ATU-R RECOMMENDATION

RELATING TO

Spectrum Evolution for Mobile/Broadband Systems

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Contents

PART A: EXECUTIVE SUMMARY

The radio spectrum is a natural, scarce and valuable resource, currently used for a wide range of applications, providing many economic and social benefits. The greater the demand for this resource, the greater the increase in the level of complexity of spectrum management.

Change of use in a particular spectrum band (or spectrum evolution) could be a key spectrum management practice in achieving optimal use of spectrum. Spectrum regulators have various practices at their disposal to facilitate a change towards higher value use. The choice of the most appropriate practice depends on how certain the regulator is of the benefits of the change.

To unlock the full potential of broadband in Africa, the current and next wave connectivity will provide an optimal platform for the near-and long-term. It is therefore critical for African countries to make sufficient spectrum available for wireless connectivity and allow newer generations of mobile technology access to low, mid and high spectrum bands. Flexibility in spectrum usage (migration, re-farming, repurposing) is one of the spectrum management method that could be/ is used for the introduction/evolution of mobile broadband technology.

PART B: BRIEF DESCRIPTION

Most of the deployments in Africa are still on 3G with some of the administration having licensed the 2G and 3G as technologies with specific spectrum. There are more 4G networks coming up. 5G is at early stage of roll out and as the world is connected and countries competing to make the economies attractive, the needs gap is increasing. In a globalised world, Africans and travellers into Africa will also start demanding access to state of the art technologies enjoyed anywhere else.

The challenge is that with the increasing demand for people to be connected, industries to be connected, while spectrum is a scarce resource, how should policy makers embrace the spectrum evolution that can see markets embracing future IMT technologies like 5G, and at the same time ensure the continuation of incumbent technologies? Spectrum evolution/refarming can be a key enabler in ensuring that coverage and capacity are coordinated to solve the digital inclusion gap.

Technology neutral spectrum licensing is widely recognised as best practice when assigning spectrum to mobile operators. It enables mobile operators to re-farm spectrum used for legacy technologies ((2G) or 3G) to modern technologies (4G and 5G) at a pace that's driven by market demand. This maximises spectral efficiency in a technical sense and also maximises efficient use of spectrum. As a result, users benefit from better mobile broadband coverage, higher data speeds and lower mobile data prices than would otherwise not be the case

Technology neutrality lets operators replace, for example, GSM with 4G and soon, 5G in a particular frequency band. For mobile operators, this evolution also represents an opportunity to sunset legacy systems, and, therefore, reduce the extra cost of running multiple networks.

Savings can be realized by:

- Simplifying network management operations and radiofrequency planning
- Avoiding costly maintenance of ageing network equipment, including equipment spares
- Eliminating ongoing costs of software licenses
- Reducing lease cost of tower space for multiple antennas; and
- Reducing energy consumption of the network.

However, this is, by no means, an effort that only benefits and involves mobile operators. Thanks to the potential for improved capacity, data speeds and broadband coverage, consumers, businesses, and the society as a whole stand to gain from innovative services based on 4G and, when the time is right, 5G.

Newer technologies can also be introduced at the same time as supporting legacy users. Spectrum evolution/migration is considered as one of the national spectrum management instruments that combines administrative, financial, and technical measures and reduces the spectrum needed to a desired limit without compromising on performance of the existing network. The process of frequency refarming must be supported, where appropriate, by the following provisions:

- The setting up of a spectrum refarming fund to support the deployment of the incoming service and the migration to the outgoing services of other frequency bands
- A regulatory framework that promotes long-term investments;
- The adoption of a policy for technological neutrality within the same radiocommunication service.
- The process can be structured in five phases and activities as outlined below:
- Phase 1: Feasibility Study – Proposal on best frequency plan, strategies to adopt, and needed actions before Carving
- Phase 2: Pre-refarming actions – Set best possible baseline scenario for spectrum carve and mobile Broadband (e.g., 4G/5G) introduction
- Phase 3: Refarming – Provide optimum frequency plan balancing network performance and future ROI
- Phase 4: Post refarming actions – Improve network performance in new challenging scenario
- Phase 5: Performance Assessment – Monitoring and final report

Where clearing spectrum from incumbent usage is not possible, innovative and flexible ways to access spectrum on a shared basis should be encouraged. Spectrum sharing techniques are appealing for broadband system to access frequency bands used by other services on managed and efficient spectrum framework.

PART C: COLLATION OF PRACTICES

This section provides an overview of the main regulatory practices that spectrum managers have used to facilitate changes in spectrum use, with examples of application.

Cote d'Ivoire Case Study

The evolution of spectrum for mobile and broadband systems has undergone two major phases in Côte d'Ivoire, materialised by the number of stakeholders present in each of the segments of the mobile telephony and Internet access market.

1. Evolution of the Spectrum Before 2016

With the advent of mobile telephony and market liberalization, the mobile telephony sector experienced rapid expansion in 1995 in terms of population coverage and service offerings. This development was marked by the presence of seven (07) mobile telephone operators and four (04) internet service providers in business, all operating under licenses specific to their business scheme. These stakeholders had access to spectral resources and as part of their activities, in a transparent and non-discriminatory manner, distributed by type of technology and by frequency band.

- **GSM 900 and GSM 1800 Bands**

175 duplex channels of 200 kHz are distributed among six operators (900 MHz band)

375 duplex channels of 200 kHz are distributed among the 7 operators (1800 MHz band)

At the launch of the 3rd generation of mobile networks in Cote d'Ivoire, only three operators were granted the right to apply for the license. The other four who were not eligible for 3G due to their inability to meet the cost of the 2G license had their licenses revoked a few years later for failure to meet their specifications, namely:

- Failure to meet financial obligations
- Failure to meet services and quality obligations
- Under-utilization and hoarding of the assigned frequency spectrum identified after a study conducted by the national frequency manager.
- 2100 MHz band for 3G UMTS technology

4 duplex channels of 15 MHz are distributed between 4 operators: 3 current operators and one expected operator: The purpose of the state was to establish a national mobile telephony market with 4 national operators.

