earmarked for Access services) | | | |
| 800 MHz | 824-844 MHz | | 869-889 MHz | | 5 | | 4G/ LTE |
| 900 MHz | 890-915 MHz | | 935-960 MHz | | 8 | | Partial spectrum allocated administratively for 2G. IMT technologies 3G/ 4G/ LTE are deployed in large scale |
| 1800 MHz | 1710-1785 | | 1805-1880 | | 3 | |
| (55 MHz has been earmarked for Access services) | | | |
| 2100 MHz | 1920-1980 | | 2110-2170 | | 1 | | 3G/ 4G/ LTE |
| (40 MHz has been earmarked for Access services) | | | |  | |  |
| 2300 MHz | 2300-2400 MHz  (80 MHz has been earmarked for Access services) | | | | 40 | | 4G/ LTE |
| 2500 MHz | 2500-2690 MHz  (40 MHz has been earmarked for Access services) | | | | 41 | | 4G /LTE |
| 3300-3600 MHz | 3300-3600 MHz  (25 MHz spectrum (3400 MHz - 3425 MHz) is identified for ISRO’s use in Indian Regional Navigation Satellite System (IRNSS) | | | | Not yet auctioned | | |
|  | **Iran** | 900 | 880 – 915 | 925 – 960 | | |  | 2G/3G/4G | |
| 1800 | 1710 – 1785 | 1805 – 1880 | | |  | 2G/4G | |
| 2100 | 1920 – 1980 | 2110 – 2170 | | |  | 3G | |
| 2600 | 2500 – 2570 | 2620 – 2690 | | |  | 4G | |
| 1800 | 1880 -1900 | | | |  | DECT-WLL | |
| 2600 | 2570– 2620 | | | |  | 4G | |
| 3600 | 3400 – 3600 | | | |  | 4G | |
|  | **Maldives** | 700 | 703-748 | 758-803 | | |  | Policy Planned for Technology Neutral | |
| 900 | 880-915 | 902- 960 | | | 2x7.40,12 | 2G/3G | |
| 1800 | 1710-1760 | 1761-1830 | | | 2x40 | 3G/4G | |
| 2100 | 1920 – 1980 | 2110 – 2170 | | | FDD | UMTS, LTE | |
| 3600 | 3400 – 3600 |  | | | TDD | 100MHz assigned to SP | |
|  | **Nepal** | 700 | 703-748 | 758-803 | | | 2x45 | Policy Planned for Technology Neutral | |
| 800 | 811-821 | 852-862 | | | 2x10 | 4G/LTE | |
| 850 MHz | 824-834 | 869-879 | | | 2x10 | CDMA | |
| 900 MHz | 880-915 | 925-960 | | | 2x35 | 2G/3G | |
| 1800 MHz | 1710-1785 | 1805-1880 | | | 2x75 | 2G/4G | |
| 2100MHz | 1920-1980 | 2110-2170 | | | 2x60 | 3G | |
| 2300 MHz | 2300-2400 | | | | 100 | WiMAX, Technology Neutral | |
| 2600 MHz | 2500 - 2570 | 2620 -2690 | | | 2x70 (FDD) | Policy Planned for Technology Neutral | |
| 2570-2620 | | | | 45 (TDD) |
| 3300 MHz | 3300-3400 | | | | 100 |
| 3400 MHz | 3400-3600 | | | | 200 |
| 3600 MHz | 3600-3800 | | | | 200 |
|  | **Pakistan** | 850 | 824 – 849 | 869 – 894 | | | FDD | LTE\* | |
| 900 | 880 – 915 | 925 – 960 | | | FDD | GSM, UMTS, HSPA+, LTE\* | |
| 1800 | 1710 – 1785 | 1805 – 1880 | | | FDD | GSM, UMTS, HSPA+, LTE\* | |
| 2100 | 1920 – 1980 | 2110 – 2170 | | | FDD | UMTS, LTE\* | |
| 3600 | 3400 – 3600 |  | | | TDD | WiMAX, LTE\* | |
| **\*NOTE: The licenses are Technology Neutral.** | | | | | | | |
|  | **Sri Lanka** | 850MHz | 824-840.5 | 869-887.5 | | Band 5 | | 4G-LTE | |
| 900MHz | 880-915 | 935-960 | | Band 8 | | 2G-GSM and 4G-LTE | |
| 1800MHz | 1710-1785 | 1805–1880 | | Band 3 | |
| 2100MHz | 1920–1980 | 2110 – 2170 | | Band 1 | | 3G and 4G-LTE | |
| 2300MHz | 2300-2400 | 2300-2400 | | Band 40 | | 4G-LTE (Fixed) | |
| 2600MHz | 2500-2690 | 2500-2690 | | Band 41 | |

