Securing the digital dividend across the entire ASEAN

A report on the status of the implementation of the APT700 band for ATRC

August 2018

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Executive summary

Overview

In ASEAN countries, which form part of the International Telecommunication Union (ITU) Region 3, significant work remains to be done to secure the benefits of the 'digital dividend' in the 700 MHz band for the region's telecommunications users. Following the conversion to digital television, spectrum bands must be cleared, the Asia-Pacific Telecommunity ('APT') APT700 band plan needs to implemented, and the provisioning of wireless broadband service using the digital dividend spectrum must be rolled out.

A few countries have completed the digital television switch-over ('DSO') and auctioned the band, with some commercial mobile network deployments, for example, in the Philippines. Some others are still considering DSO with no clear analogue television switch off date.

Table 1 Status of APT700 implementation in ASEAN

Country	Operat-ional	700 MHz allocation date or expected allocation date	Comments
Brunei Darussalam	No	Post 2019	Band currently vacant and ready for mobile broadband service. AITI and MCMC have not agreed on any technical parameters yet. Malaysian APT700 implementation should facilitate APT700 in Brunei
Cambodia	No	Post 2019	Band licensed to Digital Television and Government has tried to clear but still negotiating with existing licensees. More clarity in Q3, 2018 after Cambodian election
Indonesia	No	Post 2022, unless able to allocated regionally	In part of the country including Java the usage of the 700 MHz spectrum blocked by Supreme Court injunctions. SDPPI seeking alternative approaches to secure spectrum including legislative changes, regional licences etc
Lao PDR	No	Post 2019	MPT supported 700 MHz band for IMT and APT700 band plan since 2015. Interference concerns with Digital Television in neighbouring countries delaying implementation
Malaysia	No	2018 with use from Q1, 2019	The MCMC is evaluating a beauty contest for 8 lots of 2 x 5 MHz of the spectrum will announce more information after the Malaysian election. DSO not finalised but scheduled for the end of 2018 unless changed by new incoming Government
Myanmar	No	Early 2019	Proposed for allocation under Ministry/PTD spectrum roadmap by late 2018. Likely to be post February 2019
Philippines	Yes	June 2016	Acquired from San Miguel Corp. 2 x 10 MHz available for allocation to successful 3rd New Market Player in 2018
Singapore	No	Early 2019	Auctioned by IMDA in late 2017. DSO delayed and will be completed end of 2018. In discussions with neighbouring country regulators, the MCMC and SDPPI regarding its use in Singapore.
Thailand	No	Post 2020/21	Still being used by digital TV, then subject to refarming and repacking. Government may try and bring forward to 2020/21 depending on analogue TV concession issues and other transition issues
Vietnam	No	2020	APT700 allocation supported by ARFM after clearance of television broadcasting. DSO completed in major urban cities and soon in Delta region. MIC/VNTA also strongly supportive.

This detailed GSMA follow up report covering the assignment and deployment of 700 MHz services in ASEAN and a range of possible interference issues, finds there is strong support across the region for the release of more harmonised IMT spectrum to respond to the very strong growth in regional wireless broadband demand.

Unfortunately, there are three key factors which are holding back the availability and allocation of 700 MHz to IMT services in ASEAN: the DSO; cross-border co-ordination issues; and how the 700 MHz band, once it is available, should be allocated. These three factors can be addressed, by *inter alia* accelerating the DSO, resolving cross-border co-ordination issues to minimise harmful interference and for ASEAN regulators to commence consultations in their individual markets on how the 700 MHz spectrum band should be optimally allocated.

In the coming 6 to 12 months, the successful resolution of key cross-border co-ordination bottlenecks, will do much to accelerate the adoption of APT700 in ASEAN. Similar to the broader consensus model which underpins ASEAN and the interaction between its members, it is hoped that with considerable goodwill these co-ordination issues can be resolved.

Societal, economic and commercial benefits

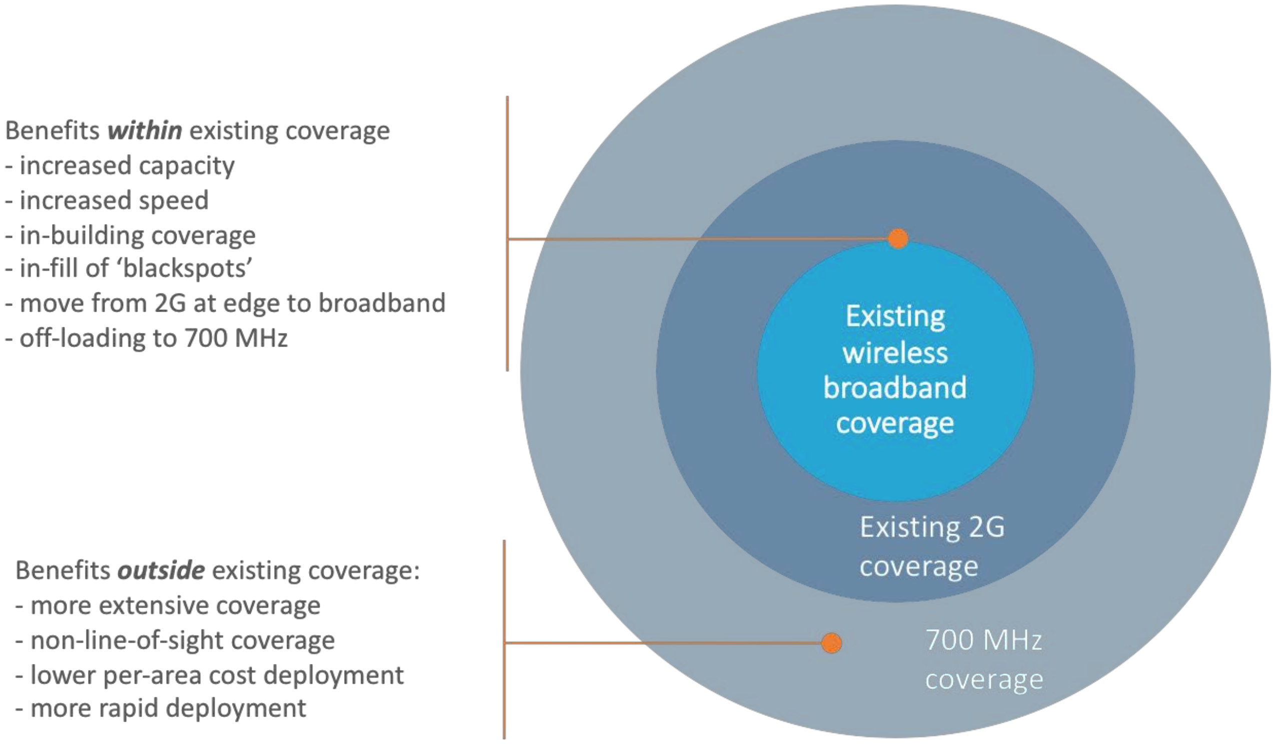
Spectrum in the 700 MHz range provides significant cost advantages over high-frequency spectrum because of its propagation characteristics. It operates over greater range than higher frequencies, provides superior performance inside buildings and is attenuated less by terrain and foliage. The increased range means that 700 MHz coverage can be up to 300 percent greater than 2.6 GHz.

These propagation characteristics deliver substantial costs savings for operators and benefits to consumers. Operators require fewer base stations and therefore face significantly lower capital cost per unit area covered and therefore they can achieve a more rapid rollout. Consumers enjoy larger coverage areas, fewer blackspots, better in-building coverage and, if markets are sufficiently competitive, will likely see lower prices for services. In practice, propagation characteristics will depend on local topography, and nature of foliage cover, which in ASEAN countries can be relatively dense.

The economic and social benefits of 700 MHz deployment arise from several sources. First, telecommunications users benefit from greater service speed and reliability as 700 MHz services add to the overall capacity of the mobile network. As described above, consumers will also benefit from more extensive coverage, better in building performance and reduction in blackspots. Importantly, the lower capital costs of deployment will mean consumers enjoy these benefits sooner than they would with deployments at higher frequencies. To the extent that 700 MHz deployments might encourage improved competitiveness in the market, consumers may also enjoy lower prices.

The economic benefits, however, are not restricted to telecommunications users alone. Improved availability and quality of telecommunication services positively influences economic growth which delivers even more widespread benefits across all of society.

Figure 1 Conceptual representation of the benefits of 700 MHz deployment over existing IMT spectrum bands



700 MHz spectrum is very well suited to providing coverage in regional and remote locations where market density is low and where communications infrastructure investment may not be commercially viable. In these situations, governments wishing to address 'digital divide' and social inclusion issues, will be able to bring services to these areas at lower levels of subsidies than would be the case at higher frequencies.

Potential cross-border interference issues

Cross-border frequency coordination cannot be addressed without considering the results of international and regional spectrum management and harmonisation. These spectrum management results provide important guidelines and restrictions on the implementation of IMT (in the 700 MHz Band) and consequently on the cross-border frequency coordination between countries (who ultimately assign spectrum and implement IMT).

Key spectrum licensing considerations

In bringing 700 MHz services to telecommunications users, four core sets of decisions regarding licensing will need to be addressed: lot sizes for spectrum allocation; establishment of rules for coexistence of adjacent services and related guard bands; programs for the phase-out of other incumbent users in the 700 MHz band (for example, wireless microphones); and arrangements for Public Protection and Disaster Relief (PPDR).

While LTE supports flexible usage, the most common practice in the region for the APT700 band is 2 x 5 MHz lots which would allow for a total of 9 lots in the available spectrum. This allocation model will encourage competition for spectrum licenses assuming that demand for services is sufficient and reserve prices are set appropriately. Auction design should enable bidders that wish to bid for larger lot allocations made up of 5 MHz increments.

As highlighted in this report, there are considerable and compelling benefits for all ASEAN countries to deploy APT700 including improved wide and indoor coverage, increased wireless broadband speeds and more efficient IoT deployments. The ability of mobile operators to quickly utilise 700 MHz spectrum in their service provisioning due to their modern LTE networks will have material benefits in terms of operator capex and opex. These benefits have been highlighted by case studies of successful APT700 implementations in the Philippines and in Australia.

Recommended six-step plan

In detail, a six-step plan is recommended in order to secure the digital dividend across the entire ASEAN. Ministries and national regulators should:

1. Accelerate the DSO process where it is not completed, potentially prioritising those areas of the country where cross-border co-ordination arrangements are required;

2. Review and revise, if necessary, the national frequency allocation table arising from the adoption for the harmonised APT700 Band for 698-806 MHz considering co-existence issues;

3. Undertake internal reviews (and market consultation processes with licensed mobile operators, if required) to determine the optimal allocation processes in accordance with national law for the APT700 spectrum. Such review should address inter alia spectrum management, PPDR, competition, and universal service issues;

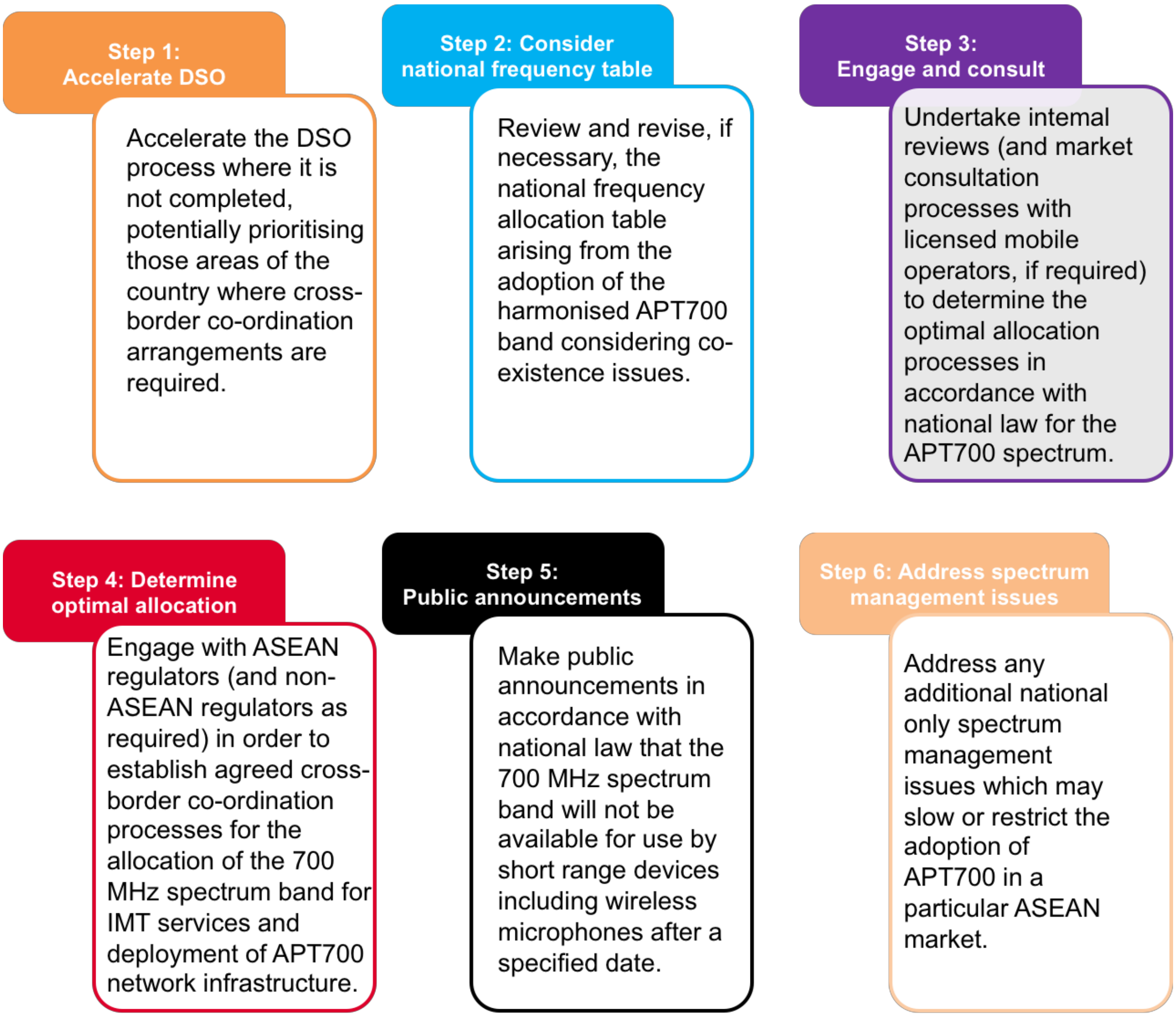
4. Engage with fellow ASEAN regulators (and non-ASEAN neighbouring regulators as required) in order to establish agreed cross-border co-ordination for the allocation of the 700 MHz spectrum band for IMT services and deployment of APT700 compliant network infrastructure and services. Resolution of the key bottlenecks to the implementation of APT700 highlighted this report (e.g. Singapore /Johor / Bintan and Bantam) should be the focus over the next 6 to 12 months;

5. Make public announcements (including specifically to industry and key equipment distributors) in accordance with national law that the 700 MHz spectrum band will not be available for use by short range devices including wireless microphones after a specified date. This date should be based on the DSO finalisation and assignment process of 700 MHz spectrum; and

6. Address any additional national spectrum management issues which may slow or restrict the adoption of APT700 in a particular ASEAN market (e.g. Indonesia's court decisions, Cambodia's existing 700 MHz allocations, Thailand's digital television licences and legacy concessions etc). In addressing such issues, the national economic, societal and

commercial benefits of making the 700 MHz spectrum band as soon as practicable should be highlighted to decision makers.