- **2300 MHz Band Identified for WIMAX AND LTE Point-to-multipoint Technologies**

Frequency blocks of 5 MHz bandwidth distributed between 3 operators

- 2600 MHz band (2500 - 2690 MHz) identified for WIMAX technology
- 100 MHz of bandwidth distributed between 2 operators with each having 5 MHz wide channels 90 MHz unused
- 500 MHz band (3400 - 3500 MHz) for WIMAX technology

Duplex Channels with 5MHz Pitches Distributed Among 5 Operators

2. Evolution of the spectrum as of 2016: Implementation of the principle of technological neutrality

a. Spectrum Refarming

Following the withdrawal of the licenses of the four operators, the State decided to refarm and reallocate the frequencies of the mobile networks between the four operators (ORANGE, MTN, MOOV and a potential fourth operator) to improve the quality of service and coverage of the territory.

Moreover, in 2016, it also renewed the licenses of the ORANGE CI, MTN CI and MOOV CI operators based on the principle of technological neutrality for periods of validity between 15 and 16 years. In this regard, and in keeping with the best practices in this sector, the purpose was to allocate licenses and spectral resources to these operators in 2016, in order to enable them deploy any type of technology, without systematically resorting to prior authorization from the State or regulator.

In addition, following the bankruptcy and / or merger-takeover of some companies in the broadband internet access market, additional spectral resources have been provided.

The State then proceeded with a comprehensive spectrum refarming intended for mobile and fixed broadband networks, based on the following principles:

- A maximum of four (04) mobile telephone operators on the national market
- Non-discriminatory treatment of operators
- Reduction of the migration impact on frequency bands with a high rate of conservation of the initial frequency bands for each operator
- The assignment of multiple frequency channel -width of 5 MHz to allow the deployment of any mobile or broadband technology
- The development of the broadband Internet market
- Optimizing the use of frequencies.

The 900 MHz and 1800 MHz bands, previously intended for the 200 kHz duplex channels, have been channelled into minimum 5 MHz duplex blocks to support 2G, 3G and 4G technologies.

Thus, the final state of spectrum occupancy by mobile and broadband services in Côte d'Ivoire is as follows:

- **900 MHz Band**

3 duplex blocks of 10 MHz for current operators

1 duplex block of 5 MHz for the potential operator

- **1800 MHz Band**

3 duplex blocks of 15 MHz for current operators

2 duplex blocks of 15 MHz for the potential operator

- **2100 MHz Band**

3 duplex blocks of 15 MHz for current operators

1 duplex block of 15 MHz for the potential operator

This frequency band has not changed as a result of the refarming.

- **2600 MHz Band**

Prior to its refarming, this frequency band was used in TDD duplexing mode, which is the C3 frequency arrangement of the 2.6 GHz band of Recommendation ITU-R M.1036.

As a result of refarming, Ivory Coast adopted the C1 frequency arrangement of the 2.6 GHz band of Recommendation ITU-R M.1036 while considering the following distribution:

- Three duplex blocks of 20 MHz distributed among the 3 current operators
- One duplex block of 10 MHz duplex the potential operator
- One FDD block of 20 MHz an Internet Service Provider
- One free FDD block of 20 MHz

- **3500 MHz Band**

One duplex block of 65 MHz distributed between 2 Internet Service Providers

One free duplex block of 35 MHz

Several frequencies have been removed from this band. The latter is under refarming in view of its use in the 5G networks and services.

b. Digital Dividends

In Côte d'Ivoire, analogue television operates only in the VHF band. The UHF band was therefore only used during the deployment of DTT.

However, when preparing this band for 4G networks, several frequency assignments used by CDMA 825 MHz were withdrawn from the various stakeholders.

Thus, the 790-862 MHz frequency band (first digital dividend) was designed for 4G and assigned to existing operators in the Ivorian market according to provision A3 of Recommendation ITU-R M.1036. The band is divided into three duplex blocks of 10 MHz among the 3 current operators

The 694-790 MHz frequency band (second digital dividend) is not yet in use. The envisaged arrangement is A7 of Recommendation ITU-R M.1036 (703-733 / 758-788 MHz).

3. Estimates for Future Requirements: Consultation of Stakeholders

As radio frequencies are sensitive resources, it is important to regularly consult stakeholders of the sector on the planning and management of the frequency spectrum.

It is against this backdrop that the public consultation launched by the regulator in August 2018 on the management strategy for radio frequencies in the telecommunications sector falls under this perspective. This public consultation mainly focused on:

- The guiding principles of the spectrum resource management strategy, in particular:
    - Manage Spectral Resources in a FAIR and TRANSPARENT manner;
    - Integrate a prospective approach in planning and allocations;
    - Favour the development of High and Very High Speed;
    - Allocate sufficient resources for the "dominant" segments of the telecommunications / ICT sector;
    - Dedicate resources to "non-dominant" segments of the telecommunications / ICT sector;
- The state of play;
- The strategic objectives of the short, medium and long run spectrum resource management framework;
- Current and future planning of frequency bands (mainly with regard to 5G).
- In addition, one-on-one meetings are frequently held with stakeholders to discuss issues related to the frequency spectrum and possible requirements for frequency refarming.

2G and 3G Sunset Case Studies

As of July 2019, a total of 20 GSM networks run by national mobile operators have been switched off completely, as well as four networks using regional 2G-like technologies (NTT Docomo's PDC in Japan, and the Personal Handyphone System used for low-cost services in China, Japan and Thailand). There have also been five total sunsets of 3G (W-CDMA) networks.

In addition, there have been seven complete sunsets of CDMA networks. These usually affect both 2G and 3G services (the dividing line between the CDMA generations, CDMA 1X and CDMA2000, are less distinct than in 3GPP technologies).