# Spectrum Assignment linked with service/ technology restrictions

* 1. The first part of the third question asked if the Spectrum assignment is linked with service / Technology restrictions in mobile spectrum usage rights.
  2. From the responses received, it is observed that in many of the SATRC countries the spectrum assignment has not been linked with service/ technology restrictions in mobile spectrum usage rights.
  3. In Pakistan, the licenses are Technology Neutral but not Service Neutral. (Fixed Mobile Convergence is expected under review of existing Licensing Framework). Pakistan implemented Technology Neutral Regime in 2003-04, however, all the incumbent operators at that time had to pay an equivalent amount to make their license and spectrum assignments technology neutral, which was paid by the new entrants in the market in 2004. In 2004, Telenor and Warid entered Pakistan Cellular market at the payment of USD 291 Million through an open auction process. Market determined price was paid by the incumbent operators to avail the benefits of the Technology Neutral Policy, and same obligations were placed on the incumbent operators as those of New Entrants to the market in 2004. For Bangladesh, India, Iran, Nepal and Sri Lanka the response is as follows:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S. No.** | **Band**  **(MHz)** | **Service/technology restricted** | **Is restriction still there? If no, provide the year till which restriction existed.** | **What regulatory procedure was adopted to remove this restriction, including any financial obligations on the licensed operators?** |
| **Bangladesh** | | | | |
| **1.** | 880 – 915/  925 – 960 | Previously restricted to GSM | No, in 2018 this restriction has been lifted and these band have been declared as ‘Technology Neutrality’ bands. | The licensees paid a fee to convert their spectrum into ‘Technology Neutral’ spectrum. |
| 1710–1785 /1805–1880 |
| 1920-1960/  2110-2150 | Previously restricted to UMTS |
| 2330-2365 | BWA(TDD-IMT) | Yes |  |
| 2510-2530  /2630-2650 | BWA(FDD-IMT) | Yes |  |
| 2585-2620 | BWA(TDD-IMT) | Yes |  |
| **India** | | | | |
| **2.** | 700 MHz | Bands assigned for mobile services are liberalized to offer any standard technology. |  |  |
| 800 MHz | Spectrum assigned through auction is liberalized i.e. TSPs are free to offer any access technology. |  |  |
| 900 MHz | Spectrum assigned through auction is liberalized i.e. TSPs are free to offer any access technology. However, technology restriction exists for some of the blocks assigned administratively earlier (prior to 2010) bundled with service license for offering the GSM (2G) services. | The technology restrictions for the administratively assigned blocks are still there. | Initially (before 2010), spectrum was assigned administratively for GSM services. The TSPs have been given a choice to get such administratively assigned spectrum liberalized (Technologically neutral) by paying the difference between market determined price and price already paid. |
| 1800 MHz |
|  | 2100 MHz | Bands assigned for mobile services are liberalized i.e. technology neutral | No restriction |  |
| 2300 MHz | No restriction |  |
| 2500 MHz | No restriction |  |
| 3300-3600 MHz | Bands assigned for mobile services is liberalized | No restriction |  |
| **Iran** | | | | |
| **3.** | 900 | Restricted to the mobile service | Yes, this restriction will remain until FMC(Fixed Mobile Convergence) implementation | Updating license of operators to achieve balanced provisions in operational and financial conditions related to mobile and fixed services (supported by market study) |
| 1800 |
| 2100 |
| 2600 (FDD) |
| 2600 (TDD) | Restricted to the fixed service | Yes, this restriction will remain until FMC(Fixed Mobile Convergence) implementation |
| 3600 |
| **Nepal** | | | | |
| **4.** | 2300 | Previously restricted to WiMAX | No, till 2018 | Technology Neutral Principle has been adopted upon request from operators and approval from NTA. and the pricing has been changed for technology neutral. |
|  | 850 | Previously restricted to CDMA | Yes | Plan to shut down CDMA by 2022 |
|  | 900 | Previously restricted to GSM | Yes, till 2016 | Technology Neutral (for 3G and 4G) has been adopted upon request from operators and approval from NTA and the pricing has been changed for technology neutral. Moreover, pricing for residual spectrum (technology neutrality) is subject to ongoing auction. |
|  | 1800 |
|  | 2100 | Previously restricted to 3G | Yes, 2016 |
| **Sri Lanka** | | | | |
| **5.** | 850MHz | 4G-LTE | Yes | **Not yet decided** |
| 900MHz | 2G-GSM and 4G-LTE | Yes |
| 1800MHz | 2G-GSM and 4G-LTE | Yes |
| 2100MHz | 3G and 4G-LTE | Yes |
| 2300MHz | 4G-LTE (Fixed) | Yes |
| 2600MHz | 4G-LTE (Fixed) | Yes |

# Regulatory procedures adopted like QoS Enhancements, Monitoring compliance, Interference related issues OR any other major or monetary obligations.

* 1. In Afghanistan**,** the operators are following the natural up-gradation paths to provide Mobile Broadband in their own assigned spectrum. New QoS enhancements and rollout (coverage) were adopted and are being monitored closely for compliance.
  2. In Bangladesh, usually the regulations regarding QoS Enhancements, Monitoring compliance, Interference related issues are mentioned in the License document awarded to the TSPs. Bangladesh, Iran and Bhutan regularly monitor whether the TSPs are following the standards or not. In addition, back in 2018, the Bangladesh Government issued a directive for ANS operators regarding the QoS that they have to maintain while providing the service[[23]](#footnote-23).
  3. In Nepal, Pakistan, Maldives and Sri Lanka, the Spectrum policy has been adopted with technology neutral principle. The technology neutral has been granted to some specific bands in Nepal based on the operator’s request having requirement of service roll-out plan for that band. Moreover, in Nepal technology based QoS obligation is in practice and the pricing is higher for technology neutral spectrum. With evolution of technologies and introduction of high speed MBB services, Pakistan adopted to introduce suitable QoS and Roll out obligations. In Maldives, the indoor coverage and QoS, becomes a challenge in capital Male’ due to fast pass of new concrete building.
  4. In Iran, a big change may happen in composition of market player due to the merger of converging smaller operators to compete with 5G-enabled operators. Monetary obligation (including revenue share and service tariff (probably)) is also move to a middle ground between mobile and fixed services.
  5. In India, TRAI had notified the Regulation on QoS of Basic and Cellular Mobile Telephone Services, 2000 vide Notification dated 5th July 2000. These regulations were subsequently reviewed in 2009. This main regulation has been amended seven times so far, latest amendment was issued in the year 2019. Amendments made time to time included revising (DL-PDR and UL-PDR) or redefining existing parameters (DCR) for network QoS or Customer Service Quality. Changes in parameters were also required to include requirements of new radio access technologies introduced in the mobile networks.

# If operators are awarded spectrum through Open auction, are they permitted to adopt any technology, which becomes available during the tenure of their license?

* 1. In Nepal, Afghanistan, India, Iran and Pakistan, the operators are awarded spectrum through Open auction they are permitted to adopt any technology, which becomes available during the tenure of their license. In Bangladesh, prior approval from BTRC is required to do so. In India, the spectrum is not bundled with the licence since 2011. To offer wireless services, the operator having license will have to obtain spectrum through a market-driven process.
  2. In Bhutan, open auction is not done yet.In Sri Lanka,the regulator decides the technology to be deployed before the assignment. In Maldives, the spectrum is assigned administratively.