Figure 2 Summary of the recommended six-step plan



Introduction

Context

Spectrum is the foundational element of the global mobile industry and at a policy level is key to the provisioning of affordable wireless broadband services to all consumers. While any spectrum is desirable, all spectrum isn't equal. For spectrum to be useful and usable, it needs to be harmonised. That is, there needs to be the uniform allocation of radio frequency bands across entire regions — not just individual countries. Uniform allocation comes with many significant advantages; it minimises radio interference along borders, facilitates international roaming and reduces the cost of mobile network infrastructure and devices.

Harmonised spectrum below 1 GHz, including the familiar 900 MHz and 850 MHz spectrum bands and now the 700 MHz frequency band, is particularly useful. This is because spectrum's propagation characteristics below 1 GHz provide greater geographic reach/coverage and better in-building penetration relative to higher frequencies. With greater reach the number of cellsites needed to serve an area is significantly less than if higher frequencies such as 1800 MHz, 2100 MHz and 2600 MHz are used. This fact, which has been well analysed and modelled, translates to lower deployment (both capital expenditures and operating expenditures) costs for mobile operators and hence more affordable services to consumers.

In ASEAN countries, which form part of the International Telecommunication Union (ITU) Region 3, the securing of the 'digital dividend' in the 700 MHz band arising from the conversion to digital television, the clearing of the band, the implementation of Asia-Pacific Telecommunity ('APT') APT700 band plan and the provisioning of wireless broadband service using the digital dividend spectrum is still disparate. A few countries have completed the digital television switch-over ('DSO') and auctioned the band, with some commercial mobile network deployments, for example, in the Philippines. Some others are still considering DSO with no clear analogue television switch off date.

The analogue to digital television switch over process was the focus of last year's GSMA report entitled *Practical Recommendations to Digital Migration in ASEAN: Vietnam case study and regional comparisons*, August 2017, primarily covering the key aspects for re-planning the band for DTT and freeing-up the 700 MHz band for mobile services. In continuation of this important work for the region, this paper, is a detailed follow up report covering the assignment and deployment of 700 MHz services in ASEAN and a range of possible interference issues. It has been prepared for the ASEAN Telecommunications Regulators' Council ('ATRC') meeting scheduled for August 2018.

Structure of this paper

The structure of this Paper is straight-forward, comprising three parts namely the licensing and allocation issues, network deployment issues and cross-border co-ordination and interference issues divided into 5 sections with some appendices as follows:

- An indicative timeline of mobile licensing of the 700 MHz using the APT700 band plan in the ASEAN countries including the current and projected implementations;
- Identification of the societal, economic and commercial benefits including cost savings for APT700/LTE Band 28 network roll out and identification of any deployment issues faced by operators and case studies from the Philippines and Australia;
- Identification of potential cross-border interference issues including assessment of potential lost benefits/ costs, from unmanaged cross-border interference in countries with particularly long borders and recommended cross-border interference mitigation and coordination approaches;
- Key considerations for licensing the 700 MHz band for mobile using the APT band plan including recommended lot sizes, other key allocation issues, options for co-existence and options for managing the phase-out of other incumbent users especially wireless microphones; and
- Conclusions and Recommendations.

Timeline of mobile licensing for APT700 in ASEAN

Introduction

Regionally in ASEAN there has been almost a decade long commitment for securing the 'digital dividend' from the transitioning from analogue to digital television broadcasting and the licensing of that spectrum for mobile services.

On 5 November 2009, at the 10th Conference of the ASEAN Ministers responsible for Information ('AMRI') the Ministers endorsed progress in ASEAN Digital Broadcasting co-operation. The ASEAN Member States at the AMRI affirmed the importance of early digitalisation to reap the benefits of the digital dividend and to ensure that terrestrial broadcasting remains relevant in the face of competition from new media platforms such as mobile and IPTV. Ministers went on to state that recognising that Member States are at different stages of readiness for digital TV implementation, ASEAN adopts a phased approach towards Analogue Switch-off over a period of time from 2015 to 2020.[1]

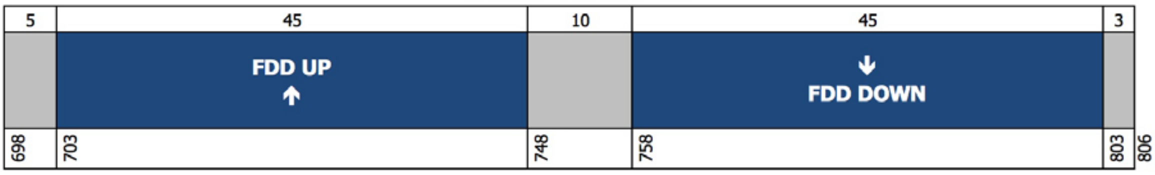
At the technical level as Asia-Pacific countries started digitising television services and thus making the recovery of a portion of the analogue television spectrum bandwidth possible, the 700 MHz band was considered as an ideal band for future low band LTE requirements. The APT Wireless Group ('AWG') developed an APT Report on "Implementation Issues associated with the use of the Band 698-806 MHz by Mobile Services"[2] in 2011. APT700 as it became known was officially standardised by 3GPP as LTE Band 28 in 2012. Simultaneously APT700 was promoted to the ITU-R which subsequently designated the band for mobile communications. This band plan then received wide acceptance globally.[3]

Further in November 2013, at the 13th meeting of ASEAN Telecommunications and IT Ministers Meeting (TELMIN) in Singapore, the Ministers: *"… supported the innovative utilisation of radio frequency in ASEAN to further enhance ICT connectivity through the continued formulation of enabling policies and regional cooperation, and intensifying cooperation for greater harmonisation of the digital dividend spectrum within ASEAN, including the Asia- Pacific Telecommunity 700 MHz band plan for the deployment of mobile broadband services."*[4]

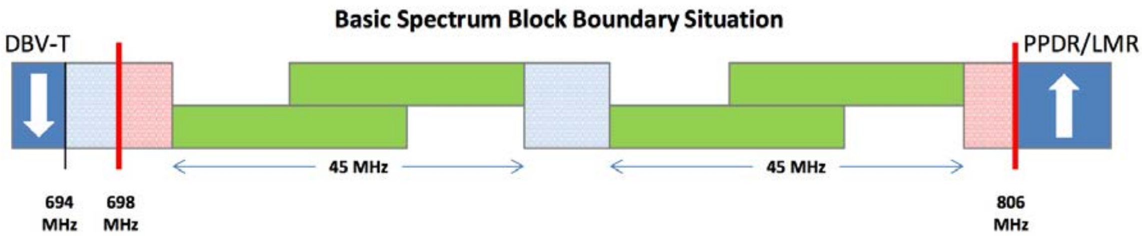
The APT700 band is officially known as LTE Band 28 within 3GPP. The UE terminal (FDD uplink) uses the frequency range from 703 MHz to 748 MHz and base station (FDD downlink) uses the range from 758 MHz to 803 MHz (as shown below). There is a 10 MHz duplex separation. The TDD variant of the band plan makes the entire 100 MHz (including the 10 MHz FDD duplex separation) available.

1 http://asean.org/?static_post=joint-media-statement-10th-conference-of-the-asean-ministers-responsible-for-information-amri
2 www.apt.int/sites/default/files/Upload-files/AWG/APT-AWG-REP-24_APT_Report_698-806_Band_Implementation_UHF.pdf
3 https://telsoc.org/sites/default/files/tja/pdf/56-611-1-pb.pdf
4 www.asean.org/wp-content/uploads/images/Statement/2013/04%20--%20final_telmin-13-jms%20__151113.pdf, paragraph 6

Figure 3 Summary of APT700 band plan (3GPP Band 28)



The relatively wide bandwidth available in LTE Band 28 plan means that two duplexers are required in the UE terminal. These two duplexers overlap by some amount allowing operators with centrally located spectrum to still be served from a single duplexer. The upper and lower green bars below represent the UE duplexers. A UE can switch between both duplexers via a front-end switch.



The lower duplexer available in a Band 28 UE is compatible with the 2nd European Digital Dividend (so-called DD2). The 1st European Digital Dividend (Band 20) uses a reverse duplexer arrangement. This means that the base station transmitter for band 20 (791 – 821 MHz) is conveniently adjacent to the base station transmit for the lower 33 MHz of band 28 (758 – 791 MHz). This results in simple interference management between these bands. The UE duplexer filters for DD2 are 30 MHz bandwidth (758 to 788 MHz) making the receive path in the UE harmonised with LTE band 20.

Where deployment of LTE is co-ordinated with the digitisation of the television services (DVB-T or other transmission standards), interference between DVB-T and LTE is mitigated through the duplex arrangement and lower 9 MHz guard band (694-703 MHz). However, where deployment occurs in a region with neighbouring countries, cross-border interference may need special consideration (which is discussed later in this report). For these regions it is strongly recommended that a common band plan (e.g. APT700) is adopted. Secondly, a co-ordinated implementation of digital TV services and LTE deployment will also be required to avoid situations where TV transmitters interfere with LTE receivers, specifically the base station receiver.

These ASEAN wide positions on the 700 MHz digital dividend and the licensing of spectrum in accordance with the APT700 Band plan were affirmed as recently as 10 May 2018. At the 14th AMRI Conference and 5th Conference of ASEAN+3 Ministers Responsible for Information held in Singapore in May 2018, the Ministers noted: *"… the progress of Analogue Switch-Off (ASO) by the respective ASEAN Member States and acknowledged the need for the Member States to strive* *towards meeting the 2015-2020 ASO timeline that was agreed at the 10th AMRI in Lao PDR in 2009 and at the 13th TELMIN in Singapore in 2013."*[5]

Status of APT700 implementation in ASEAN

As shown in Table 2 below, the situation in ASEAN markets varies from full commercial use of the band to having not yet started their analogue to digital television transition necessary to secure a digital dividend in the 700 MHz band.

Table 2 Summary of current status of APT700 implementation in ASEAN

Country	Oper at-ional	700 MHz allocation date or expected allocation date	Comments
Brunei Darussalam	No	Post 2019	Band currently vacant and ready for mobile broadband service. AITI and MCMC have not agreed on any technical parameters yet. Malaysian APT700 implementation should facilitate APT700 in the country
Cambodia	No	Post 2019	Band licensed to digital television and Government has tried to clear but still negotiating with existing licensees. More clarity in Q3, 2018 after Cambodian election
Indonesia	No	Post 2022, unless able to allocated regionally	In part of the country including Java the usage of the 700 MHz spectrum blocked by Supreme Court injunctions. SDPPI seeking alternative approaches to secure spectrum including legislative change, regional licences etc.
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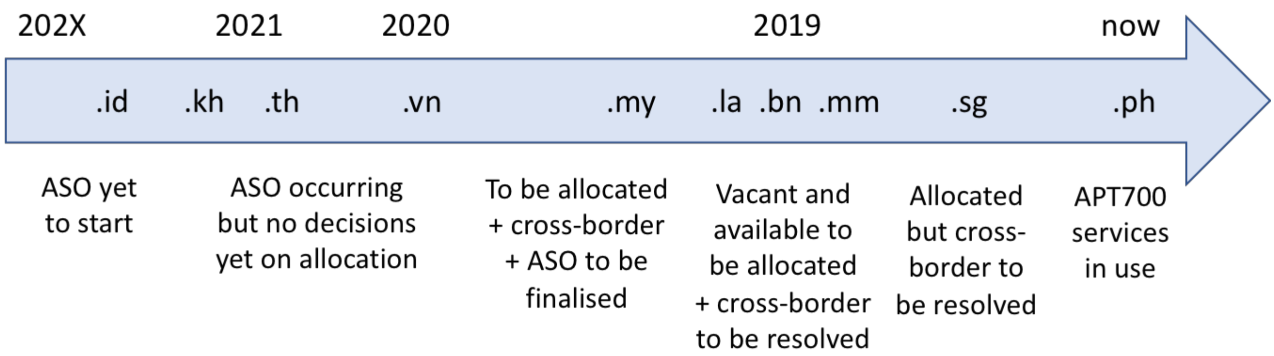
Vietnam	No	2020	APT700 allocation supported by ARFM after clearance of TV. DSO completed in major urban cities and soon in Delta region. MIC/VNTA also strongly supportive.