Firm dates before 2026 have been set for sunsets of a further 15 GSM and 13 W-CDMA networks (in five cases an operator has set a timeline for both switch-offs). There are also three further CDMA sunsets scheduled.

Practices from Countries Where 2G Networks Have Been Switched Off

a. APAC Countries

The most active APAC countries in sunsetting 2G are countries with very dense populations with high levels of mobile data usage, a combination of factors which has put pressure on operators to free up spectrum for LTE. For instance, all three South Korean operators turned off 2G networks (GSM or CDMA) in 2011; all three Japanese MNOs turned off 2G between 2008 and 2011; the three Singaporean operators switched off GSM in 2018; and in Taiwan, the four MNOs turned off 2G in 2017 and followed with 3G (UMTS) in 2018.

b. South Korea

South Korea Telecom faced delays enforced by the regulator, KCC, and a class action lawsuit from 900 subscribers, in the process of sunsetting its 2G network from 2011 to 2012. The operator was initially denied permission by KCC to switch off 2G, because it still had 5% of its total base (about 810,000 users at the time) on 2G. By contrast, operators which had already turned off 2G in other countries, such as Softbank and NTT Docomo in Japan, had successfully reduced 2G numbers to a far lower level before the sunset – in Docomo's case, only 0.3% of its base, or 202,000 users, at the time of sunset in 2011. KT also gave only three months' notice to subscribers that it planned to switch off 2G, whereas Docomo had publicised its intention more than three years before the final termination date.

In order to reverse the suspension of its sunset, the operator offered various incentives for users to move to 3G including exemption from 3G subscription fees for the first three months, followed by discounted rates for two years; free devices (with 34 available to choose from); and a payment of KRW33,000 for a returned 2G device. Other benefits included loyalty points and air miles.

c. Japan

Japan was the earliest market to experience 2G switch-off, with the first occurring in 2008, and complete switch-off of 2G services by all three operators by 2012. The 2G switch-off schedules in Japan were initiated by the MNOs, with each selecting the most appropriate timing given individual circumstances. Frequencies that had been assigned to each of the operators for 2G were utilised continuously as these were reused for 3G services.

The regulator's role was to ensure the adoption of adequate consumer protection measures. Accordingly, operators were requested to make appropriate announcements to the public on the timing of 2G service cessation. Operators initiated marketing campaigns and provided incentives to consumers to upgrade services. Japan's mobile operators have already announced switch-off schedules for their 3G networks, starting in 2022 with KDDI.

d. Australia

In Australia, all three MNOs have switched off their 2G services. Telstra switched off in December 2016, with Singtel Optus following by August 2017 and Vodafone Australia in June 2018. In relation to 3G services, Telstra switched off 3G connectivity on its 2,100 MHz spectrum on 25 March 2019. The operator has also announced the eventual switch-off of 3G technology in June 2024. Vodafone switched off 3G services at 2,100 MHz in 2019 but will continue to operate 3G services on 900 MHz spectrum. The key takeaway from Australian is that the timing of the 2G switch-off is critical and depends on the 2G penetration of the operator's customer base.

e. New Zealand & Singapore

Other examples are New Zealand, where the process was completely market driven, with no regulator involvement, and Singapore, where all three MNOs switched off 2G networks in 2017, in a process initiated by the MNOs, but approved and supported by the regulator.

Spark switched-off its CDMA network in 2012 and 2 Degrees closed its 2G network in March 2018.

f. North America

Non-GSM operators are leading moves to sunset older networks because technologies like CDMA and Sprint's iDEN ended up without a 4G migration roadmap of their own. That limits options for sharing spectrum flexibly between multiple generations of technology which is possible with the 3GPP standards. This has been seen in:

Canada where Bell, Telus and several regional players turned off CDMA systems in 2017 or 2018, in order to make more efficient use of their spectrum resources and avoid being left at a competitive disadvantage against their GSM-based rivals. USA, Sprint turned off iDEN in 2013; while Verizon Wireless plans to sunset 2G and 3G CDMA by the end of this year.

Sprint has said it will do the same in 2021 or 2022, though this plan may be accelerated should its proposed merger with T-Mobile USA proceed. T-Mobile itself planned to sunset GSM in 2020, It has been using progressively less spectrum for 2G and says most of its remaining GSM connections are for M2M (about 96% in 2019). It has been investing heavily in NB-IoT and claims to have a "nationwide" network in 600 MHz, covering one million square miles in 44 states.

It will also offer a series of different promotions and introductory tariffs to encourage users of consumer M2M applications to transition ahead of shutdown, under its NB-IoT Bee Aware brand. The advantage that T-Mobile has over other US carriers is extensive sub-GHz spectrum, following its spending in the 600 MHz auction, for LTE and 5G. This makes it easier for the operator to achieve 2G levels of coverage at affordable capex cost and so ensure that very few 2G users are left behind. For M2M customers, T-Mobile is offering a financing program to help business users, or those with home automation services on GSM, transition to LTE devices. It did not share many details but said the financing scheme would extend over periods of up to five years and in some cases would require no upfront payment.

The need to abandon a legacy technology is not the only factor behind an early sunset in North America. AT&T however switched off 2G in 2017 in order to free up spectrum for LTE and to reduce its operating costs by supporting fewer networks. At the end of 2020, the plan was that there would be no GSM networks operating in North America.

g. Switzerland

Sunrise has turned off one band (1800 MHz) it used for 2G. but still retains 2G services in 900 MHz. CNT in Ecuador has also completed both 2G and 3G sunset, switching off CDMA (2G and 3G) in 2014. The other important aspect of its migration strategy was to invest in expanding VoLTE over its entire 4G footprint so that it dramatically reduced the need for users to fall back to 2G (or 3G) when they were in gaps in VoLTE coverage. Sunrise differentiated itself from Swisscom when it deployed LTE initially in 800 MHz rather than 1800 MHz, which has enabled it to achieve 4G coverage and in-building penetration that is closer to that of 2G, for lower capex cost than attempting that in a higher spectrum band. Sunrise said the improved propagation made a 2G network in 2.1 GHz spectrum redundant, and that it will have matched its 2G coverage with VoLTE by the time it turns off its 900 MHz network.