# In the next 5 years, plans for allocating new bands for IMT services (including 5G)

* 1. In India, to take the advantage of 5G services for Digital India, the mid band (3.3-3.6 GHz) has already been identified for IMT and the millimeter band (24.25-27.5 GHz) is under active consideration for 5G services subject to co-existence studies and global deliberations.
  2. Pakistan is looking forward for frequency bands like 24.25 GHz and others for IMT 2020 (5G). Ministry of Information Technology and Telecom has issued a Policy Directive to conduct 5G Trials in Pakistan highlighting 2.6 GHz, 3.5 GHz and mm-Wave bands.
  3. Afghanistan has planned to award more spectrum under the technology neutral licensing regime through auction for providing IMT services in the frequency bands 1800 MHz, 2100 MHz, 2600 MHz.Iran has planned to allocate 700 MHz (694-790 MHz), 800 MHz (790-862 MHz), 1427-1518 MHz, 2300 MHz (2300-2390/2400 MHz), 3.3-3.4 GHz, 3.6-3.8 GHz frequency bands.
  4. Maldives has allocated 3.6GHz at present, and newly identified band for IMT 2020 in WRC 19, for 5G, 24.25GHz will be allocated if requirement arise.Sri Lanka is planning to assign 3.5GHz band for 5G.
  5. In Bangladesh, Nepal and Bhutan, the issue is still in planning stage and no plans are formally established yet.

# 3.5 GHz spectrum awarded for BWA services

* 1. In Iran, the frequency bands are used for Fixed Wireless Access (FWA) networks. Government of Pakistan and Bhutan has announced this band for 5G trials and testing. In Pakistan, 3.5 GHz band is assigned to Wireless Local Loop operators till 2024, however, Pakistan is working on the procedures for early vacation of these bands.
  2. In Nepal, India and Bangladesh this band is not awarded for any BWA services. In India, it was being earlier used for point to point or point to multi point microwave links, however, it has been now refarmed and has been identified as the prime band for IMT 2020 services in below 6 GHz category. The spectrum in the band is slated for auctions by DoT in near future.
  3. Maldives has assigned 3.5GHz to the service providers and one of the then have already implemented in capital Male’.
  4. In Sri Lanka and Afghanistan (3400 MHz- 3600 MHz), this band is previously assigned for Wi-Max service. In Afghanistan, two operators have been assigned a total of 30 MHz spectrum in the frequency bands 3400-3600MHz.

# Bundling of spectrum assignment and service license

* 1. In Bangladesh, the operators having service license can only apply for necessary spectrum. Technology neutral provision is applicable in 900 MHz, 1800 MHz and 2100 MHz band which can be used for 2G, 3G and 4G service/ technology.
  2. In Bhutan, India and Sri Lanka the spectrum assignment and service license are unbundled. In India, Prior to 2010, the spectrum was assigned administratively bundled with service license for offering the 2G or CDMA services and additional spectrum was assigned based on subscriber base linked criteria. From 2010 onwards, the spectrum has been unbundled from the license and is assigned through auction process. In Iran, at the time of introducing an operator for first time, CRA issues service license with the spectrum license simultaneously, but the amount of licensed spectrum would increase based on demand and market situation without renewing license.
  3. In Afghanistan, Nepal, Pakistan and Maldives, spectrum and service license is bundled. However, in Maldives, spectrum assignment is not charged. In Pakistan, the license is issued for right to use spectrum. In Nepal, as per spectrum policy 2016, the new entrant is also allowed to participate in the auction in new spectrum band 700 MHz and 2600 MHz and the winner of the Auction will be granted broadband service license.

# With the auction of more cellular spectrum in recent years, the existing operators are issued with a new license OR spectrum with some additional Terms and Conditions like QoS and Roll out (coverage) are added in the license?

* 1. In Maldives, Iran, Nepal, India, Afghanistan and Sri Lanka, there is no need to acquire a new license for an existing licensee, every time the spectrum is won through auction, however, the existing operations are provided with new terms and conditions like QoS, Roll out etc.In India, as any eligible non-licensed entity can also participate in auction, the new entities will be required to obtain requisite service license for provision of service. The conditions are prescribed specifically by DoT through the respective Notice Inviting Applications (NIA) published for conducting the auctions and consequent to introduction of new technology / services, TRAI issues QoS parameters separately as the need arises to review the existing parameters.
  2. In Bhutan, Cellular spectrum has never been auctioned till now.
  3. In Pakistan and Bangladesh, usually a new license is issued every time a new spectrum was awarded for cellular services with new QoS and Roll Out obligations. In Pakistan, however, this practice is under review.

# Method of Spectrum Assignment (Administratively/ auction/ any other method)

* 1. Maldives issues frequency Spectrum to the service providers administratively.
  2. In Nepal, Pakistan (Cellular and BWA licenses), Bangladesh and India (access spectrum assignment) currently, the spectrum is assigned via auction.
  3. In Sri Lanka, depending on the spectrum demand and availability, the assignment method will be selected. Previously administrative and auction methods were used.
  4. In Afghanistan and Iran both are used. In Iran, it depends on market situation and "temperature" of frequency band.
  5. Bhutan uses first come first serve. The application of the TSPs is reviewed and the spectrum is assigned accordingly. But enough spectrum is reserved for future operators.

# Duration of Spectrum Assignment to the mobile operators

* 1. The duration of spectrum assignment varies from 10 to 20 years. In Maldives, Pakistan, Afghanistan, Bangladesh it is for 15 years. In Iran it is mostly 15 years but there are also 5-years periods’ assignment. In Nepal, the duration of spectrum assignment to the mobile operators is till the service license period.
  2. In Sri Lanka, it is normally 10 years and it should be renewed yearly. In Bhutan, Spectrum license term is as per the term of mobile license. However, they have to pay annual spectrum utilization fee. In India, currently, the spectrum assignment is for 20 years from the date of allotment both for the administrative process or auctions.