5 http://asean.org/storage/2018/05/14th-AMRI-JMS-FINAL.pdf

A more detailed individual country summary of the current status of APT700 implementation in ASEAN is contained in Appendix A.

The timeline in ASEAN for the availability and allocation of 700 MHz to IMT services and the adoption of APT700 Band plan can be summarised as shown in Figure 4. The three key factors which are holding back the deployment in order of importance are the analogue to digital television migration, cross-border co-ordination issues and how the 700 MHz once it is available should be allocated.

Figure 4 ASEAN timeline for availability and allocation for 700 MHz for IMT and APT700 band plan



Source: WPC, August 2018

Considering cross-border co-ordination issues, Figure 5 highlights which countries need to enter into discussions in order to co-ordinate implementation and minimise interference, given their adjacent borders and/or close proximity.

Figure 5 Critical decision points for cross-border co-ordination concerning the implementation of the APT 700 band

However, it should be noted that:

- Singapore's co-ordination issues with Indonesia and Malaysia, can be addressed, in the case of Indonesia, if a technical solution can be found in relation to the co-ordination of analogue/digital television and mobile services in Bintan and Bantam islands and in the case of Malaysia with Johor;
- Myanmar's co-ordination issues with Bangladesh, China, India, Thailand and Lao PDR, are more likely to be with Thailand as (i) the 700 MHz spectrum is vacant in both Lao PDR and Bangladesh and ready to be allocated for APT700 and (ii) the borders with China[6] and India are mountainous. Likewise, Lao PDR's key cross-border co-ordination negotiation is with Thailand, given the location of Vientiane on the Mekong River directly on the Lao PDR-Thailand border;
- Vietnam's co-ordination issues with China, Lao PDR and Cambodia in 2020 are made easier as the 700 MHz spectrum is vacant in Lao PDR and the borders between Lao PDR and Vietnam (i.e. the Annamite Range) and between China and Vietnam are mountainous. Any co-ordination issues if they exist will be more likely, between Vietnam and Cambodia;

6 The border begins at Hkakabo Razi (5881m) the highest mountain in South East Asia passing through the mountain ranges of Jiongshan and Jiangaosh (3302 m).

- Malaysia and Indonesia co-ordination issues in Sarawak/Sabah and Kalimantan respectively should be relatively straightforward given the reduced number of terrestrial broadcasting services utilising the UHF band on Borneo Island;[7] and
- Brunei Darussalam can immediately implement APT700 once the ASO is completed in Malaysia.

Compatibility with future 5G spectrum allocations

The other advantage for ASEAN adopting APT700 is that the 700 MHz band could, in the future, become the affordable coverage layer for future 5G services given its designation as a 5G in the EU since December 2016.[8] It is now the view from the European Commission's Radio Spectrum Policy Group that in Europe in relation to 5G services:

"The 700 MHz band can be used to provide wide area coverage, the 3.6 GHz band can be used to provide high capacity and coverage, using both existing macro cells and small cells. The 26 GHz band is likely to be deployed in areas with very high demand, for example transport hubs, entertainment venues, industrial or retail sites and similar."[9]

As in many ASEAN countries the 3.6 GHz band is not available given its use by satellite broadcasters, the 700 MHz spectrum band becomes more important, along with the 2600 MHz band providing additional capacity. The use of the future harmonized L-Band (1500 MHz) may also be supported.

7 For example, the use of NJOI, - the free satellite television service launched in 2012, as a collaboration between the Government of Malaysia and Astro. See www.astro.com.my/njoi

8 See http://europa.eu/rapid/press-release_IP-16-4405_en.htm

9 EC, Radio Spectrum Policy Group, *Strategic Spectrum Roadmap towards 5G for Europe: RSPG Second Opinion on 5G networks, RSPG18-005 FINAL*, 30 January 2018.

Societal, economic and commercial benefits

Comparative cost savings for APT700 and deployment issues

Optimising a country's provision of mobile services involves balancing two different costs to industry: the network capital cost required for operators to provide capacity for a given amount of spectrum (e.g. BTS/e-node B construction and maintenance) and the economic or opportunity cost of assigning more spectrum to mobile in order to increase spectrum resources in productive use. As the supply of mobile spectrum is increased, existing base stations can supply increased capacity with modest additional network capital investment. In contrast, where the supply of usable mobile spectrum is restricted, the network capital cost increases.

The ability to deploy APT700 in the 700 MHz spectrum band brings with it a range of coverage, speed and costs benefits which are explored below.

Coverage benefits of APT700 deployment

Mobile operators can take advantage of the lower RF path loss that accompanies the lower frequency.

The theoretical increase in cell radius for 700 MHz equates to a 300 percent increase in area coverage over 2600 MHz.[10] In dense urban environments the coverage area increase can be up to 7 times. As with 3G deployments at 850 or 900 MHz, LTE at 700 MHz will have significantly better in-building penetration compared to 1800, 2100 and 2600 MHz deployments.

With typical link budget parameters and configuration, uplink coverage is limited. A comparison based on the uplink edge rate from dense urban to rural environments and the coverage radius of a single site utilizing 700 MHz, 800 MHz, 1.8 GHz, 1.9 GHz, 2.1 GHz, and 2.6 GHz is shown in Table 3.

From Table 3, a single site coverage area using the 700 MHz band in various scenarios is the equivalent of 7 to 8 times that of the 2.6 GHz band. In other words, to cover the same area, the number of sites used for 2.6 GHz will be 7 to 8 times what is used for 700 MHz.

[10] The Area covered is calculated by the formula Area = πr^2. As such for the example mentioned if the cell radius increases from 14km to 24km then the comparative area is 3 times larger.

Table 3 Uplink coverage comparison of typical scenarios

Morph		Dense Urban	Urban	Suburban	Rural
Cell Edge User Throughput	kps	512	256	128	64
700 MHz					
UL Cell Range	km	0.70	1.21	3.37	8.48
Coverage Area	km^2	0.95	2.84	22.16	140.37
800 MHz					
UL Cell Range	km	0.63	1.09	3.04	7.65
Coverage Area	km^2	0.78	2.33	18.06	114.22
1800 MHz					
UL Cell Range	km	0.38	0.64	1.67	4.40
Coverage Area	km^2	0.27	0.80	5.42	37.71
2.1 GHz					
UL Cell Range	km	0.32	0.55	1.41	3.77
Coverage Area	km^2	0.21	0.60	4.00	27.69
2.3 GHz					
UL Cell Range	km	0.30	0.51	1.31	3.44
Coverage Area	km^2	0.17	0.50	3.35	23.08
2.6 GHz					
UL Cell Range	km	0.27	0.45	1.16	3.04
Coverage Area	km^2	0.14	0.40	2.63	18.06

Source: ZTE, APT700, Best choice for nationwide coverage, June 2013

However, in rural areas greater coverage per site implies fewer sites. While sometimes this is calculated based on theoretical networks, in practice the number of sites required is dependent upon the terrain and the specific topology, distance between population centres, etc. It is still necessary to deploy a site in every place where there is a need for good coverage (e.g. in the population centres). The main difference is that fewer sites will be required in order to provide coverage along rural roads, etc. In order to compute the real cost benefits of deploying APT700 it would be necessary to model each specific country. In drive tests, in tropical countries there are a number of additional kilometres of weaker but usable coverage in rural areas with moderate foliage. This would be of considerable benefit in many ASEAN countries given their climate and vegetation.

In areas where coverage is anyhow limited (e.g. by terrain such as hills) the benefit to the MNO in having a reduced number of sites (and associated backhaul, site acquisition and opex) might be lower than in a large sparsely populated flat area. In urban areas the cost benefit is more limited as a mobile operator needs a dense network with a larger number of sites and small inter-site distance for capacity reasons. However, in general it can be stated; the coverage utilising the 700 MHz spectrum is more extensive and of better quality and the indoor coverage is often better (due to the lower indoor propagation loss).

Deploying APT700 with LTE1800

Notwithstanding the inter-site distance of a mobile radio network designed for 1800 MHz is smaller, it is still possible to add a 700 MHz layer, and with it comes a number of significant advantages including better in-building penetration as well as the higher speeds with carrier aggregation.

To add such a layer, it is important to select a good high gain antenna with a very narrow vertical opening angle (7 degrees or less). This will ensure that the operator is able to focus the signal within the cell and to reduce the spill-over into neighbouring cells. Low-gain antennas with a larger vertical opening are not recommended. It is important to note that it is not possible to solve any issues with more tilting – this is because the vertical beam is not sharp enough to have good signal within the cell and sufficiently fast signal reduction beyond the cell. An antenna with less than about 17.5-18 dB gain and/or close to 7 or less degrees vertical opening angle is therefore not suitable. Even higher gain antennas are desirable but quickly they become unpractical due to their physical size.

In the urban areas where an operator is able to overlay a 700 MHz network layer on top of a dense and good 1800 MHz layer, antenna selection and good electrical downtilting of high gain, narrow vertical opening angle antennas, is therefore the key issue.

Faster speeds - carrier aggregation options with APT700

Given all ASEAN markets already have LTE services deployed in a range of IMT bands including 900, 1800 (most typical), 2100, 2300 and 2600 MHz (FDD and TDD), another key benefit of deploying APT700 services is an increase in speed or bandwidth which can be offered to consumers. The increase in bandwidth is achieved by utilizing LTE carrier aggregation/channel aggregation ('CA') which combines multiple LTE carriers to increase bandwidth and achieve higher data rates of LTE-Advanced ('LTE-A')[11] and LTE-A Pro.[12]

LTE supports flexible usage of bandwidths of 1.4 MHz, 3 MHz, 5 MHz, 15 MHz, and 20 MHz standardised by 3GPP. These are called component carriers ('CC') and the current standards allow for a maximum of five CCs to be aggregated.[13] Therefore maximum bandwidth that can be achieved is 100 MHz. CA with APT700 is already available in 2, 3 and 4 inter bands configurations with all of the other common ASEAN IMT spectrum bands (see Table 4). Such additional bandwidth will significantly improve the quality of service offered to consumers.

11 See www.3gpp.org/technologies/keywords-acronyms/97-lte-advanced

12 LTE-Advanced Pro (LTE-A Pro) is be used for specifications defined under 3GPP's Release 13 (R13) and Release 14 (R14). See www.3gpp.org/specifications/releases

13 See www.3gpp.org/technologies/keywords-acronyms/101-carrier-aggregation-explained for full CA configurations.

Table 4 Selected common ASEAN IMT bands usable in CA with APT700

Configuration	Bands	Max aggregated bandwidth [MHz]	3GPP Release
Carrier Aggregation inter band (2 bands)			
1A-28A	APT700 (b28) & 2100 MHz (b1)	40	3GPP R12.6
3A-28A	APT700 (b28) & 1800 MHz (b3)	40	3GPP R12.0
7A-28A	APT700 (b28) & 2600 MHz (b7)	35	3GPP R13.0
8A-28A	APT700 (b28) & 900 MHz (b8)	30	3GPP R14.0
28A-40A	APT700 (b28) & 2300 MHz (b40)	40	3GPP R13.2
28A-41A	APT700 (b28) & 2600 MHz (b41)	30	3GPP R13.2
28A-42A	APT700 (b28) & 3500 MHz (b42)	40	3GPP R13.2
Carrier Aggregation inter band (3 bands)			
1A-3A-28A	APT700 (b28) & 2100 MHz (b1) & 1800 MHz (b3)	60	3GPP R13.0
1A-7A-28A	APT700 (b28) & 2100 MHz (b1) & 2600 MHz (b7)	55	3GPP R13.0
1A-8A-28A	APT700 (b28) & 2100 MHz (b1) & 900 MHz (b8)	50	3GPP R14.1
3A-7A-28A	APT700 (b28) & 1800 MHz (b3) & 2600 MHz (b7)	60	3GPP R13.0
3A-28A-38A	APT700 (b28) & 1800 MHz (b3) & 2600 MHz (b38)	80	3GPP R15.2
3A-28A-40A-D	APT700 (b28) & 1800 MHz (b3) & 2300 MHz (b40)	60-100	3GPP R13.2
3A-28A-41A&C	APT700 (b28) & 1800 MHz (b3) & 2600 MHz (b41)	60-80	3GPP R14.2
Carrier Aggregation inter band (4 bands)			
1A-3A-7A/C-28A	APT700 (b28) & 2100 MHz (b1) 1800 MHz (b3) & 2600 MHz (b7)	80-100	3GPP R13.3
1A-3A-8A-28A	APT700 (b28) & 2100 MHz (b1) 1800 MHz (b3) & 900 MHz (b8)	70	3GPP R15.0