Spectrum Re-Farming Case Studies

Spectrum refarming is commonly used as a process to govern the repurposing of spectrum bands to more efficient technologies and/or new services, technology neutrality allows for license holders to evolve the technology deployed and the services delivered as markets develop.

a. France

France presented a success story of operator-driven in refarming of the 900/1800 MHz. All 2G licensees had their licenses which were scheduled to expire in 2006 renewed. ARCEP-French NRA launched a public consultation in July 2003 to initiate the renewal process. ARCEP had a policy of promoting equitable spectrum holdings across operators through the refarming process. 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 roll out were imposed for renewal (NERA, 2011). The new license allows for new technology deployment, but all licensees focused on reuse of 2G for 3G (UMTS) services. Refarming in the 1800MHz band was not implemented as none of the incumbent operators had requested at that time.

In 2013, ARCEP made two decisions. Firstly, authorizing to SFR and Orange France for refarming the 1800MHz band for LTE use from 25 May 2016, on the condition that 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 20142. 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 hold 20 MHz, while smaller rival Free Mobile has 15 MHz.

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 timescale than waiting for the expiry of a licence. A redeployment fund can be funded from several different sources for example:

- the new entrants could pay into the fund collectively,
- all licence holders could pay via part of the licence fee,
- spectrum pricing fees could be transferred to the redeployment fund or
- fees from auctioning of licences 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 other than in 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 the NRA need to be carried out (ITU-R SM.1603-2, 2014)

b. Germany

Refarming the 800MHz band in Germany was aimed for using the spectrum as a means of providing universal broadband access across the rural areas of Germany which are driven by the government broadband strategy. However, the refarming process was complicated due to the separation regulation responsibility between the broadcasting, which is undertaken by Federal States (Bundesländer) and licensing of spectrum for electronic communications services, which undertaken by the national government and the NRA-BNetzA. It means that BNetzA could only be used this band if the Federal States agreed and the demand for capacity for broadcasting transmissions were satisfied. The Federal States released its broadcast deployment plan earlier in 2008 on deploy six digital terrestrial television (DTT) and one mobile TV (DVBH) multiplexes. It indicated that all spectrum was occupied. Then, the parliament has to take role as the government plan to allocate broadcasting services to mobile services

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. All the coverage obligations had to be met by 2016 at the latest. 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.

The process of clearing the 800 MHz band not only affects the households and broadcasters on analogue switch-off, but it also affected the use of program-making and special events (PMSE). The compensation was implemented only for the broadcaster and PMSE users, however. The households did not get subsidy on set-top box due to its cost rapidly fall together with aggressive market strategy of the broadcasting transition by the Federal States. So, impact on households was minimized. Broadcasters got financial incentive to analogue switch off and use of new platform. PMSE users typically make use of the spectrum on a license-exempt basis and they are not protected from any interference with other authorized (primary) uses in the band. Therefore, the allocation of the 800MHz band for mobile services raised concerns on the frequency interference and users were not aware of this risk. Compensation mechanism for migration cost and criteria were set.

c. Australia

In Australia, the Radio communications (Spectrum re-allocation) declarations (Declaration No.1 of 2011 and No.2 of 2011) which related to the 700 MHz band and 2.5 GHz were proposed by Australian Communications and Media Authority. Both bands were allocated for issuing as spectrum license. However, there were several different licenses actively operating in these frequency bands. The mechanism used to clear the services in each band depends on the type of license. ACMA has consulted extensively with stakeholders about its plans for the re-allocation of these bands, 700 MHz band including the marketing plan. A variety of communication methods have been used to reach as many stakeholders as possible at each stage of the re-allocation planning process. ACMA began its public consultation in October 2010.

The 700 MHz band was occupied by the commercial, national or community television broadcasting and low interference potential devices. The clearing process began from moving broadcasting services to other channels referred to as restack, occurred on an area-by-area basis. To accelerate the clearing process of 700 MHz band, government provided a financial incentive together with a clear timetable of restack implementation for the broadcasting industry to ensure the on timely clearing process with minimal disruption for viewers. At the same time, 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

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 auction process ran smoothly and resulted in the three remaining bidders, Optus Mobile, Telstra and TPG Internet securing the reallocated spectrum in the auction5. 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).

d. United States of America

Major refarming in the US can be categorized into two events. First is the relocation of 1710-1755 MHz band for commercial use. The Federal Communications Commission (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

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 to be auctioned for commercial purposes. The Office of Management and Budget (OMB) were responsible for transferring relocation expenses from the SRF to agencies. 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. 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. A portion of the auction proceeds was used to facilitate relocation of FCC systems.

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. 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 the rest is going to be auctioned off. The U.S. House of Representatives approved a budget for analogue switch-off in 2006. In March 2008, the FCC auctioned spectrum in the 700 MHz block or known as Auction 73, which had previously been allocated to analogue television. Auction generated $19.6 billion in revenue, nearly double prior estimates and the highest amount for any U.S. spectrum auction.

During the relocation process, the FCC placed rules on public safety for auction 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

Technology Neutrality Case Studies

Technology neutrality lets operators replace, for example, GSM with 4G and, soon, 5G in a particular frequency band. This process, which is also called refarming, allows spectrum to be used more efficiently, which should always be overarching the spectrum management goals for all regulators and governments. For mobile operators, this evolution also represents an opportunity to sunset legacy systems, and, therefore, reduce the extra cost of running multiple networks. Savings can be realised by:

- Simplifying network management operations and radiofrequency planning;
- Avoiding costly maintenance of ageing network equipment, including equipment spares;
- Eliminating ongoing costs of software licences;
- Reducing lease cost of tower space for multiple antennas; and
- Reducing energy consumption of the network.

a. Trading and Technology/Service Neutrality

Trading facilitates change in use. When licences are tradable, a higher value user can purchase the licence from a licensee who puts lower value in the spectrum access rights. This will lead to change of user (i.e., the licensee) and improved efficiency within a specific service. However, this does not facilitate a change in use – where a more efficient spectrum application or service replaces a lower value one. Change in use is facilitated by technology and service neutrality. This means removing technology and usage restrictions in licences unless those restrictions are necessary for the efficient management of the radio spectrum (to protect other users from interference, for instance). Neutrality is key to facilitate the introduction of new technologies for a new service or application.