# Spectrum sharing and trading; Infrastructure sharing

* 1. In Afghanistan, Bhutan, Bangladesh, Maldives,Nepal andSri Lanka, as of now spectrum sharing is not allowed. In Nepal, Afghanistan, Bhutan, Sri Lanka, Bangladesh, there are no plans yet. Also, there is no provision made yet for active infrastructure sharing in Nepal, Bhutan, Afghanistan and Sri Lanka.
  2. In Iran, the so-called "RAN Sharing Regulation" is under process.In Iran, Spectrum trading has been regulated and the regulation of spectrum sharing is still under the process. For spectrum trading case, a seller operator may announce deal if receive advance approval of the Authority. A new spectrum license would then be issued by the Authority for buyer once seller and buyer are agreed upon the trade condition. Moreover, seller's spectrum license would be updated in accordance with the trade.
  3. Infrastructure sharing without spectrum sharing is termed as ‘Tower Sharing’ in Bangladesh[[24]](#footnote-24).
  4. In Pakistan, GoP Telecommunication Policy 2015[[25]](#footnote-25)(Section 8.15 and 8.16) supports and encourages spectrum sharing and trading along with active infrastructure sharing; however, the guidelines, frameworks and regulations are expected to be finalized soon for practicing the same.
  5. Spectrum Sharing[[26]](#footnote-26) in India has been permitted w.e.f. 24th September 2015. The spectrum sharing provides an opportunity to the TSPs to pool their spectrum holdings and thereby improve spectral efficiency. The detailed guidelines for Spectrum Sharing are accessible on DoT website. Through Spectrum sharing, both licensees having access spectrum, in the same band can pool their respective spectrum in the same Licensed Service Area for their simultaneous use, using a common Radio Access Network (RAN). The shared RAN will be connected to the core networks of each of the licensee. Both the licensees will continue to hold their primary right over their own spectrum. All access spectrum i.e. spectrum in the bands of 700/800/900/1800/2100/ 2300/2500 MHz will be sharable provided that both the licensees are having spectrum in the same band.
  6. In India, Spectrum Trading[[27]](#footnote-27) is permitted w.e.f. 12th October 2015. Sharing of Active infrastructure amongst Service Providers based on the mutual agreements entered amongst them is permitted. Active infrastructure sharing permitted is limited to antenna, feeder cable, Node B, Radio Access Network (RAN) and transmission system only.

# Spectrum allocation PAN-country basis or regional basis to the mobile operators

* 1. In Afghanistan, Nepal, Bangladesh, Bhutan, Pakistan and Sri Lanka, the spectrum is assigned to MNOs on PAN-country basis. In Bhutan, there are 2 TSPs. Each TSP holds about 80MHz each in IMT services.
  2. Spectrum allocation in India is on Licensed Service Area (LSA) basis. India is divided into 22 geographical areas (LSAs). The licensee has to acquire spectrum for each LSA through auction. Presently, 5 Telecom Service Providers (TSPs) are in operation and providing the cellular mobile services.
  3. In Iran below 3.4 GHz, spectrum was mostly allocated on PAN-country basis. Above 3.4 GHz, it was allocated provincially. The study is for the millimeter wave bands. There are 3 mobile operators on PAN-country basis, but they have different bandwidths for some places. In capital: Total bandwidth per operator varies from 52 MHz to 68.4 MHz. In other places it is from 52 MHz to 63 MHz.
  4. In Maldives, Nepal and Pakistan Cellular Spectrum licenses are issued on PAN country basis.
  5. In Pakistan, Wireless BWA Licenses are issued on Regional Basis and are valid till 2024. There are 14 Telecom Region in Pakistan. There are few assignments in 479 MHz, 450 MHz and 1900 MHz for Fixed BWA as well.

# Existing policy/regulation regarding spectrum re-farming

* 1. In Afghanistan, Bangladesh and Sri Lanka there is no policy/regulation regarding spectrum re-farming. In Pakistan, GoPTeleom Policy 2015, Section 8.5[[28]](#footnote-28) describes about Spectrum Re-farming, however, the framework for the same is yet in development stage and requires approval of Government of Pakistan.
  2. In Maldives, Bhutan, Iran and Nepal re-farming policy/ regulation is in place. In Bhutan, there are National Radio Rules and spectrum re-farming can be done as per the requirement. In Nepal, there is a spectrum policy 2012 and 2016[[29]](#footnote-29) which contains spectrum re-framing provision as well.
  3. In India, the Spectrum assignment has been delinked from the license since 2010. A licence holder is required to obtain spectrum through a market driven process and all the access spectrum assignment are through auction mechanism. However, for the case of administratively assigned spectrum, technology specific Licenses were given prior to 2010, for a period of 20 years. As the license agreement is binding on both licensee as well as the licensor; it was decided that the assigned spectrum cannot be re-farmed mid-way. Therefore, whenever the licenses would come up for renewal that would be the most appropriate time for re-farming the spectrum. Alternatively, the administratively assigned spectrum can be liberalized (technology neutral) any time by paying the market determined price.
  4. In Iran, different methods are used for conversion of frequency bands (from individual licensing regime to spectrum licensing regime) and for frequency band that are already converted.
* Method A. In case of conversion, the government stops issuing new radio license some years before implementation of bands under planned spectrum license. During this period, all licensees get informed about the decision of authority and they are invited to cease their operation or to move operation to new other frequency bands. Remaining operations, then, processed case-by-case basis.
* Method B. In the case of re-farming a frequency band that was already utilized by same-service operators, the government initiates a series of coordination meeting with all parties to establish a detailed and precise geographical/spectrum-wise action-plan. After approval of action plan, a phase-by-phase implementation would be lunched under supervision of parties as well as authority, until finishing spectrum re-farming.