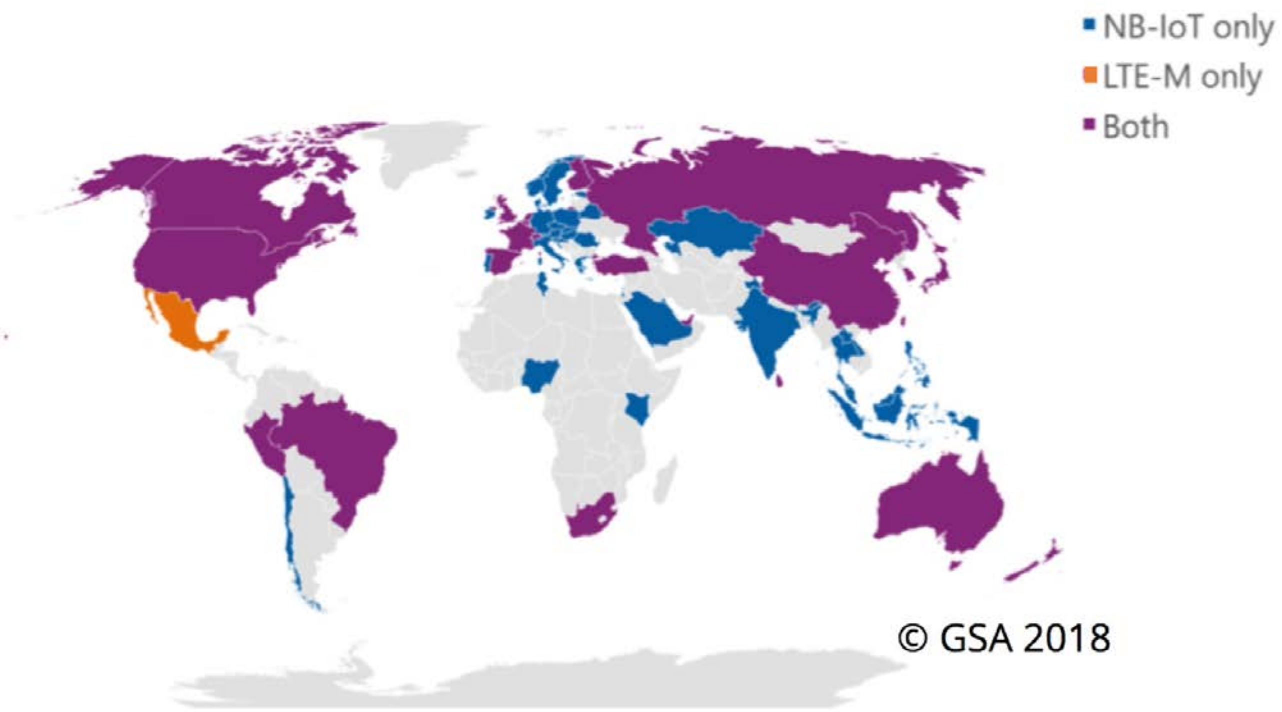
Source: http://niviuk.free.fr/lte_ca_band.php E-UTRA CA Configurations 36.101 (Rel 15 Mar 2018)

Wider IoT service deployment using APT700

From a 3GPP Internet of Things ("IoT") technology perspective, NB-IoT (also known as Cat-NB1) and LTE-M (as known as Cat-M1) [14] are set to become the global dominant Low Power Wide Area ('LPWA') technologies (see Figure 6).

[14] NB-IoT and LTE-M were defined in 3GPP Release-13, completed in June 2016.

Figure 6 Countries with deployed / launched NB-IoT and LTE-M networks



Source: GSA, GSA Report, NB-IoT and LTE-M: Global Market Status, March 2018.

Globally, according to the GSA 44 operators have deployed or commercially launched NB-IoT networks, 13 operators have deployed or commercially launched Cat-M1 networks and 34 new networks are planned or being deployed using Cat-M1 or NB-IoT.

The use of low bands (<1 GHz) should be a primary goal for mobile operators when offering NB-IoT solutions including those in ASEAN and APT700 is an obvious candidate band. It should be noted that the NB-IoT chipset fully supports APT700 along with other IMT bands below 1 GHz.[15]

Antenna issues

In terms of the site infrastructure requirements, 700 MHz LTE deployments will benefit from lower feeder loss (from the base station transmitter to the antenna). This will allow for radio units to be deployed at the bottom of the tower leaving the upper part of the tower free for 1800/2600 LTE deployments. Also related to the site deployment, antenna technology currently exists to support multiple frequency bands ranging from 700 MHz to 2600 MHz using multiple ports in a single radome. This can reduce the number of antennas required to support a multi-band network.

[15] In Australia, Telstra has launched both NB-IoT and LTE-M znetworks utilising the 700 MHz band (band 28) as this provides the greatest coverage and in-door penetration.

Societal benefits of 700 MHz deployment

The societal benefits of deploying 700 MHz services can be described and analysed in a standard economics framework which has as its objective the maximization of consumer welfare. The concept of the long-term interest of end users of telecommunication services is based on this economic framework and it is used to guide regulatory decision-making, taking into account factors that influence consumer benefits currently and into the future such as current prices and services, operator margins and capacity to invest, and the incentives for service innovation.

In the case of 700 MHz spectrum specifically, a description of the societal benefits is based on the benefits of increased capacity that flow from increased spectrum use in general, plus the particular benefits arising from the deployment of spectrum in the 700 MHz band. Compared with higher frequency spectrum, the particular benefits of 700 MHz spectrum band are its greater range and its propagation characteristics, in particular, its capacity to penetrate buildings and, more generally, provide coverage in non-line of sight scenarios.

Spectrum in the 700 MHz range provides particular benefits to developing economies. Because of its greater range, the capital costs associated with expanding coverage are significantly lower and deployment can be achieved more quickly.

There is a significant economics literature on the positive influence of telecommunications services on economic growth. Developing economies are now able to access these economic benefits via the process of ‘telecommunications leap-frogging’, by which developing economies use wireless infrastructure to bypass fixed network infrastructure deployment. Use of APT700 using the 700 MHz spectrum band enables these economic benefits to be realized sooner at lower cost.

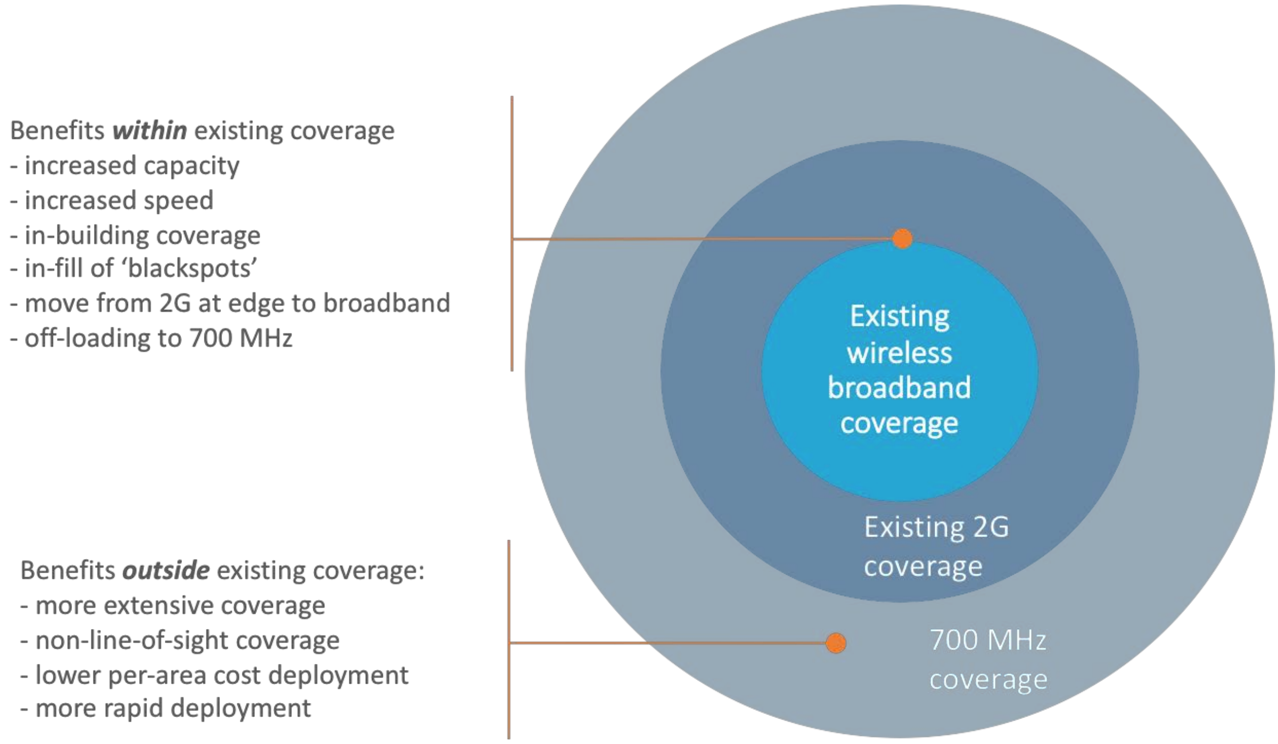
This leapfrogging process is delivering significant benefits to developing economies. It does, however, place a premium on capacity, speed, reliability and coverage of wireless networks in these jurisdictions. If coverage is patchy or unreliable, it is unlikely that certain pro-economic development use patterns will be established in these areas, for example, the creation of businesses that are relatively highly dependent on good communications.

Figure 7 provides a conceptual representation of the benefits of 700 MHz deployment layered over existing bands. In a typical existing deployment scenario, only the core area closest to tower infrastructure has access to wireless broadband services, using say higher IMT frequencies while a larger coverage area around this has access to legacy 2G voice services and SMS.

When 700 MHz services are deployed from the same site users who are covered by existing services experience a number of benefits including: decreased contention, increase speed, better in building coverage, infill of blackspots, access to broadband services in areas previously serviced only by 2G, and improve wireless broadband capacity in the pre-existing bands as traffic is offloaded to 700 MHz and/or LTE-A with carrier aggregation is deployed.

With its greater range, 700 MHz services are available at greater distances from the tower site, benefiting users who were previously out of range. Because of superior range and propagation characteristics, these deployments can be achieved at lower cost and higher speed than those in higher IMT frequency bands.

Figure 7 Conceptual representation of the benefits of 700 MHz deployment over existing IMT spectrum bands



Another consideration in assessing the benefits of 700 MHz spectrum use is the distinction between efficiency and equity goals of government. The discussion above relates to the positive impact of wireless deployment on economic growth. This growth is achieved primarily via reductions in communications and co-ordination costs which, in turn promote higher productivity, increased competitiveness and growth. Because the deployment of telecommunication services will be geographically uneven (especially in the early stages), benefits of these services will also be unevenly distributed. Typically, higher cost and uneconomic rural and remote users and communities will be the last to receive coverage. These communities typically have lower incomes than urban populations.

Governments are concerned with equity as well as efficiency, however, and most national governments mandate universal service funds and programs to subsidise telecommunications access. Again, 700 MHz spectrum is particularly attractive in this role because it means that services can be provided to remote communities at significantly lower capital cost and therefore at lower ongoing operating costs.

Finally, when considering societal and economic benefits of deploying 700 MHz is it pertinent to emphasise the benefits arising from the revenues to governments from sale of the spectrum. Given that there are no significant technical risks associated with LTE deployments in the 700 MHz band, there are no significant economic benefits to delaying deployments. The sooner revenues can be secured, the sooner they can be put to use in reducing government debt or in useful economic or social programs. It should also be emphasised that the benefit from such activity compounds over time, especially in the case of debt retirement or productivity enhancing economic programs – opportunities missed now cannot be regained in the future.

Growing APT700 ecosystem

The GSA reports on the 700 MHz network deployments and the device ecosystem as at 23 January 2018.[16] There are now 44 commercially launched APT700 Band 28 operators in many countries including large markets like Brazil, Nigeria, Mexico, Japan, Philippines, Egypt, Germany, France, South Korea, Argentina, Saudi Arabia, Peru, Australia, Taiwan and Chile (in order of population). Countries with a population of almost 4 billion people have allocated 700 MHz spectrum compatible with APT700/LTE Band 28 devices with an addressable market of more than 1.2 billion people.

The GSA and other studies emphasise there is a growing maturity of the ecosystem in the 700 MHz band. While APT LTE Band 28 is only the 12th most popular of all LTE handsets ever released into the market, this is historical, and examining those handsets currently on sale on the market there would seem to be strong device vendor support for the APT700 band.

Case studies of country APT700 deployments

For the purposes of this report, input from mobile network operators operating in the Philippine and Australian markets were sought in order to the following case studies.

APT700 deployments in the Philippines

700 MHz Band 28 deployments in the Philippines by end of Q1, 2018 resulted in immediate improvements in LTE service experience for customers with APT700 LTE Band 28-capable devices. However, the limited penetration of these devices constrained, at least in the short term, total benefits. Having said that, even users without APT700 capable LTE devices experienced improvement in services because of offloading traffic to this band.

Although formal assessments have not been undertaken by Philippine operators, anecdotally, in-building coverage improvement appears to be minimal which may be due to dense heavily built accommodation in high-end residential areas in Manila and other key urban markets. The indoor penetration losses even on 700 MHz band seems to be at least 4dB - 6dB per wall.

As would be expected, the increased availability of LTE 700 MHz services has encouraged the uptake of APT700 capable devices. Although, particularly in low-income rural areas, LTE device

[16] GSA Snapshot: *LTE in APT700 Spectrum Global Status*, February 2018.

costs generally are a barrier, at least until LTE device prices fall further, which is their current trajectory. Philippine operators are working their device partners to provide more affordable LTE devices capable of supporting APT700.

The experience in the Philippines is that 700 MHz deployments have been much cheaper than greenfield builds because of pre-existing site and tower infrastructure and this has significantly improved service extent and coverage. It will be necessary, however, over time, to add additional layers to provide sufficient capacity as demand grows. In the meantime, 700 MHz services have been particularly beneficial in alleviating the challenge of acquiring new tower sites in the highly space-constrained urban Philippine market.

As the Philippine telcos look into becoming enablers for a digitally empowered nation a robust 700 MHz ecosystem is also very important for an archipelago like the Philippines. The deployment of APT700 with the ability to support NB-IoT / LTE-M devices can facilitate the use of the wireless broadband network for e-agriculture, remote monitoring of environment conditions, river pollution, weather monitoring or telemetrics and similar applications.