Trading can be efficient in improving the value of mobile spectrum. For instance, smaller licensees whose spectrum lies fallow may sell to operators with stronger finance who can deploy the network. Neutrality also improves efficiency, since it allows mobile licensees to deploy better technologies and more innovative services, according to market demand and to the evolution of the technology.

Trading and neutrality are "soft" regulatory interventions – the regulator does not impose its own view on who is the most valuable use or user. As a result, they are suitable to a scenario where the regulator has a bias against intervention, or the regulator is not certain that there is or will be excess demand from a potentially higher value use. However, spectrum markets are far from perfect: there may be transaction costs, coordination problems, absence of price information and strategic behaviour. Change in use(r) may take a long time to crystallize or not happen at all. In those cases, the regulator may consider more interventionist measures, such as AIP or clearance.

b. Administered Incentive Pricing

Administered Incentive Pricing (AIP) is another tool that the regulator can use to pursue change to a more valuable use. AIP means that licence fees are set to reflect the opportunity cost of spectrum denied to other uses and users[1]. The regulator would act as a substitute of the secondary market and would set licence fees using its own estimate of the value of the spectrum to alternative users.

AIP has effects in the long term, as incumbents adapt to the new spectrum cost as part of their normal investment cycle. Therefore, introduction of AIP based fees is suitable when there is no urgent need to change use in a band. The main drawback of this approach to change in use is that it relies on the regulator impersonating the market: the regulator must estimate current and future demand from existing and alternative uses and put a price to it. These estimates are subject to a high level of uncertainty and can be contested by stakeholders, who may argue that they are based on arcane economic analysis.

1 See Ofcom´s Strategic Review of Spectrum Pricing for detailed guidelines on when and how to apply AIP: https://www.ofcom.org.uk/consultations-and-statements/category-1/srsp

In summary, AIP is appropriate if the regulator suspects that the current use is not the most valuable but trading and neutrality will not be effective (for instance, when migrating a band from FS use to mobile use) or removing existing users would be too disruptive or carry too high costs, or the new use will only become the highest value one in the long term.

c. Mandatory Refarming

Refarming is a regulatory intervention where the regulator imposes a change in the access conditions of certain licensees to enable a new use. Often this means that spectrum access is lost, but it doesn't need to (it could be a move to a different band, a different location[2], or introduction of stricter licence conditions[3]).

Trading, neutrality and AIP enable change in use by giving existing licensees the opportunity, but not the obligation, to free the spectrum they use. They are appropriate when the regulator does not have certainty about if, what, and when new users have higher spectrum value. However, in some cases the regulator is certain that a new use is more valuable, or there is a legal requirement for the change such as an update of the ITU Radio Regulations. In these cases, the regulator may decide to remove existing users. It should, as soon as possible, serve notice to these users that their licences would be revoked after a reasonable period of time. If sufficient notice cannot be given, the regulator may consider some form of redress, such as a move to a different band or a compensation.

Refarming is not without risks and costs. It is a more interventionist regulatory action than enabling trading or charging AIP: it is the regulator – and not the existing licensees and prospective new users – who makes the decisions on how and when change takes place. The regulator may get these decisions wrong: for instance, it might err on timing, with the result that it clears the spectrum too soon and it lies fallow for a time, or leave it too late, delaying benefits and incurring substantial opportunity costs. In addition, revoking licences may not be straightforward: the regulator may not have the legal power to do so, or may get embroiled in a legal dispute with the incumbents.

2 The use of the 3400-3800 MHz is currently precluded in the geographic region above the Amsterdam-Zwolle line due to an earth station at Burum site (used for national security). Co-existence between 5G in the region and satellite interception in the C-band is not possible without serious hindrance to the satellite reception. The impact could be limited with a 50 km exclusion zone, but this would cover the cities of Assen, Groningen and Leeuwarden. The Dutch Telecom Agency administration has assessed the value from 5G use of the band against the value associated with the national security. The Dutch government is now considering moving some of the activities in the earth station to another location – possibly in a different country. https://nos.nl/artikel/2264322-afluisterpark-nederlandse-veiligheidsdiensten-verhuist-naar-buitenland.html

3 The 2700-2900 MHz band is used in the UK for aeronautical radiolocation. The introduction of the mobile service in the 2600 MHz band created a risk of interference to these radars. Ofcom assessed the coexistence scenario and concluded on a high risk of interference to radars. Ofcom and the UK government established a radar remediation programme that involved the upgrade of the receiver filters of close to 100 radar installations across the UK. https://www.ofcom.org.uk/__data/assets/pdf_file/0022/32872/im.pdf

One way to mitigate these risks and costs is consider partial refarming. This means that a newcomer is awarded rights over a band that has incumbent users, but the rights of those incumbents are preserved in the precise frequencies and locations where they operate, either within the period after which the licences are revoked, or until the expiration of their licences.

Partial refarming allows the newcomer to start using the spectrum immediately, and allows the incumbents to continue operating[4,5]. In order to account for the fact that the newcomer cannot access the resources occupied by the incumbents (i.e. the opportunity cost), the licence fee of the incumbents is updated to reflect what the newcomer pays for the spectrum.