# Spectrum re-farming undertaken: bands and methodology of re-farming

* 1. In Bangladesh and Bhutan, spectrum re-farming has never been undertaken.
  2. In Maldives, Cellular Operators have re-farmed within their existing assignments, which are assigned administratively on a technology neutral basis. They are going to start re-farming in 40MHz of 2500MHz Band and re-assigned to Service Providers and that will be used for 5G.
  3. In Sri Lanka it was done in the following bands:
* 1800MHz band – Giving compensation for government users in the band and for private sector users gave a grace period for the migration.
* 2600MHz band - All government and private sector users gave a grace period for the migration.
  1. In Iran, following was the methodology for re-farming:
* Method A: 2.3-2.4 GHz, 450 MHz and 900 MHz band bands,
* Method B: 3.4 – 3.6 GHz, 1800 MHz and 2100 MHz bands
  1. In Pakistan, Cellular Operators have re-farmed within their existing assignments (without change in the start and stop frequencies i.e. no alternate user, no alternate spectrum only alternate use) which are assigned through auction on a technology neutral basis. More recently, 1900 MHz Band assigned to few WLL Operators was re-farmed to make available 1920-1980/2110-2170 complete band available to IMT services.
  2. In Nepal, by adopting new spectrum policy following bands have been re-farmed:
  + CDMA 1900MHz to CDMA 800 MHz band allowing more spectrum in 1800 MHz and 2100 MHz bands.
  + GSM 900 MHz band has been extended to EGSM 900 MHz band.
  + GSM900 MHz band made technology neutral to allow 3G services.
  + GSM 1800 band made technology neutral to allow 4G services.
  + 3G 2100 band made technology neutral.
  + WiMAX 2300 MHz band for technology neutral to allow 4G/LTE services.
  1. In India, the licenses awarded for Cellular Mobile Telecom Service (CMTS) in 1994-95 were mostly having spectrum in the 900 MHz band. Some chunks of the spectrum were assigned in 1800 MHz band to these licensees for offering 2G services. Further, the licensees having spectrum assigned in 800 MHz band for CDMA services had intended offering 4G/ LTE services in the same band and started shutting down the CDMA services. When these licenses, came up for renewal, after due deliberation, it was decided that the entire spectrum should be refarmed and incumbents should not be allowed to retain any spectrum. Accordingly, entire spectrum held by them in 900/1800/800 MHz bands was put to auction and the incumbent licensees were required to take part in the auction to regain it. The following methodology was adopted:
  + 900 MHz (used earlier for CMTS) and 1800MHz (used earlier for offering 2G services) are re-farmed for offering 4G/LTE services. In 900/1800 MHz band more than 50% of the spectrum assigned is a liberalised spectrum as on date. The licensees who held the non-liberalised spectrum were given an option to re-farm their spectrum for the liberalised use by paying the auctioned determined period pro-rated of the remaining validity period of the license validity.
  + 800 MHz (earlier for CDMA) was intended to be used for 4G/ LTE services, is completely liberalized i.e. no TSP is holding administratively assigned spectrum.
  + The 3300-3600 MHZ band was being earlier used for point to point or point to multi point microwave links and for Radiolocation services, however, it has been now refarmed and available for IMT. The existing users were shifted in other non-IMT bands.
  + The 600 MHz band (617-698 MHz) was earlier used for terrestrial television transmission. This band has now been refarmed and recently re-purposed for IMT services.
  + 500 Mz band (526-582 MHz), which was used for deployment of transmitters for broadcasting services, is being refarmed for IMT use in coordination with Ministry of information & Broadcasting. The use will be coordinated with minimum keep out distance from MIB transmitters.
  1. In India, consequent upon re-farming of 800/900/1800 MHZ bands, the operators who were earlier offering 2G services, have mostly deployed the 4G services in these bands and transitioned to Mobile Broadband.
  2. In Sri Lanka, to fulfill the demand for broadband service, it was necessary to allocate new bands for IMT services. Therefore, new IMT bands were released by vacating the existing users by re-farming. Many new IMT bands are occupied by microwave links and these links can be vacated by replacing fiber optics or microwave links in another bands. Allocating new IMT bands will cater the ever-increasing broadband demand and it will be benefited to the society as whole.
  3. After the re-farming in Nepal, the frequency bands are made available to adopt mobile broadband technologies such as 3G and 4G.

# Benefits of Refarming

* 1. Some of the benefits of re-farming in Iran are - Saving CAPEX of operators, increasing spectrum efficiency, implementing broadband, increasing penetration of MBB, introducing better public network instead of individual networks, upgrading old networks to new technologies.
  2. As India has become the top country in the world in terms of highest data consumption per user i.e. more than 10GB per user per month, in order to fulfill the demand of high data usage, spectrum re-farming was done. With spectrum re-farming, the TSPs have more technology neutral spectrum in their kitty, which can be clubbed together by using carrier aggregation, resulting in higher spectral efficiency. Higher spectral efficiency with latest technology adoption has resulted in exponential growth in data usage.
  3. In Nepal, the Bandwidth in 1800 MHz and 2100 MHz has been increased to full 75 MHz and 60 MHz respectively. CDMA 1900 MHz band was re-farmed to allocate more spectrum bandwidth in 1800 MHz and 2100 MHz bands. And CDMA 850 MHz band was introduced for CDMA while 1900 MHz band was unallocated.

# Chapter 5: Conclusion/Recommendations

* 1. The radio spectrum is a finite, natural resource which must be used judiciously for communications and economic development to maximize the benefits. With the advancements in mobile communication technologies in the recent decades, the older technologies must be gradually phased out, thereby making way for more efficient new radio technologies by reassigning spectrum resources to improve the spectral efficiency and data throughput. The spectral efficient newer radiocommunication technologies can lead to a faster economic growth of a country. Spectrum re-farming is a key process in spectrum management to reallocate frequency bands for more efficient technologies with higher throughput. Therefore, refarming is essential to cater to the market demands with the development in wireless applications throughout the world. Adopting the right approach to spectrum refarming is important to enable smooth implementation of a new spectrum plan. Spectrum refarming should be included in the administration’s national spectrum strategy together with the mechanism identified to assist implementation of refarming. It should be considered equally with all other options, i.e. sharing, removing restrictions, and not as a last resort.
  2. Mobile network operators are required to use the existing spectrum resources from GSM and UMTS to LTE in the most efficient way, so to accommodate new radio technologies by reassigning spectrum resources.
  3. The latest mobile broadband networks offer much higher spectrum efficiencies in comparison to the traditional GSM and CDMA (2G) systems. There is a global trend of switching off 2G Networks gradually with the increase in mobile broadband networks. While implementing technology neutral approach in traditional technology specific frequency bands, refarming the technology specific legacy bands, like GSM, CDMA, WiMAX etc. is a natural solution for more efficient mobile broadband coverage. With technology neutral approach, it becomes easier for the telecom operators to plan for migration from old technology to a newer one. However, if the spectrum is technology specific, the telecom operators may not be able to deploy the spectrum for newer technology as per the market demand.