APT700 deployments in Australia

In Australia both Telstra and Singtel Optus primarily deploy networks utilising low band spectrum (especially the 700 MHz band)[17] to provide the coverage layer of the network. The advantages of these ranges for coverage can observed in the cell radii – 700 MHz provides almost 3 times greater cell radii than 2600 MHz, thereby significantly reducing the cost of covering the same geographic area. Call coverage, signal strength, drop outs and voice and aural quality with the use of 700 MHz is better than customers may have experienced in the past.

In Telstra's view, APT700 spectrum has been instrumental in extending 4G coverage to regional and remote areas of Australia that otherwise would not have been possible to cover economically, or at all, using high band spectrum only. Prior to APT700 deployment Telstra's networks covered approximately 85 percent of population and around 100,000 sq. km.

The use of APT700 with existing and new 4G sites has helped push Telstra's 4G coverage to over 99 percent of the population and more than 1.6m sq. km of the land area in Australia.

APT700 has also allowed Telstra to participate more effectively in the Australian Government's Mobile Blackspot program[18] and to offer and deliver new coverage to areas that they would otherwise have been unable to serve. To date, Telstra have deployed more than 450 new APT700 base stations (on route to a total of over 650) and the coverage reach of the band has meant it have been able to grow its 4G coverage by more than 160,000 sq. km. in regional and remote areas so that more Australians can experience the benefits of 4G in more places they live work and travel. This investment, aided by the improved reach of APT700, is important for opening up

17 Including 900 MHz band in the case of Singtel Optus and previously the 850 MHz band in the case of Telstra.
18 www.communications.gov.au/what-we-do/phone/mobile-services-and-coverage/mobile-black-spot-program

digital doors to education, health and business opportunities to benefit some of Australia's most remote communities.

Telstra considers that the improvement with respect to in-building coverage over 4G in higher bands is significant. With 4G in higher spectrum bands few buildings had extensive reliable indoor coverage without the presence of dedicated antenna systems. The introduction of APT700 means that most urban buildings could get reasonable in-building 4G coverage, with only larger buildings in the denser urban areas of central business district's typically requiring some augmentation via dedicated antenna systems.

Without going into detail, Telstra confirms that there are material cost benefits in deploying 700 MHz over 1800 MHz spectrum. These benefits are most fully realised in lower population density areas of regional, rural and remote Australia where the key deliverable is coverage. If one considers a 700 MHz base station costs much the same as an 1800 MHz base station while the 700 MHz base station covers several times the area of an 1800 MHz base station, the cost benefits for covering such lower population density areas should be clear.

In high population density metropolitan environments, delivering capacity is equally important and this requires a greater density of sites regardless of band used so the cost benefits, while still present to some degree, are not as great.

Telstra is also utilising the 700 MHz (band 28) spectrum for:

- Both its NB-IoT and LTE-M networks as this spectrum provides the greatest coverage and indoor penetration. Telstra footprint for its Cat-M1 services is one of the world's largest.[19] Cat-M1 technology is suited for IoT use cases like telematics, wearables and smart metering. Telstar's IoT business is one of the most successful globally with the company's IoT revenues approaching AUD200 million per annum;[20] and
- For its recently launched Telstra 4GX-lite Mobile Satellite Small Cell offering which is being used to bridge coverage gaps. This new mobile satellite service ('MSS') solution combined with APT700 equipment helps people living and working in some of Australia's most remote places purchase their own coverage extension of the Telstra 4GX (LTE) mobile service at an affordable price.[21]

19 www.ericsson.com/en/news/2017/2/telstra-deploys-ericsson-software-to-enable-one-of-the-worlds-largest-cat-m1-networks-

20 www.iothub.com.au/news/telstras-iot-business-one-of-the-most-successful-globally-485329

21 www.telstra.com.au/aboutus/media/media-releases/Telstra-signs-first-customer-and-launches-the-Telstra-4GX-lite-Mobile-Satellite-Small-Cell-to-bridge-coverage-gap

Potential cross-border interference issues

For allocating the APT 700 MHz Band (698 – 807 MHz) for IMT in Region 3, and for the ASEAN countries in scope of this report, two key spectrum management efforts should be pursued:

1. The migration from analogue television (ATV) to digital terrestrial television broadcasting (DTTB) as to free-up spectrum for IMT and taking advance of more spectrum efficient broadcasting technologies. This Digital Switch Over (DSO) process was the focus of GSMA report "*Practical Recommendations to Digital Migration in ASEAN*", dated August 2017 and many other international publications[22];
2. Cross-border frequency coordination as to avoid harmful interference between countries planning or having deployed IMT or DTTB. Also, several ASEAN countries (e.g. Indonesia, Thailand and Vietnam) still have ATV services in operation and Analogue Switch-Off (ASO) has not occurred yet. This cross-border frequency coordination process, its international context and its necessity, is addressed in this report.

Identifying cross-border interference cases for IMT and other services

In this section, first a general overview is provided of possible cross-border interference cases between IMT and other services in the range 470 to 694/698 MHz. Secondly, a more detailed overview is provided of cross-border interference cases between IMT and DTTB.

General overview of cross-border interference cases

Identifying cross-border interference cases is a key step in resolving and managing harmful interference. As indicated in Appendix B for the allocation of IMT in the 700 MHz (and other bands), a range of compatibility studies have been carried out internationally. The CPM report for the WRC-15 includes a wide range of these studies and their results.

The focus of this report is on any incompatibility between IMT and DTTB, given the scope of this report; i.e. introducing IMT in the 700 MHz band whilst neighbouring countries may still deploy other services, most notably broadcasting services, in this band. Figure 8 provides a general overview of possible incompatibilities between IMT and other services in the 470 – 694/698 MHz (i.e. cross- border interference cases) [23].

22 Such as the ITU, *Guidelines for the Transition from Analogue to Digital Broadcasting*, edition 2012 (for Asia Pacific) and 2014.

23 See CPM report, Chapter 1, Section 1/1.1/3.2.1.

Figure 8 General overview of possible incompatibilities between IMT and other services in the range 470 to 694/698 MHz

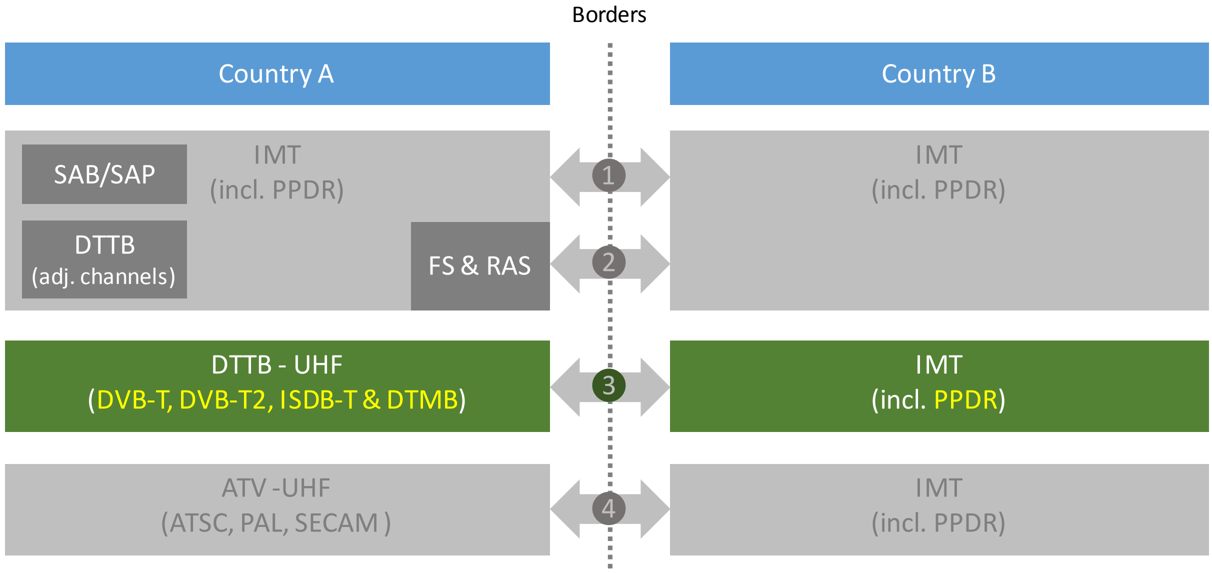


Figure 8 shows the following:

1. Cross-border interference cases, number 1 and 2:
    a. Interference case 1 may arise in the final stages when Administrations have adopted IMT and their stations' emissions are within the coordination zone for these services. As included in Appendix B the HCM Agreement provides procedures and parameters for managing possible cross-border interference between IMT services;
    b. Interference cases 2 were identified in the CPM report for WRC-15. Fixed Services (FS) and Radio astronomy services (RAS) may be incompatible with IMT. It is noted that in the ITU -RR RAS has only a primary allocation in Region 2 (and hence this possible interference case is not applicable for Region 3);
2. Interference cases *within* a country between IMT and respectively SAP/SAB and DTTB. Figure 8 also shows that a country may have interference issues between IMT and SAP/SAB. SAP/SAB includes for example lower power wireless microphones, which even may still operate in co-channels with IMT.[24] Also, IMT and DTTB may still have adjacent channel interference within a country;[25]
3. As mentioned before, PPDR systems may be based on IMT, for these PPDR systems separate frequency arrangement have been agreed.[26] Also, Administrations may have agreed shared frequencies for these systems, allowing for cross-border operations;
4. Cross-border interference case, number 3. This case entails the possible incompatibilities between IMT and DTTB. The latter including the four different transmission standards

[24] Cross-border interference between IMT and SAP/SAB is ignored here, as this would imply for example wireless microphones crossing the border from one country to the other.
[25] Any form of co-channel operation of IMT and DTTB within a country has been excluded. See also footnote 28.
[26] See ITU-R Recommendation M.2015-2 (01/2018).

applied in the ASEAN countries. These transmission standards matter as their transmitters have different frequency characteristics, bandwidth and modulation schemes. Consequently, they have different interference potential;

5. Cross-border interference case, number 4. This case entails the possible incompatibilities between IMT and ATV services. Again, the latter includes the three different ATV systems still in operation in the ASEAN countries in the UHF Band. It is noted that in the cross-border coordination between countries, both interference cases number 3 and 4 may need to be addressed, if ASO has not occurred yet.

Detailed overview of cross-border interference cases between IMT and DTTB

Interference case number 3 of Figure 8, is further detailed in this Section. Figure 9 provides an overview of the interference cases between IMT and DTTB.

Figure 9 Overview of interference cases between IMT and DTTB

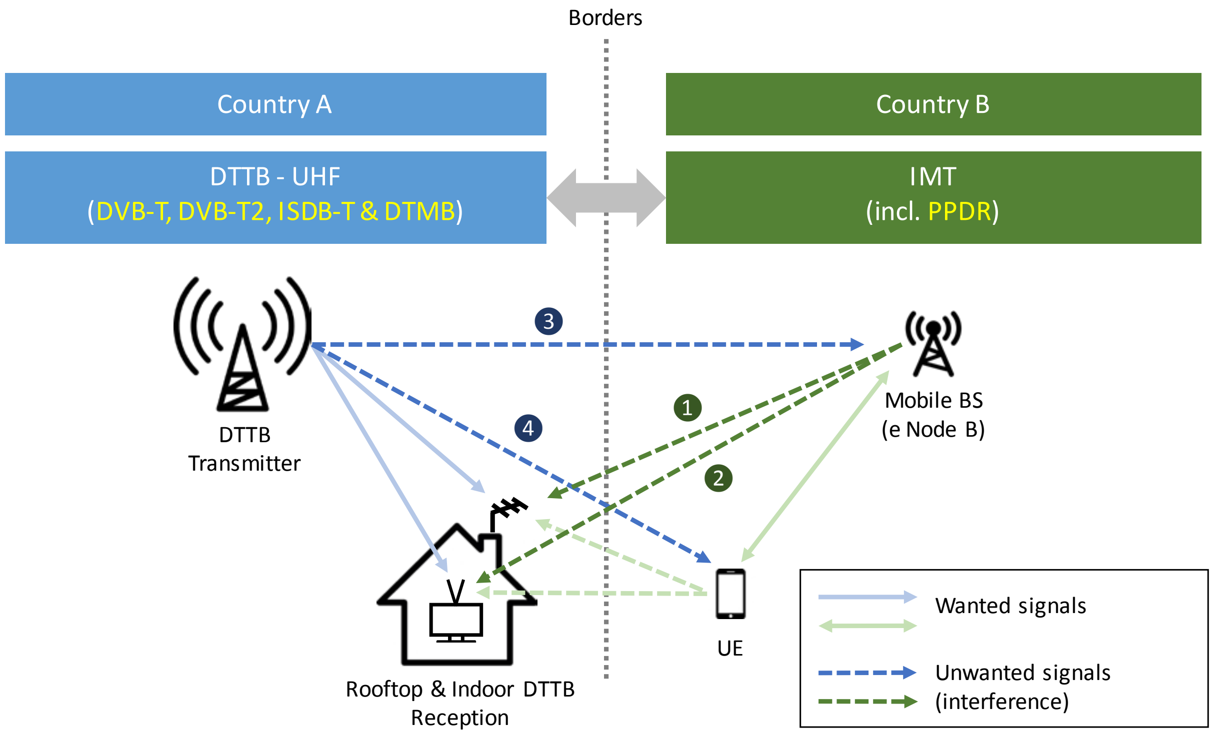


Figure 9 shows the following:

1. In ASEAN different DTTB transmission standards are deployed (and in some countries even more than one, for example in Cambodia). However, the most widely applied standards are DVB-T and DVB-T2;

2. Four interference cases are identified (numbered 1 to 4). For each interference case the interference field strengths should be calculated and compared to the permissible field strength (as to avoid harmful interference) for the service to be protected:

a. DTTB rooftop and indoor reception interfered by an IMT base station, i.e. by the IMT downlink (green dotted lines)[27];

b. IMT base station (i.e. uplink receiver) and IMT user equipment (EU)/mobile terminal (i.e. downlink receiver) interfered by DTTB (blue dotted lines), and;

3. The interference case of the UE (of country B) uplink interfering with DTTB reception (in country A), may be ignored for cross-border frequency coordination. As this would assume foreign UE (country B) permanently roaming in country A, near DTTB reception (and then mainly indoor reception).