An additional advantage of this approach is that the refarming process is driven by the users and not the regulator. For instance, the newcomer could gain access to the spectrum rights of an incumbent before revocation, if both parties reach a deal after which the incumbent would surrender its licence. This deal would only happen at the locations where access to spectrum is more valuable to the newcomer than to the incumbent.

The drawbacks of this partial refarming are that it may be technically complex to specify the licence conditions of the new use if incumbents are numerous, and that the licence would be less valuable to the newcomer than a clean slate, since it has to engage in clearance itself.

A variation of this approach is to introduce a new use in a certain geographical area where it is more valuable than the incumbent service, while preserving the incumbent use in other locations of the country.

d. Refarming of Licence Exempt Bands

Under licence exemption, the conditions for spectrum access are determined by regulations and not by licences issued to individual users. Typically, licence exempt devices are low power and mass market. This means that, in practice, it is impossible to stop licence exempt use and to refarm a band to a different service. Since users do not have a licence, they cannot be reached by the regulator to revoke their access. Therefore, before opening a band for use without licence, a spectrum manager must be absolutely certain that it is the most valuable use for the long term.

4 A method to calculate the exclusion areas for the case of FSS-mobile coexistence in 3400-3600 MHz is described in ECC Report 254.

5 Ofcom release of the 3600-3800 MHz band contemplates restriction zones around satellite earth stations. See Annex 25 of the Award of the 700 MHz and 3.6-3.8 GHz spectrum bands: https://www.ofcom.org.uk/__data/assets/pdf_file/0014/130730/Annexes-19-26-licences-and-licence-procedures.pdf

PART D: PRACTICES AND ASSOCIATED IMPLICATIONS

Technology Neutrality

A technology neutral spectrum license allows a mobile operator to migrate the technology of its network according to its assessment of the demand from users and the state of the technology development. An operator would know when and at what locations it is more efficient to introduce newer technologies – for instance, using part of a block in the 1800 MHz band for LTE in certain urban areas but maintaining 2G/3G in the band in the rest of the country.

Service Neutrality

Service neutral spectrum licensing is widely recognised as best practice when assigning spectrum to mobile operators. It enables operators to refarm spectrum for use with not just a newer technology, but also in deploying new services that come with innovation in both services and technology. This can be associated with services that will rely on existing and newer bands, such as IoT, all at a pace that's driven by market demand. As a result, users benefit from a larger portfolio of services, when available and based on their needs.

Spectrum Reallocation/Refarming

1. Key issues and questions to be considered in preparation of spectrum evolution/ refarming for IMT/Broadband network deployment

a. Spectrum Harmonization;
b. Maturity of the technology to be introduced;
c. Device availability and affordability;
d. Market trends;
e. Radio Interface standards referring to ITU-R Recommendations and Reports;
f. Demographics and services (e.g. support of new services and applications);
g. Time frame for transition;
h. Assistance to customer in changeover to new technology; and
i. Compatibility with incumbent telecommunication systems.
j. General Migration process

Phase 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:

a. Operator restrictions;
b. Maturity of the network;
c. Expected traffic growth and
d. Network evolution.

Phase 2 - 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.

There are several functions which 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.

Phase 3 – Refarming (Frequency Plan Elaboration and 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:

a. Frequency Plan,
b. Updated Neighbour List,
c. Fall-back plan,
d. Fall back to the previous frequency plan,
e. A fast reactive process to identify and troubleshoot the worst performing sectors.

Phase 4 - Post Refarming Actions

A 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:

1. Ensure no severe degradation is present post-Re-farming. If this is the case, then a fall-back plan will be auctioned.
2. Acknowledge the necessary actions to be carried out in order to meet the agreed Acceptance criteria

Phase 5 - Performance Assessment

After Implementation, the network will be monitored mainly through the Operational Support Systems (OSS)-based tool. Other tools may also be utilized for specific monitoring tasks.

2. IMT/Mobile Broadband Technology and Deployment Considerations

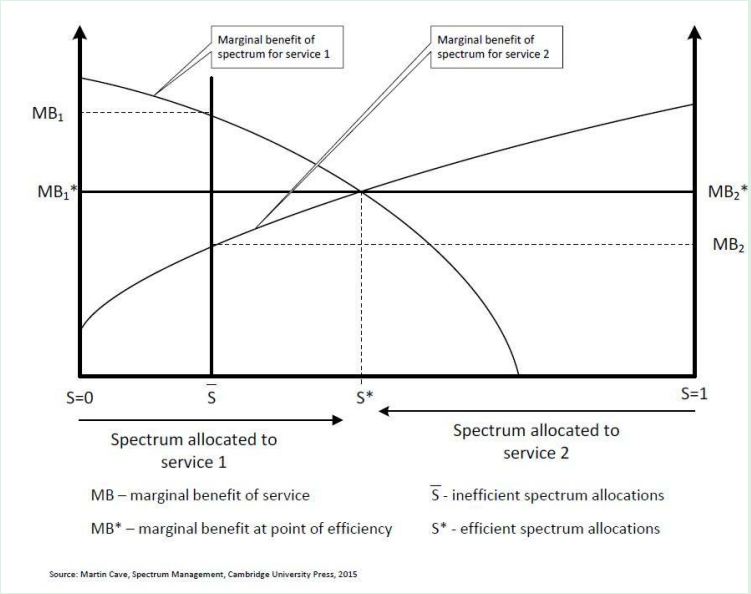
It is important to consider bandwidth, coverage and capacity requirements when intending to implement a new IMT/Mobile Broadband system.