**Additional bands identified by WRC-19 to enable standardized 5G (IMT 2020) deployment:**

* 1. WRC-19 identified additional globally harmonized (**millimetre wave**) frequency bands for **International Mobile Telecommunications (IMT), including IMT-2020** (known as 5G mobile). The frequency bands **24.25-27.5 GHz, 37-43.5 GHz, 45.5-47 GHz, 47.2-48.2 and 66-71 GHz** have been identified for the deployment of 5G networks by WRC-19. In total, 17.25 GHz of spectrum has been identified for IMT by the Conference, in comparison with 1.9 GHz of bandwidth available before WRC-19. Out of this number, 14.75 GHz of spectrum has been harmonized worldwide, reaching 85% of global harmonization.
  2. New Resolutions approved at WRC-19 noted that **ultra-low latency** and very high bit-rate applications of IMT 2020 will require larger contiguous blocks of spectrum than those available in frequency bands that had previously been identified for use by administrations for IMT. Harmonized worldwide bands for IMT are essential to facilitate global roaming and the benefits of economies of scale.
  3. As can be seen from the responses from the SATRC member countries, the main issues which need to be tackled are as under:

1. the IMT bands identified by ITU, which are currently allocated and are being used for some other purposes need to be freed for provisioning of IMT services. Regulators need to facilitate clearing of globally harmonized IMT bands.
2. The technology specific bands need to be made technology neutral. This would enable the telecom operators to utilize the available spectrum for newer efficient radiocommunication technologies.
3. It is equally important for the regulators and the operators to ensure continuity to the existing services in the legacy 2G and 3G bands till all the subscribers are ready to migrate to use the new services.
   1. As with any technical solution, spectrum refarming presents numerous challenges. One of the major challenges is meeting its prerequisites like availability of sufficient contiguous spectrum to support the simultaneous operation of two or three technologies in a frequency band. Simultaneous mixed use of frequency bands presents challenges regarding bandwidth allocation across bands. The same operator should be using both sides of the spectrum adjacent to the dividing point. Adjacent channel interference must be dealt with using guard bands. While allocating spectrum to the telecom operators, efforts should be made by the administrators that the spectrum holding of the telecom operator is in a contiguous manner. However, spectrum is assigned over a period of time; further, during such time, some spectrum is surrendered, some is assigned, some may be trading, all this could lead to fragmentation of spectrum, which may lead to inefficiencies and may also come in way of spectrum refarming. The Administrators can perform spectrum harmonization exercises, wherein the frequency blocks assigned to different telecom operators are reassigned in a way that the spectrum holding of the telecom operators becomes contiguous.
   2. Avoiding disruption to existing users on the band/technology that will be refarmed and encouraging them to migrate to new services is also a major challenge. The operator needs to maintain GSM quality as the process takes place, not compromising customer satisfaction and experience. Avoiding service degradation means understanding traffic patterns and managing how traffic will be served. In Sweden, assignments in 900MHz band were granted based on the need for the spectrum for continuing the provision of GSM services which was considered very important to the Swedish society and its consumers. Spectrum may be interleaved between operators, requiring reconfiguration to avoid fragmentation. This can require considerable coordination and cooperation. After reconfiguration, a full site/cluster audit needs to be carried out to understand new coverage, traffic distribution, and interference/quality.
   3. Some handsets and machine-to-machine devices cannot work with multiple bands or must continue with the old technology. This can be a big challenge when discontinuing the use of a legacy network—any interruption in services can significantly affect roaming revenues. Fortunately, the rate of change in consumer mobile devices is quite rapid. Once the spectrum is made available for use with the target technology, for example, refarming GSM to LTE, the spectrum needs to be cleaned up of external interference often caused by legacy signals left behind.
   4. In recent times, a trend of shutting down of 3G service is also being noticed. Any migration to a newer technology should be made smooth and it should cause least disturbance to the existing subscribers. Spectrum sharing techniques can help telecom operators to pool their spectrum holdings and benefit from increased spectrum efficiency. As the spectrum efficiency increases non-linearly, by using spectrum sharing, the telecom operators can ensure satisfactory quality of service even during the migration phase. Spectrum trading is another tool that helps telecom operators to manage their spectrum holding according to the demand and their business plans. Spectrum sharing is all the more important for the success of newer technologies such as 5G. Spectrum trading provides a secondary market for spectrum acquisition. From the inputs provided by the member countries, it has been noticed that many countries do not have spectrum sharing and trading guidelines in place. The member countries may examine the benefits of spectrum sharing and spectrum trading and take necessary steps for permitting spectrum sharing and spectrum trading.
   5. The timely deployment of technology is very essential to get full use of any technology; otherwise, it may be outdated or obsolete within a short period of time, sometimes even before the implementation. The delay may cause financial loss to the country as well as the disturbance of the social benefits to the society at large. The demand for frequency band will be decreased with time and hence the administration will lose the maximum value of the spectrum when the band is offered. Sometimes, delays may result in no demand at all. As in Denmark, existing licensees were given approximately one year to carry out their re‐planning and accomplishing the process of spectrally moving transmitters. Therefore, the administrations should give prompt attention to start the process of the approval of higher authorities, well in advance, to avoid unnecessary delays.