For cross-border frequency coordination, the primary focus is on calculating and avoiding *co-channel* interference (of the four identified interference cases)[28] between *primary* services (such as IMT and DTTB)[29]. However, adjacent channel interference may also be addressed (for example in the situation of case-based frequency coordination). Adjacent channel interference is often limited to relative small areas in the service or coverage areas of the service under consideration.

For carrying out the interference calculations a range of parameters should be considered, depending on the applied calculation method (for example free-space calculation, ITU-R P.1546-4 or CRC-predict):

1. Planning criteria (such as protection ratios, overload thresholds and minimum field strengths);

2. Transmitter and terrain databases;

3. System parameters (such as frequency bandwidth, modulation scheme, code rate, etc.);

4. Stations frequency characteristics (such as ERP, centre frequency, spectrum mask/unwanted emission limits);

5. Antenna characteristics (such as horizontal, vertical radiation diagram and tilt), and;

6. More specifically for mobile services, the traffic load (scenarios)[30].

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27 Whether indoor or rooftop reception should be considered, depends on the regulatory requirements for DTTB. In most countries rooftop reception is stipulated. However, some countries (like Thailand) also have a requirement for indoor reception (in defined areas).

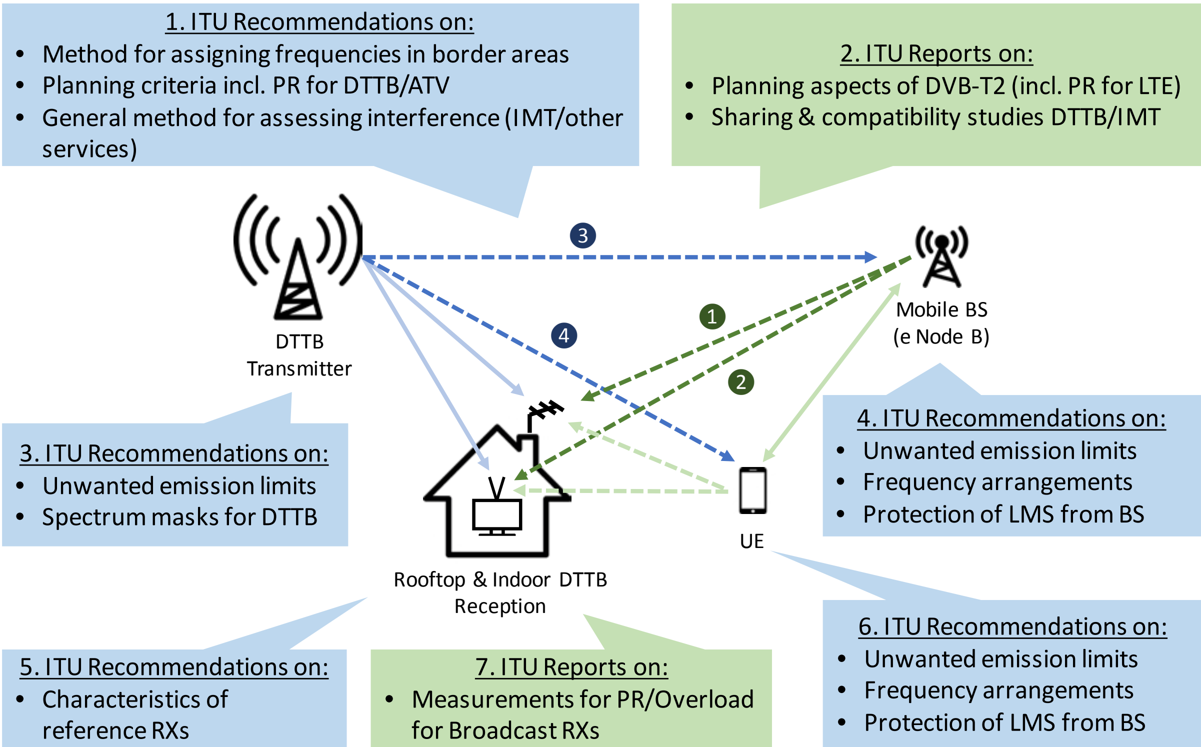
28 Compatibility studies have demonstrated that sharing the same frequency (co-channel) between IMT and DTTB in neighbouring countries is very difficult. IMT BS uplink receivers in country A can be interfered by DTTB transmissions in country B up to a few hundred kilometres inside the IMT country A. See ITU-R Reports BT.2247-3 (07/2015) and BT.2337-0 (2014).

29 Because stations of a *secondary* service shall not cause harmful interference to stations of primary services and cannot claim protection from harmful interference from stations of a primary service (ITU-RR, 5.29/5.30).

30 IMT traffic load scenarios should be considered because protection rations and overload threshold vary. Low traffic loadings increase the time variation in the LTE interference signal which causes degradations in protection ratios and overload thresholds in some receiver designs. Three load scenarios are commonly included; 0%, 50% and 100% base station traffic loading.

For providing guidelines and parameters for these IMT-BS (DTTB/ATV) interference calculations and cross-border frequency coordination, the ITU-R has issued a range of Recommendations and Reports. Figure 10 provides an overview of these Recommendations (blue) and Reports (green).

Figure 10 Overview of ITU-R Rec/Rep relevant for IMT-BS interference calculations and cross-border coordination.



In APPENDIX D: ITU-R RECOMMENDATIONS AND REPORTS, a comprehensive list is provided. It is important to note that, given the specific interference case, the correct Recommendation (and Report) and its included parameters are selected and applied. For example, consideration should be given to the included DTTB/IMT system and frequency range. It may occur that a sought-after parameter may not be directly covered in a Recommendation, but can still be derived from other Recommendations or by extrapolation.

Lost benefits and costs from unmanaged cross-border interference

Unmanaged cross-border interference is very likely to occur in the absence of any cross-border frequency coordination. As compatibility studies have demonstrated co-channel cross-border interference from DTTB broadcasts affect the IMT service a few hundred kilometres inside the IMT country[31].

Any remaining and accepted cross-border interference may also occur, even if cross-border frequency coordination has taken place. It depends on how exhaustive all interference cases have

[31] See footnote 285.

been addressed. As previously indicated, cross-border frequency coordination is primarily addressing co-channel interference and adjacent channel interference may not be included. Administrations may consider addressing any remaining adjacent channel interference by applying some local measures (e.g. some additional filtering of an IMT base station or of DTTB receivers) or initiating additional frequency coordination (case-based).

Hence, for assessing the potential costs from unmanaged cross-border interference, the status or scenario of the cross-border coordination should be considered. Figure 11 provides a schematic overview of possible cross-border coordination scenarios, any remaining or accepted interference, its impact on the service and possibilities for mitigation (which may include additional coordination efforts and/or operational measures).

Figure 11 An overview of cross-border coordination scenarios

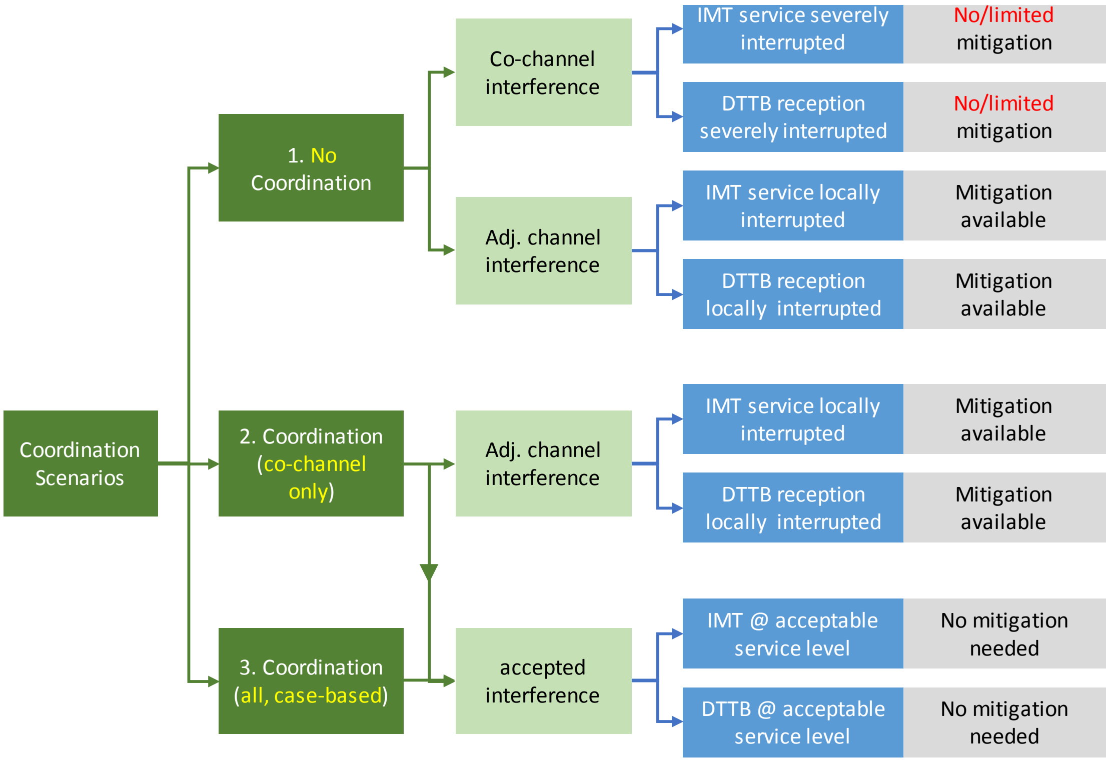


Figure 11 shows the following:

1. No coordination. The absence of any cross-border frequency coordination may result in co-channel and adjacent channel interference. Especially co-channel interference may severely interrupt both the IMT services as well as the DTTB reception. As no coordination is taking place under this scenario, no or limited mitigation is possible. For example, co-channel interference cannot be resolved by applying additional filtering. Neither will repositioning of the receiver (either DTTB or IMT) help, unless for many kilometres (i.e. outside the minimum required co-channel frequency separation distance). Hence, the IMT or DTTB services will not be available in large parts of their respective service or coverage areas along the borders (either due to harmful interference or network operators not deploying in these areas). This will impact the earning capacity of the mobile operator and

the DTTB service provider. Also, reputation damage will occur for the market parties involved, as well as the NRA. Clearly, such a scenario should be avoided;

2. Coordination of co-channels only. Under this scenario co-channel interference has been resolved. Possibly some adjacent channel interference cases may remain. These cases could be dealt with in additional frequency coordination meetings, at the time of planning and deploying the networks (IMT/DTTB) in detail (i.e. all site and transmitter characteristics are being planned)[32]. Adjacent channel interference can then be mitigated by these additional coordination meetings. Operational measures can also help mitigate adjacent channel interference. The latter under the assumption that some level of adjacent channel interference is accepted in the frequency planning. These operational mitigation measures can include additional filtering (at the IMT base station or DTTB receiver), repositioning of receiving antennas and changing the antenna diagram of transmitting antennas. Obviously, these operations measures have costs, which are addressed in more detail in section *Quantifying interference impact from previous experience*. After dealing with adjacent channel interference, either through additional coordination and/or operational measures, some accepted interference in the frequency planning may remain (see item 3);
3. Coordination of all interference cases (often case-based). Addressing all interference cases (as depicted in Figure 10) for co- and adjacent channel interference, would result in bringing down all interfering field strengths below the maximum permissible interference levels. Bringing interference under the permissible interference level does not imply that all interference is resolved in the frequency planning. However, this level of interference is accepted as the minimum required service level is reached (in terms of service reliability and reception quality)[33]. Consequently, under this scenario no mitigation is needed.

In the next Section, the operational mitigation measures are addressed in more detail, under the scenario of cross-border coordination of co-channels only (see Figure 10).

Operational mitigation measures and their costs

In various laboratory and field tests, operational mitigation measures have been investigated between IMT and DTTB, operating in adjacent channels[34]. Interference can result to an interrupted reception of the wanted signal and some specific receiver (RX) problems, including:

1. Overloading (DTTB and IMT/LTE receivers): the receiver begins to lose its ability to discriminate against interfering signals at frequencies differing from that of the wanted signal. In the case of DTTB receivers, overloading means in practice that usually all frequencies are interfered and hence all television services;

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32 Especially for the IMT services the mobile network operator will start planning the networks in detail only after frequency assignment. For most sites the exact site locations are often not known at the time of assignment. This may be different for DTTB networks. High-tower high-power sites are often scares and known. However, DTTB networks tend to be denser (then ATV) and for the DTTB network operators not all site locations may be known either.

33 As incorporated in the ITU-R Recommendations (see APPENDIX D: ITU-R RECOMMENDATIONS AND REPORT). It is noted that the values are recommended, and that Administrations can deviate from these values. For example, as they plan to have some operational measures or would like to have a higher service level (e.g. for PPDR).

34 See also ITU-R Report BT.2215-7 (04/2018) and Recommendation BT.2036-2 (03/2018).

2. Image channel interference (ATV and DTTB specific): heterodyne receivers (i.e. most radio frequency receivers) produce internally an intermediate frequency which can be interfered by a specific frequency (i.e. the image channel, which can be mathematically determined);
3. Automatic gain controller (ATV and DTTB specific) disruption: the automatic gain controller is part of the amplifier system of the receiver which ensures a relative constant output signal of the receiver.