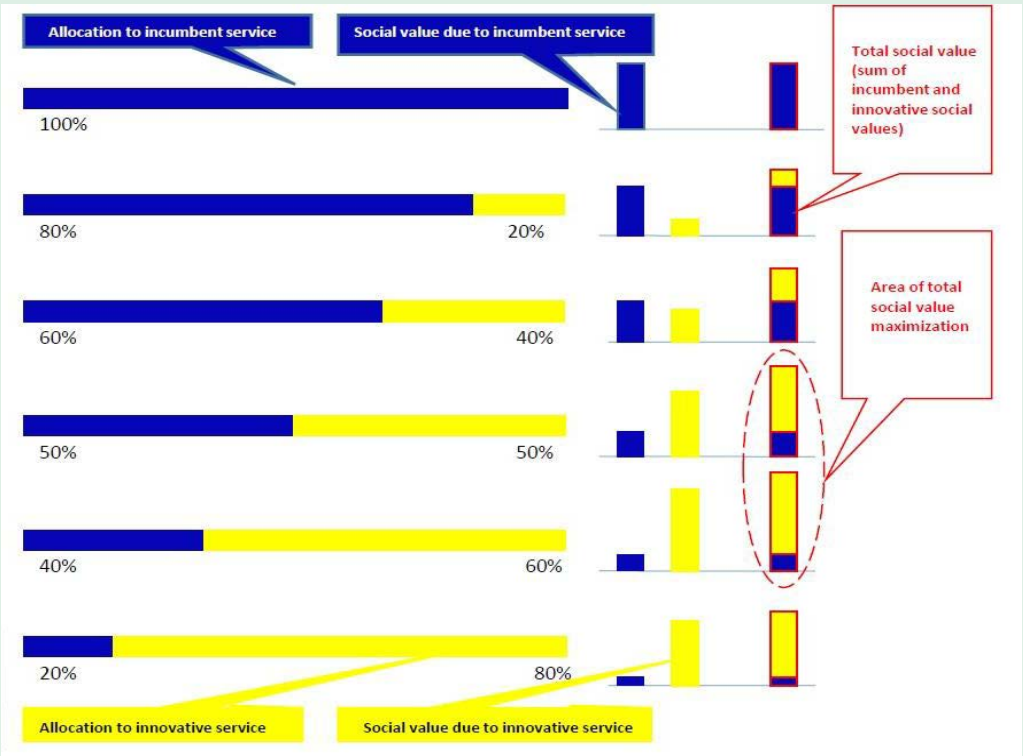
For more information on criteria leading to technology decisions, please refer to section 7 in the ITU-R Handbook on Global Trends in IMT - Edition of 2015.

A key to supporting the increasing data requirements of IMT/Mobile Broadband systems is the provision of sufficient backhaul capacity to avoid the creation of a bottleneck (please refer to section 6.4 in the ITU-R Handbook on Global Trends in IMT - Edition of 2015).

For applying spectrum re-allocation in certain cases, administrations should consider that spectrum re-allocation is the potentiality to obtain additional benefits to society arising from the optimal distribution of spectrum to innovative services, taking due account of incumbent uses. The key objective is to guarantee the balance between retaining enough spectrum to provide the services of the incumbent users and releasing as much as possible for perspective users while maximizing total social value from the optimal reallocation of the whole band.

How to Obtain Efficient Re-allocation [Egypt to make the diagram more readable]





The core challenge is to determine optimal ratio of spectrum resources allocated to incumbents and newcomers so as to maximize the overall social welfare, Market methods are highly eligible

The proposed method for calculating the compensation (financial) cost is: [the reference to be provided]

a) In case of facility replacement, financial cost (C_F) is given by:

$$C_F = (C_A - V_{RE}) \times \left(1 - \frac{1}{(1+R)^N}\right)$$

b) In case of facility supplement, financial cost (C_F) is also given by:

$$C_F = C_A \times \left(1 - \frac{1}{(1+R)^N}\right)$$

where C_A is acquisition cost of new facilities, V_{EF} is residual value of existing facilities, R is interest rate, and N is residual durable years.

Mitigation from 2G and 3G

A sunset takes place when a mobile network operator (MNO) switches off a particular generation of cellular technology, at which point all devices and services on that technology cease to be served. Many, but not all, consumer devices, such as phones, support multiple generations of mobile technology as standard, minimising the impact of a sunset.

However, industrial use cases for cellular technology, such as machine- to-machine (M2M) communications, are typically based on a single cellular technology. Hence the impact of a technology sunset varies by use case and device. For the worldwide global mobile communications market, the dominant standard for cellular networks is the Global System for Mobile Communications (GSM) with 90% of the mobile market according to the GSM Association.

Motivations for Technology Sunset:

- Free up spectrum for other technologies that offer better cost efficiency and greater revenue-generating functionality.
- Avoid the cost of refreshing and maintaining end-of-life equipment. Newer RATs (Radio Access Technologies) tend to be more cost-efficient to maintain, and the return on investment (ROI) in modernising 2G or 3G equipment will be lower than on expanding 4G or implementing 5G.
- Rationalise technologies to lower the operating complexity of running three or four different networks.
- Phase out inefficient or power-hungry base stations and devices.
- Reduce the variety of devices that need to be tested, provisioned and supported.
- Optimise the overall customer experience by migrating the entire user base to a more functional technology.
- Maximise the revenue opportunity by exposing all users to full mobile broadband applications and shift the service and marketing focus towards higher value users and services.

Risks of Technology Sunset:

- Possible reduced coverage, which may impede the MNO's ability to comply with regulatory coverage targets.
- Reduced coverage may also make it impossible for the operator to serve certain users or applications, and a decision must be made about the impact on the business of this loss.
- Even within the coverage area of the newer networks, the MNO may lose some subscribers who do not migrate. Again, an MNO must set a clear policy on which users it can afford to lose.

- A service may be migrated to the newer network, but may prove more expensive to run, because the new functionality is 'overkill'; or users may refuse to pay more for additional performance they do not require.
- On a newer network, MNOs may incur higher costs to finance or support more complex devices, even though the users may be using them only for basic functions, so those costs are not matched by increased service revenue.
- There may be negative impact on public image and reputation if the MNO is perceived to have 'left behind' vulnerable users, such as the elderly, or jeopardised important services, such as smart metering.