   6. The other main challenge administrations are facing is the reluctance of vacation of band by the existing frequency users, particularly when the spectrum is being held by the government entities such as the Military, the Police, disaster management, Terrestrial broadcasting. There may be several reasons for this situation. Such situations can be handled by examination of spectrum utilization by the spectrum holders by way of conducting spectrum audit. Spectrum Audit should be conducted by an Independent agency for all the spectrum holders, especially for the spectrum assigned administratively to government agencies, which may include the examination of spectral efficiency parameters, quantity assigned vs. quantity used etc. To handle timely vacation of bands by such users, approval from the higher authorities, is very essential and outcomes of spectrum audit will provide the empirical evidence and thus, be helpful in getting the necessary approvals. Also, lack of funds for the compensation for existing users, is also one of the main challenges in spectrum re-farming. In UK, an Independent Audit of Spectrum Holdings was conducted in 2005, wherein it was revealed that the public sector holds around half of the frequencies below 15 GHz. In March 2006, the government, with Ofcom’s support, accepted the recommendations of the Independent Audit of Spectrum Holdings by Professor Martin Cave to reform public sector spectrum management. A key recommendation was to make public sector spectrum holdings tradable in order to provide incentives and opportunities to promote greater efficiency in their use.
   7. Spectrum Administrators should facilitate clearing of globally harmonized IMT bands well ahead of market needs to provide certainty to CSPs who need to identify strong business cases, seek appropriate funding from internal governance processes, and award contracts to vendors and service partners. Availability of a Spectrum roadmap helps the Industry with increased certainty about the government’s future allocation plans and management of the radio spectrum. Accordingly, the Administrators should create and declare a spectrum Roadmap for at least the next 5 years.
   8. Sometimes, the administration needs to clear bands for the applications like disaster management or national security. In this kind of situation, the administration is not able to get the value of the spectrum (upfront fee) or annual spectrum fee from new users. Therefore, re-farming fund should be maintained to handle such scenarios. In the US, the Spectrum Relocation Fund (SRF) provides a funding mechanism for relocation cost and authorizes the spectrum to be auctioned for commercial purposes. The Office of Management and Budget (OMB) was responsible for transferring relocation expenses from the SRF to agencies. United States Government Accountability Office (GAO) was directly involved in reviewing the costs to relocate federal spectrum users and revenues from spectrum auctions in order to ensure that auction revenues will be exceeded relocation costs and relocation cost estimation is a sustainable approach.
   9. Consequent upon refarming, 4G / LTE enables data transmission at much greater speeds in terms of Mbit/s compared to 2G or 3G. Data speeds are the key ingredient in delivering a good user experience. Regulators who have proactively refarmed the spectrum have empowered the citizens of their countries with the benefit of true mobile broadband enabled by 4G /LTE. For the operators, spectrum refarming is a cost-effective way to increase capacity for mobile telecommunication services without the need to acquire additional new spectrum.
   10. Globally the developed countries are adopting 5G technology, the SATRC countries also need to start planning for the introduction of 5G in a timely manner.5G technology is initially being introduced using mid-bands (3300-3700 MHz) and mmWave bands (26 GHz and 28 GHz bands). However, due to inherent properties of wave propagation, the coverage in mid-band is low and still lower in mmWave which requires the deployment of a large number of small cells. To improve the coverage of 5G network, it is desirable to introduce 5G technology in coverage bands also, that is, in the bands from 700 MHz band to 2500 MHz. However, almost all these coverage bands are pre-occupied with deployment of 4G or other technologies in most of the countries. Further, from the responses received from the member countries, it is seen that some countries have not yet earmarked the prime 5G mid-band i.e. 3.5 GHz band for IMT. Needless to mention, the newer wireless technologies are capable of having a strong positive impact on the economic growth of the country; thus, any delay in the launch of new technology also delays the economic development of the nation.
   11. There can be three different ways to enable the deployment of 5G in lower FDD bands:
4. **Hard Re-farming** – One of the ways can be switching off the LTE/3G or 2G Network and using the spectrum for 5G technology - This method is generally not recommended as the subscriber of the older network will suffer mainly as all the subscribers of the older network technology may not have mobile handsets to migrate and support 5G technology.
5. **Static Spectrum Sharing** - In this method, the available spectrum is divided into two parts and one part is used for 4G, whereas the other part is used for 5G technology. For example, 20 MHz spectrum currently used to provide LTE based services is split into two parts of 10 MHz each. Therefore, 10 MHz is used to provide 4G LTE service and another 10 MHz is used to deploy 5G New Radio for providing 5G services. However, this method suffers from capacity limitations as both the technologies shall have less spectrum at their disposal. As the spectrum distribution is static, it will lack its optimum utilization.
6. **Dynamic Spectrum Sharing** – It is a spectrum sharing technique which can be used for the deployment of 5G technology in a band in which the existing 4G technology is already deployed. In this method, the entire spectrum is used jointly by both the technologies and the spectrum is allocated dynamically to 4G (LTE) and 5G (NR) based on instantaneous traffic in the cell. By this method, we can introduce 5G in the existing 4G bands without any hard/static refarming of spectrum. In this way, the Dynamic Spectrum Sharing will allow “soft re-farming” to 5G New Radio with minimal impact to LTE performance. It results in better spectral efficiencies.

Annexure-I

|  |  |  |
| --- | --- | --- |
| APTlogogreen3 | ASIA-PACIFIC TELECOMMUNITY | **Document:** |
| **Meeting of the SATRC Working Group on Spectrum** | **SAPVII-SPEC1/OUT-02** |
| 11 – 12 June 2019, Tehran, Islamic Republic of Iran | 12June 2019 |

**SATRC Working Group on Spectrum**

**QUESTIONNAIRE FOR THE WORK ITEM ON SPECTRUM RE-FARMING**

**Section 1: Elementary Part**

**1.1 Introduction:**

With the advancement in mobile communication technologies, latest mobile broadband networks offer much higher spectrum efficiency compared with traditional GSM and CDMA (2G) systems. There is a global trend of switching off 2G Networks gradually with the increase in mobile broadband networks. Some Regulators have adopted technology neutral principles in those bands.

While implementing technology neutral approach in traditional technology specific frequency bands, refarming technology specific legacy bands, like GSM, CDMA, WiMAX etc. is a natural solution for more efficient mobile broadband coverage.