These above listed interference types, result in different operational mitigation measures which can be applied. The following two tables provide an overview of the interference types and their operational measures for respectively LTE interfering DTTB rooftop reception (Table 5) and DTTB interfering LTE (Table 6)[35].

Table 5 LTE to DTTB interference types and their operational mitigation

Interference type	Operational measures					
	1a. Apply filter at LTE-BS TX	2a. Apply filter at DTTB RX	3a. Reposition or change of DTTB rooftop antenna	4a. Reposition or change LTE BS antenna	5a. Reduce ERP of LTE BS TX	6a. Increase distance between UE and DTTB RX
LTE BS TX > DTTB RX (overloading)		√	√	√	√	
LTE BS TX > DTTB RX (unwanted emissions)	√		√	√		
LTE BS TX > DTTB RX (auto gain controller)		√	√	√	√	
LTE BS TX > DTTB RX, (image channel)		√	√	√	√	

35 Derived from the Anatel (the NRA of Brazil) compatibility study between LTE and DTTB (ISDB-T) in the 700 MHz Band. Both the laboratory and field test reports are available on the Anatel website: http://www.anatel.gov.br.

Table 6 DTTB to LTE interference types and their operational mitigation

Interference type	Operational measures					
	1b. Use of critical mask at DTTB station	2b. Filter at LTE-BS RX	3b. Reposition or change DTTB antenna	4b. Reposition or change LTE BS antenna	5b. Reduce ERP of DTTB station	6b. Reposition or use a more robust UE
DTTB signal > LTE BS RX (overloading)		√	√	√	√	
DTTB signal > LTE BS RX (unwanted emissions)	√		√	√	√	
DTTB signal > LTE UE RX (overloading)						√
DTTB signal > LTE UE RX (unwanted emissions)	√					√

From Table 5 and Table 6 the following can be observed and concluded:

1. In Table 5 in the two last interference types (automatic gain controller and image channel) the operational measures are greyed, meaning that these interference types are deemed unlikely to occur as DTTB receivers constantly improve and are well shielded[36];
2. In Table 5, measure 6a is deemed not applicable. As concluded in the section *Detailed overview of cross-border interference cases between IMT and DTTB*, the permanently roaming of foreign EU near DTTB receivers was excluded as relevant for cross-border frequency coordination;
3. In Table 5 in total five measures are deemed applicable (depending on the interference type); 1a to 5a. The application of filters (1a and 2a) refers to applying (additional) band-pass filters which pass the wanted frequencies within a certain range and rejects (attenuates) the unwanted frequencies outside that range;
4. In Table 5, measure 6b is deemed not applicable as repositioning of the UE is constant (as people move around and hence any interference would be very short-lived) and the UE technical specifications are nowadays a given for most markets;
5. In Table 5 in total five measures are deemed applicable (depending on the interference type): 1b to 5b. The use of a critical mask at the DTTB station (1b) refers to applying a more strict or better filtering of out-of-band emission by the DTTB transmitter. The ITU-R has defined for sensitive cases these critical spectrum masks[37].

36 This may be different for ATV receivers. In ATV frequency planning it is common to check for image channel interference. For DTTB frequency planning it is not common practice to check for image channel interference.

37 See ITU-R Recommendation BT.1206-1 (01/2013) and SM.1541-6 (08/2015).

The operational mitigation measures, as included Table 5 and Table 6, have a varying impact on the operations of the IMT/DTTB network operators and consumers. Hence, they have different financial impact. The magnitude of their impact is strongly correlated to the magnitude of the predicted (and experienced) interference, which can only be assessed from (case-based) interference calculations or can be indirectly assessed from previous, similar experiences. The latter is addressed in the section ***Quantifying interference impact from previous experience***.

Table 7 includes an initial assessment of the relative (financial) impact of the operational mitigation measures, as included Table 5 and Table 6.

Table 7 An initial assessment of the relative impact of operational mitigation measures

Measure number	Impact	Impacts	Cost Drivers	Relative score
1a. + 2b. Apply filter at LTE-BS TX/RX	• Install a better band-pass filter at the LTE-BS • Industrial grade equipment • Filters readily available	• LTE network operator	• Number of frequencies interfered • Number of LTE BS involved	+
2a. Apply filter at DTTB RX	• Send consumers a small filter for DIY installation • Consumer market product • Consumer help scheme and communications • Product certification labels[38]	• DTTB households (consumers)	• Number of households affected • Number of households eligible for aid (financial and/or installation)	++
3a. + 3b. Reposition or change of DTTB rooftop antenna	• Reposition or replacement may be the same39 • Purchase of new antenna (consumer market product) • Consumer help scheme and communications	• DTTB households (consumers)	• Number of households affected • Number of households eligible for aid (financial and/or installation)	+++
4a. + 4b. Reposition or change LTE BS antenna	• Reposition or change of LTE base antenna may require a temporary service interrupt or site • Industrial grade equipment • Antennas readily available	• LTE network operator	• Bandwidth of installed antenna • Number of LTE BS involved	+
5a. Reduce ERP of LTE BS TX	• Reduction may result in a smaller service area and/or additions sites	• LTE network operator	Number of LTE BS involved	+
1b. Use of critical mask at DTTB station	• Additional costs for filter section of the DTTB TX • Industrial grade equipment • May require a specific order	• DTTB network operator	• Number of DTTB sites involved (likely to be just a few)	+
5b. Reduce ERP of DTTB station	• Results in smaller service area	• DTTT network operator	• Number of DTTB sites involved (likely to be just a few)	+

38 To assist the consumer and installer to purchase/acquire the correct filter.

39 Experience in the UK with the initial DTTB deployment learned that repositioning of rooftop antennas resulted in most cases in replacing the old ATV antenna (which in principle was usable).

From Table 7, it can be concluded that the largest (financial) impact is from those measures involving consumers. The operational measures impacting the LTE or DTTB network operator can be planned well ahead of the deployment. This operational mitigation will result in additional costs, which may be even marginal, depending on the calculated / perceived interference.

Quantifying interference impact from previous experience

Several countries and their NRAs have reported on the impact on households of adjacent channel interference between LTE and DVB-T, when both systems have been deployed in their territories. These reports give an indication of the magnitude of any remaining interference that can be expected, after cross-border frequency coordination.[40] It is very important to note that these reports:

1. Address any remaining adjacent channel interference cases *within* a country, when both systems (DVB-T and LTE) have been deployed in the country. However, for assessing the magnitude of cross-border interference from adjacent channels, the number of interference cases can be expected to be less, i.e. only in the border areas within the interference distance. As discussed in section ***Detailed overview of cross-border interference cases between IMT and DTTB***, (case-based) calculations will provide the best insight in the magnitude of interference (for cross-border coordination);
2. Address also the additional measures taken, to further eliminate any remaining interference. These additional measures can include re-planning of the stations characteristics before actual frequency assignment (when any remaining interference is calculated/found);
3. Address different frequency arrangements, system parameters and frequency characteristics for both networks.[41]

Table 8 shows national field reports on adjacent channel interference between DVB-T and LTE.[42]

Table 8 National field reports on adjacent channel interference between DVB-T and LTE.

Country	Case description	Network deployed (at time of report)	Reported interference	Remarks
Australia	• DVB-T in 520-694 MHz (restacked) • LTE in 700 MHz band	• DVB-T nationwide (i.e. around main cities) • Fully deployed (Optus and Telstra only)	• No significant impact on DTTB • Some cases of TV distribution amplifiers being overloaded by LTE BS signals (within 1 km	• No specific mitigation scheme for LTE 700 MHz interference. Hence no formal reporting. • LTE 700 MHz Band edge licence conditions applied

40 In the case of the European countries, cross-border frequency coordination was conducted by means of the procedures included in the GE06 Agreement. In order words, harmful co-channel interference from abroad was eliminated.

41 However, it is noted that these differences mainly refer to the DVB-T network. Also, it is noted that some system variants of DVB-T and DVB-T2 have similar interference potential.

42 Derived from ITU-R Reports BT.2301-2 (10/2016) and BT.2247-3 (07/2015) and ACMA (Australia).

			range)	• ACMA site provides DTTB viewers mitigation measures, to apply filters and change RX antenna (see 2a. + 3a in Table 7)[43]
France	• DVB-T in 700 MHz band • LTE (DL only) in 800 MHz band	• DVB-T nationwide • 16,283 LTE BS (mid-way deployment stage)	• 67,857 reports of DVB-T interference (i.e. 168,778 households) • Most reported interference type was DTTB RX overloading • 78,500 DTTB RX filters distributed and used (see 2 in Table 7) • For 99% of the reported cases, the interference distance was below 2.1 km	• Obligation for LTE licensees: • Apply LTE BS filters (see 1a. in Table 7) • Resolve any interference • Have an interference help-desk operational • 1 MHz guard band between DVB-T and LTE DL • However, no relationship found between small guard band and overloading of DTTB receiver, based on initial experiences with LTE 700 MHz deployment (having a larger frequency separation)
Germany	• DVB-T in 700 MHz band • LTE in 800 MHz band	• DVB-T nationwide • 6,000 LTE BS (first deployment stages)	• 10 cases (caused by LTE) • Reported cases mitigated by: • Apply filter at DTTB receiver (see 2a in Table 7) • Reposition of DTTB antenna (see 3a. in Table 7)	• Obligation for LTE licensees not to interfere DVB-T • Frequencies to LTE BS only assigned after interference test show no harmful interference
Netherlands	• DVB-T in 700 MHz band • LTE in 800 MHz band	• DVB-T nationwide • 5200 LTE BS (mid-way deployment)	• No interference reported	• Obligation for LTE licensee to take measure to protect systems in adjacent frequency bands • Additional technical requirements for out-of-band emissions (of LTE BS) • DVB-T network designed for indoor reception

43 See https://www.acma.gov.au/Citizen/TV-Radio/Television/TV-reception/whats-the-link-between-mobile-broadband-and-tv-reception

From Table 8, the following can be observed and concluded:

1. Although the deployed systems are the same (DVB-T and LTE) and operate in similar frequency bands, the reported number of interference cases vary significantly. Consequently, caution should be taken with the interpretation of these results and generalising these outcomes;
2. Additional measures, such as applied in Germany, can significantly eliminate any remaining interference (i.e. simply by checking for any potential interference at the time of network deployment);
3. NRAs make trade-offs between:
    a. On the one side (the costs of) imposing additional technical requirements (such stricter or additional filtering of the LTE BS) and the re-planning of stations during deployment, and;
    b. On the other side applying operational measures, such as distributing filters and organising a contact centre and consumer help schemes.

Recommended cross-border interference mitigation and co-ordination approach

As indicated in the section above, two key spectrum management efforts should be pursued; the migration from analogue television to digital terrestrial television broadcasting and cross-border frequency coordination. The latter as to avoid harmful interference between primary services (LTE and DTTB).

Following the addressed cross-border interference issues and the impact of unmanaged cross-border interference above (and Appendix B), the following recommendations are provided:

1. **Incorporate cross-border frequency coordination in the national licence assignment procedure**. NRAs manage the national spectrum resources and ultimately assign frequencies to applicants. In their respective frequency assignment procedures, NRAs should assign spectrum only when the necessity of cross-border frequency coordination has been checked, and if deemed necessary, has been conducted. These activities should be incorporated as a formal process step in their national licence assignment procedure. For assessing this necessity, the guidelines as provided in section ***Identifying cross-border interference cases for IMT*** and other services can be used;

2. **Formalise cross-border frequency coordination**. As covered in Appendix B, cross-border frequency coordination Agreements have different scopes and varying degrees of process and technical detail. It is for NRAs to agree the best coordination process, suited to their needs and possibilities. However, having a simple cross-border agreement, for example just including a meeting calendar or forum, is better than no coordination at all. As a minimum co-channel interference should be avoided as the impact is potentially very large and cannot be effectively mitigated (see section ***Operational mitigation measures and their costs***);

3. **Identify, agree and calculate interference levels**. Identifying and agreeing the cross-border interference cases, and subsequently calculating interference levels, lay at the heart of any cross-border frequency coordination process. The guidelines as provided in the section ***Identifying cross-border interference cases for IMT and other services*** and a wide range of ITU Recommendation and Reports can assist NRAs in this process (see APPENDIX D: ITU-R RECOMMENDATIONS AND REPORTS). Under the framework of a cross-border Agreement, the described process steps in Figure 21 in Appendix B, can help in structuring this process;

4. **Balance licence obligations against operational mitigation**. As indicated in Appendix B, NRAs balance on one side the option of imposing additional technical requirements and possibly the re-planning of stations, if harmful interference is found, and on the other hand the option of operational mitigation. NRAs should explicitly balance these two options as to assess the best way forward. The provided operational mitigation guidelines (see section ***Operational mitigation measures and their costs***) and the field experiences from abroad (see Appendix B) can assists NRAs in making this trade-off;

5. **Plan spectrum for the future**. Cross-border frequency coordination talks may result in NRAs agreeing a best (re)allocation of spectrum for both countries. To minimise potential interference and promote efficiency it is advisable to accommodate DTTB operations in the lower part of the band to begin with (if possible and depending on the immediate demand for capacity), avoiding unnecessarily scattered channel use. This would also allow an orderly ongoing review and planning of DTTB frequency assignments in relation to future demand, for example for facilitating more high definition television services later.