PART E: RECOMMENDATIONS

Spectrum Evolution Framework

ATU recommends Member States to:

1. **Publish** long-term spectrum utilization plans that prioritize the benefits of public welfare over state revenues;
2. **Develop** a clear roadmap for spectrum assignments in order to allow operators to plan and budget effectively, providing the predictability needed to encourage investment.
3. **Adopt** flexible rules to accommodate new technologies within existing spectrum licensing frameworks to facilitate rapid deployment.
4. **Provide** flexibility to mobile network operators to use their existing mobile licenses to offer service using newer technologies, particularly when deploying to unserved and underserved areas.
5. **Develop** dynamic spectrum assignment techniques in order to reduce the limitation of spectrum access in the mobile service;
6. **Ensure** adequate spectrum is available to deliver mobile broadband backhaul, including through new technologies. Proper spectrum regulation and licensing of backhaul spectrum are essential for rapid deployment of new mobile broadband technologies.
7. **Make available** databases of spectrum licenses and usage across service types in order to enable more efficient mobile/broadband network planning and to promote coordination between and coexistence of existing and emerging technologies.
8. **Establish** a common African agenda for a harmonised commercial launch of new mobile technologies
9. **Discourage** any attempts to extract additional revenue from converting technology-specific licenses to technology-neutral licenses as such actions hold strong potential to misfire and hold back the introduction of new mobile technologies.
10. **Periodically publish** national plans and frequency usage perspectives for mobile access networks on platforms allowing neighbouring countries to be aware of developments envisaged by neighbouring countries.
11. **Facilitate exchange** of best practices between Member States on spectrum auction design, cross-border coordination, etc. Member states could engage with the industry, through consultations and workshops, on emerging technology trends and ways to improve the regulatory frameworks necessary to support the digitisation of the society and industries.

Spectrum Licensing Neutrality

ATU recommends Member States to:

12. **Avoid** technology-specific spectrum licensing practices (e.g., issuing separate licenses for 2G, for 3G, for 4G, etc.) and adopt technology-neutral spectrum licensing frameworks that allow subsequent appropriate mobile standards within licensed IMT spectrum bands according to the market needs.
13. **Promote** technology neutral licenses to enable network voluntary legacy sunset, depending on specific market and operators' circumstances (e.g., user base) and potential obligations. A reasonable formal notice period commonly comes along with a well-designed campaign targeting affected customers, possibly assisted by the regulator in order to manage the temporary coexistence of both legacy and new technologies.

Refarming / Evolution Process

ATU recommends Member States to:

14. **Assess** the value to society that different spectrum services bring, in particular in bands where there is an incumbent use but there is also demand for mobile use.
15. **Consider** migrating to mobile service when their assessment indicates that it is the most valuable use of the band from a socio-economic perspective. However, migration may not be possible or preferred straight-away and nation-wide. In such cases, it is recommended that incumbents are given notice that their use of spectrum would terminate after a period of time. Until that time arrives, incumbent use carries an opportunity cost. This is because the higher value mobile use is precluded. It is recommended that this opportunity cost is reflected in the licence fees of the incumbent
16. **Introduce** mobile at the locations where the incumbents do not operate, while preserving incumbent use at its current location. This is applicable when considering migration to mobile services in a band with incumbent use. It would require careful technical coordination to avoid interference between the two services. In practice, this could be put in place for each incumbent installation (for instance a point-to-point link, or an earth station), or for a large geographical area (for instance exclude mobile deployment from rural areas).
17. **Encourage** spectrum evolution strategies including 2G and 3G sunset taking into consideration the pace of technology development and adoption in the developing African countries. In case of avoiding the risks of 2G or 3G technology sunset and the above point, it is highly recommended to free up spectrum for new technologies that offer more spectrum efficiency usage

18. **Use Market** methods and indicators to determine the optimal ratio of spectrum resources allocated to incumbents and newcomers so as to maximize the overall social welfare, in applying spectrum refarming;
19. **Give priority** to refarming options that minimize its impact on quality of service and also from financial and technical perspectives (network shutdown, configuration of stations, etc.);
20. **Adopt** a general migration process that consist of 5 phases i.e.
    a. Feasibility Study,
    b. Pre-refarming actions,
    c. Refarming,
    d. Post refarming actions and
    e. Performance Assessment
21. **Consider** providing a spectrum refarming fund that could be used to finance spectrum refarming.

Coexistence with Incumbent Services

ATU recommends Member States to:

22. **Promote** the use of frequency bands identified and allocated to IMT to enable efficient assignment to mobile services, whilst taking into consideration existing services
23. **Organise** periodical frequency coordination meetings at the borders (bi/multi-lateral, sub-regional) under the auspices of the ATU and the various regional sub-groups.

PART F: ABOUT THIS RECOMMENDATION

Development: This recommendation was developed by an ATU Task Group on Spectrum Recommendations from July 2020 to February 2021. This group was led by the following:

Name (Country)	Role
Dr Mohamed EL-MOGHAZI (Egypt representing North)	Chair – Task Group
Wilson BOKATOLA (Congo representing ECCAS)	Rapporteur – Recommendation 001- 0
Alfred Joseph BOGERE (Uganda representing EACO)	Rapporteur - Recommendation 002- 0
Gabriel KOFFI (Cote d'Ivoire representing ECOWAS)	Rapporteur - Recommendation 003- 0
Dick SONO (South Africa representing SADC)	Rapporteur - Recommendation 004- 0

Validation: This recommendation was validated in a validation forum that was held from 4th to 5th March 2021. The forum was led by the following bureau:

Chair: Valéry Hilaire OTTOU (Cameroun representing ECCAS)

Vice-Chair: Ahmed BORAUD (Niger representing ECOWAS)

Rapporteurs: Stella BANYENZA (Tanzania representing EACO/SADC)

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Official Launch: This recommendation was officially launched on 22 April 2021 by the Minister of Posts and Telecommunications of Cameroun, **Mrs LIBOM LI LIKENG née MENDOMO AWOUMVELE Minette**

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