Refarming is a strategy where telecom service providers reuse their frequency resources to introduce latest radio communication technologies to improve the spectral efficiency and data throughput. For example, in 900 MHz refarming solution, the service providers free up about 5 MHz of GSM in 900 MHz band and deploy UMTS or LTE in that 5 MHz of 900 MHz Band.

Spectrum refarming requires careful planning and management to guarantee a smooth transition to mobile broadband networks. To solve this issue, this study will investigate following areas:

* Spectrum Migration Strategy
* Technical Methods to re-arrange existing traditional spectrum bands

**1.2 Objectives**

In order to seek information from SATRC Member countries, a questionnaire has been prepared to get the information about refarming and study the status in each country.

**1.3 About Your Administration**

Name of Administration :

Name of Contact Person :

Telephone Number :

Postal Address :

Email Address :

**Section 2: Questionnaire Part**

**Question 1:**

Have the bands identified by ITU for IMT services as mentioned in the Table below been adopted for IMT services in your country? If assignment is for services other than IMT services, please specify the purpose.

|  |  |  |  |
| --- | --- | --- | --- |
| **Uplink** | **Downlink** | **Duplex Mode** | **Purpose** |
| 824 MHz – 849 MHz | 869 MHz – 894 MHz | FDD |  |
| 880 MHz – 915 MHz | 925 MHz – 960 MHz | FDD |  |
| 832 MHz – 862 MHz | 791 MHz – 821 MHz | FDD |  |
| 703 MHz – 748 MHz | 758 MHz – 803 MHz | FDD |  |
| 663 MHz – 698 MHz | 617 MHz – 652 MHz | FDD |  |
| 1920 MHz – 1980 MHz | 2110 MHz – 2170 MHz | FDD |  |
| 1850 MHz – 1910 MHz | 1930 MHz – 1990 MHz | FDD |  |
| 1710 MHz – 1785 MHz | 1805 MHz – 1880 MHz | FDD |  |
| 2500 MHz – 2570 MHz | 2620 MHz – 2690 MHz | FDD |  |
| 2570 MHz – 2620 MHz | | TDD |  |
| 2496 MHz – 2690 MHz | | TDD |  |
| 1432 MHz – 1517 MHz | | TDD |  |
| 1427 MHz – 1432 MHz | | TDD |  |
| 1710 MHz – 1780 MHz | 2110 MHz – 2200 MHz | FDD |  |
| 1695 MHz – 1710 MHz | 1995 MHz – 2020 MHz | FDD |  |
| 1427 MHz – 1470 MHz | 1475 MHz – 1518 MHz | FDD |  |
| N/A | 1432 MHz – 1517 MHz | SDL |  |
| N/A | 1427 MHz – 1432 MHz | SDL |  |
| 3300 MHz – 4200 MHz | | TDD |  |
| 3300 MHz – 3800 MHz | | TDD |  |
| 4400 MHz – 5000 MHz | | TDD |  |
| 1710 MHz – 1785 MHz | N/A | SUL |  |
| 1920 MHz – 1980 MHz | N/A | SUL |  |
| 26.5 GHz – 29.5 GHz | | TDD |  |
| 24.25 GHz – 27.5 GHz | | TDD |  |
| 37 GHz – 40 GHz | | TDD |  |

**Question 2:**

Details of the bands allocated for IMT services in your country.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Band | Uplink Frequency | Downlink frequency | Band Plan | Which technology is currently deployed using this band |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

**Question 3:**

(a) Has the spectrum assignment linked with service/ technology restrictions in mobile spectrum usage rights? If yes, please answer as per the Table below

|  |  |  |  |
| --- | --- | --- | --- |
| Band | Service/technology restricted | Is restriction still there? If no, provide the year till which restriction existed. | What regulatory procedure was adopted to remove this restriction, including any financial obligations on the licensed operators? |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

(b) If the country is already following a technology neutral regime and operators are following the natural up-gradation paths to provide Mobile Broadband in their own assigned spectrum, what regulatory procedures were adopted like QoS Enhancements, Monitoring compliance, Interference related issues OR any other major or monetary obligations?

(c) If operators are awarded spectrum through Open auction, are they permitted to adopt any technology, which becomes available during the tenure of their license?

**Question 4:**

In the next 5 years, are there any plans for allocating new bands for IMT services (including 5G) in your country? Please specify, if any.

**Question 5:**

Is currently 3.5 GHz spectrum awarded in your country for BWA services?

**Question 6:**

Is spectrum assignment and service license bundled in your country?

**Question 7:**

With the auction of more cellular spectrum in recent years, the existing operators are issued with a new license every time OR only spectrum with some additional Terms and Conditions like QoS and Roll out (coverage) are added in the license?

**Question 8:**

What is the method of Spectrum Assignment in your country? Please explain. (administratively/ auction/ any other method)

**Question 9:**

What is the duration of Spectrum Assignment to the mobile operators?

**Question 10:**

Is spectrum sharing and trading allowed in your country?

1. If yes, provide the guidelines.
2. If no, are there any plans in the near future?
3. Is active infrastructure sharing allowed (with or without access spectrum sharing )?

**Question 11:**

Is spectrum allocated on PAN-country basis or regional basis to the mobile operators?

1. If PAN-country basis, how many TSPs are there and how much spectrum each TSP holds.
2. If regional basis, please complete the table below:

|  |  |  |
| --- | --- | --- |
| Region | No. of mobile operators in the Region | Spectrum holding (in MHz) operator-wise |
|  |  |  |
|  |  |  |

**Question 12:**

Do you have any policy/regulation regarding spectrum re-farming? If yes, please describe.

**Question 13:**

Has the spectrum re-farming been undertaken in your country? If yes,

1. Please specify the bands and methodology of re-farming?
2. Please specify how your country has benefitted from spectrum re-farming (within own assigned spectrum) for transitioning to Mobile Broadband?
3. How has your country benefitted from spectrum re-farming? Please specify.

**Question 14:**

Please provide any additional information on the topic, if not covered above.

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