Key considerations for the licensing of 700 MHz band spectrum for mobile

Identification of key issues

In addition to clearing the 700 MHz spectrum band, the successful licensing of the 700 MHz band for mobile services requires the identification of key policy issues and for decisions to be taken by Government and/or regulators in relation to those issues. The key items which need to be resolved for the successful licensing of this band include *inter alia:*

- Recommended options for lot sizes in relation to the 700 MHz spectrum band licences and other allocation issues;
- Recommended options for coexistence with adjacent services and related guard bands;
- Recommended options for managing the phase-out of other incumbent users in the 700 MHz spectrum band, namely wireless microphones; and
- PPDR broadband spectrum allocation issues.

Recommended lot sizes in relation to the 700 MHz spectrum band licences and other key allocation issues

Recommended lot sizes

While LTE supports flexible usage of bandwidths of 1.4 MHz, 3 MHz, 5 MHz, 15 MHz, and 20 MHz standardised by 3GPP, FDD implementations below 2 x 5 MHz are rare. As shown Figure 12 the APT700 band plan comprises 2 x 45 MHz. This lends itself to a division of the spectrum band into 9 lots of 2 x 5 MHz.

Regionally and indeed globally, most regulators as shown in below, have adopted an approach of allocating APT700 spectrum into 9 lots of 2 x 5 MHz. The exceptions are those markets where the APT700 spectrum is not assigned by a spectrum auction but rather by way of a tender of beauty contest.

Table 9 Selected country lot sizes for 700 MHz spectrum allocations

Country	700 MHz Lot size	Type of assignment
Australia	2 x 5 MHz	Auction
Chile	Two lots of 2 x 10 MHz & One lot of 2 x 15 MHz	Beauty Contest
Japan	2 x 10 MHz	Tender
Germany	2 x 5 MHz	Auction
Malaysia	2 x 5 MHz	Beauty Contest
New Zealand	2 x 5 MHz	Auction
Peru	2 x 15 MHz	Tender
Singapore	2 x 5 MHz	Auction

Source: WPC analysis of industry sources, June 2018

Importantly, using larger lots requires pre-judging efficient lot sizes and number of lots of each size, both of which have implications on the structure of downstream markets; misjudging this might preclude an efficient allocation of spectrum, and could also facilitate market division by incumbent operators and the possible denial of entry of new market parties. It also ensures competition for 700 MHz spectrum even where there is a small number of operators in a market (say 2 or 3 licensees) as operators compete in any spectrum auction for the marginal lot of 2 x 5 MHz in order to secure an optimal allocation of say, 2 x 20 MHz. Spectrum then need not be left fallow or unused except in unusual cases where there is low demand, perhaps where reserve prices are set too high.

It should be noted that while the use of 5 MHz lot sizes introduces frequency-based exposure risk, where successful bidders obtain frequency lots that are less than their minimum requirement this has been addressed by spectrum auction design allowing bidders to specify a minimum lot size of say 20 MHz or higher.44 Having said that there are some examples in other markets for larger lot sizes including 10, 15 or 20 MHz especially where an auction format has not been used or for higher frequencies (eg. Austria[45] and Ireland[46]). But for the most part for good reasons regulators prefer 5 MHz lot sizes.

Going forward it should also be noted that the lot sizes for state-of-the-art IMT technologies such as 5G[47] remains 2 x 5 MHz for FDD implementations. 5G networks are also optimised for multiples of 5 MHz channels and using such sized blocks enables greater flexibility for potential bidders, including smaller companies, to obtain amounts of spectrum suited to their needs, for

44 See ACMA, *Draft Allocation instruments for 3.6 GHz band (3575-3700 MHz) metropolitan and regional lots auction*, May 2018 and Ofcom, *Public Sector Spectrum Release, 2.3 and 3.4 GHz bands*, 7 November 2014

45 Refer to www.rtr.at/en/inf/Konsult5GAuktion2018/Consultion_award_3400-3800_MHz.pdf

46 Refer to www.comreg.ie/media/dlm_uploads/2016/08/ComReg-1671.pdf

47 Which includes the 700 MHz spectrum band in Europe as well as spectrum in higher frequency bands like 3.6 GHz.

example, 20 or 30 MHz. Small 5 MHz substitutable generic lots, where possible, reduces complexity and substitution risk and increases the administrative ease of allocation.

Other key allocation issues

In terms of other key spectrum allocation issues for the 700 MHz spectrum band, the following should be noted:

- In relation to ***licence terms***, exemplar practice supports a licence period of 15 to 20 years based on the licences granted thus far regionally and globally for 700 and 800 MHz band spectrum.[48] Such licence terms provide greater certainty to support new investment in rolling out networks and deploying new technologies and services. They are also consistent with the basis of the expected payback period for substantial new network investments; and
- In relation to ***coverage requirements*** consistent with global practice, coverage obligations, if they are to be imposed rather than being left to competitive market forces, are best put on sub-1 GHz IMT spectrum. This is because the propagation characteristic of such bands means that the cost of providing such coverage is minimised. Coverage requirements were attached to 700 MHz spectrum licences in Singapore and New Zealand but not to spectrum licences in markets like the Philippines and Australia. Any coverage requirement in the 700 MHz spectrum licences should be realistic, consistent with other rollout/ coverage obligations of the network operator (e.g. imposing separate and different rollout obligations on a number of spectrum bands does not make sense in a LTE-A environment where the radio access network can support multiple spectrum bands) and align with a country's universal service targets and schemes.

Recommended options for co-existence

Looking at the recommended options for co-existence for APT700 services, the APT through the APT Wireless Forum ("AWF-9") has undertaken extensive study and analysis as part of and following on from the agreement by APT members for a harmonized frequency arrangement for the band 698-806 MHz.

These studies[49] were designed to provide useful information for national planning for the implementation of these band plans in the APT region including ASEAN. Deterministic analysis was performed for a range of cases including fixed point to point services, trunked land mobile services and LTE services, and probabilistic and empirical analyses were performed for selected cases. Further studies have been undertaken in other regional jurisdictions in assess possible harmful interference (e.g. New Zealand in relation to fixed service systems)[50].

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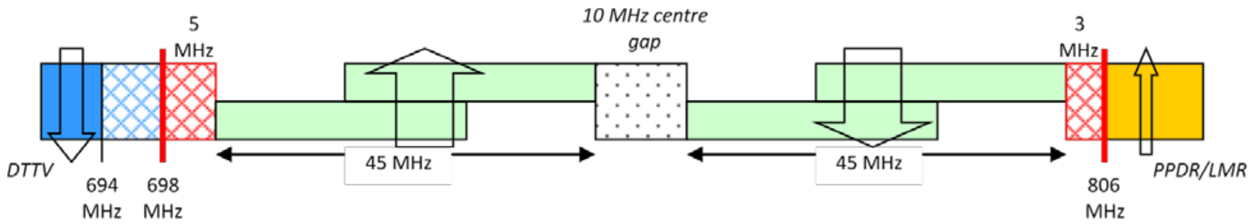
48 Australia's spectrum licences for 700 MHz spectrum are for 15 years, as are Singapore's spectrum licences while those in New Zealand are for 18 years and the United Kingdom and France are for 20 years.

49 APT, APT Report on Implementation Issues associated with the use of the Band 698-806 MHz by Mobile Services, APT/AWG/REP-24, September 2011 and APT, APT Report on Coexistence Between Services at the Boundary of the 700 MHz and 800 MHz Bands, APT/AWG/REP-44, March 2014. Both are available at www.apt.int/AWG-RECS-REPS

50 New Zealand, Ministry of Business, Innovation and Employment, *Coexistence of LTE in the 700 MHz band and Fixed Services Systems in the KK Band*, May 2013.ˇ

As show in Figure 12, the APT700 band plan envisages that a guard-band of at least 5 MHz or 9 MHz will exist between the uppermost television channel and the lower end of the FDD uplink block while a guard-band of 3 MHz exists from the lower end of the FDD downlink block and other users.

Figure 12 Harmonised APT700 band plan for 698-806 MHz



The results of those APT studies were that guard-bands shown above should permit the coexistence of IMT services in this band although the actual required guard-band depends on the channel bandwidth of the deployed IMT services and technical characteristics. This may include factors such as filtering and acceptable outage probability as well as traffic volume, density of UE, allocation of LTE resource blocks and service requirements. Such studies recommended that APT700 services can coexist with *inter alia* (i) trunked land mobile services and (ii) other IMT services (e.g. LTE) which allocated spectrum from 807 MHz.

Such studies noted that some filtering and other mitigation mechanisms may be required to be deployed to ensure co-existence the level of which depends on the guard-band put in place. Generally, a larger guard band between services in APT700 and LTE services above 803 MHz (e.g. LTE services deployed in LTE Band 26 or 27) means less mitigation mechanisms would be required to protect services utilising APT700.

Options for managing the phase-out of other incumbent users

Phase-out of incumbent users in the 700 MHz band

With the ASO, securing of the digital dividend and the allocation of 700 MHz spectrum band for IMT services, the use of short range devices ('SRD')[51] including wireless microphones which have traditionally utilised the UHF band (namely 470 to 806 MHz) will be disrupted. This is because the wireless microphones have previously operated in this band sharing this spectrum using a "class licence," low power device exemptions, operating in the gaps or "white space" will not be able to do so. Devices will have to use lower frequencies once the 700 MHz band is exclusively assigned to APT700 services.[52]

[51] See for example, in one ASEAN market, Singapore - IMDA, Telecommunications Standards Advisory Committee (TSAC), *Technical Specification, Short Range Devices,* April 2018

[52] The 10 MHz centre gap of 748-758 MHz could however still be used for low power devices.

Given the possible impacts on *inter alia* live sports broadcasting, live music concerts, large conferences, fitness clubs and religious observance (e.g. many mosques and churches utilise wireless microphones for prayers and sermons) it is critical to communicate their changes to business and users who may be affected, restrict the sale of non-conforming devices and ensure that vendors of wireless microphones and similar are fully informed.

In ***Singapore*** since 2015, the Infocomm Media Development Authority ("IMDA") and its predecessor the Infocomm Development Authority ("IDA") has communicated with industry, including key vendors like Shure and Sennheiser, on the implications for wireless microphones and other devices on the digital dividend and the allocation of the 700 MHz band for IMT use.

In ***Malaysia***, on 15 November 2017, the Malaysian Communications and Multimedia Commission ("MCMC") announced that the usage of Wireless Microphone Device(s) utilising 694 to 798 MHz will be cancelled effective on 1 July 2018.[53] Usage of these wireless microphone devices will no longer be permitted from the stated date onwards.

Internationally in ***Australia***, from 31 December 2014, wireless microphones were no longer able to operate in the 694-820 MHz frequency range due to the migration of digital television. The Australian Communications and Media Authority (ACMA) communicated to the public that it would be advantageous for users to delay the purchase of new wireless audio equipment until the new television channel plans are finalised. The ACMA then recommended the purchase of equipment that operated in the remaining 520-694 MHz band, with the widest possible tuning range. Because the larger the range of frequencies over which a piece of equipment can operate, the more likely it will be able to find an available portion of spectrum among the parts in use.[54]

In the ***European Union***, Decision (EU) 2017/899 of the European Parliament and Council sets an implementation deadline for Decision 2016/687 of 30 June 2020 and sets a time limit that Member States shall adopt and make public their national plan and schedule for the 700 MHz band no later than 30 June 2018 and that these roadmaps should, where appropriate, include measures to limit the impact of the transition process on wireless audio and video device use.[55]

As such, it is recommended that ASEAN regulators communicate to the public and industry about the communicate their changes to business and users who may be affected, restrict the sale of non-conforming devices and ensure that vendors of wireless microphones and similar are fully informed. This should be done at least 6 months, but preferably at least 12 months before the use of the 700 MHz spectrum band by mobile operators.

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53 www.skmm.gov.my/skmmgovmy/media/General/pdf/Public-Notice_Notis-Pemberitahuan-(wireless-microphone).pdf

54 www.acma.gov.au/Industry/Spectrum/Spectrum-planning/About-spectrum-planning/acma---wireless-microphones-and-the-digital-dividend-1

55 Radio Spectrum Policy Group 2017, '*Opinion on a long-term strategy on future spectrum needs and use of wireless audio and video PMSE applications'*.

Alternative approach to the clearance of the 700 MHz band

An alternative approach to the clearance of the 700 MHz band, which may be considered by ASEAN Governments and regulators who may not have the resources to (fully) fund the ASO and spectrum restack efforts, the Brazilian approach may be considered. The approach to secure the digital dividend in the 700 MHz band in the Brazilian market resulted in the winners of the 700 MHz spectrum auction in 2014 paying for the costs of migration from analogue to digital television. The approach is summarised below.

Following the decision to prioritize both the Analogue Switch-Off (ASO) and the availability of the 700 MHz band for other services, it was decided by the National Telecommunications Agency in Brazil (ANATEL) that the winners of the 700 MHz auction in 2014 would be required to pay all of the costs of migration from analogue to digital TV in order to clear the bands.[56] The digital switchover began in 2015, is scheduled to be completed in some metropolitan areas by 2018 (with the final deadline for the ASO established for 31 December 2023 for remaining cities), and is estimated to cost the winning operators USD1.1 billion.[57]

In this regard, ANATEL decided that a specific third-party entity, created by the auction winners, would manage the amount raised by the auction for restacking digital TV services. Labelled the Digitization Management Entity (EAD, as per its acronym in Portuguese), the entity also has the task of safeguarding that the switchover to digital TV is completed, alongside ensuring the avoidance of interference between IMT and broadcasting services in the UHF band.

The reason for the decision was to avoid money transfers between the parties involved, and to standardize the receiving and transmission equipment used in the migration of television channels and transition to digital broadcasting, reducing costs and allowing for coordinated implementation. A centralized entity responsible for acquiring equipment, the logistics and the implementation of the infrastructure can make the process easier and accelerate the transition.[58]

PPDR broadband spectrum allocation issues

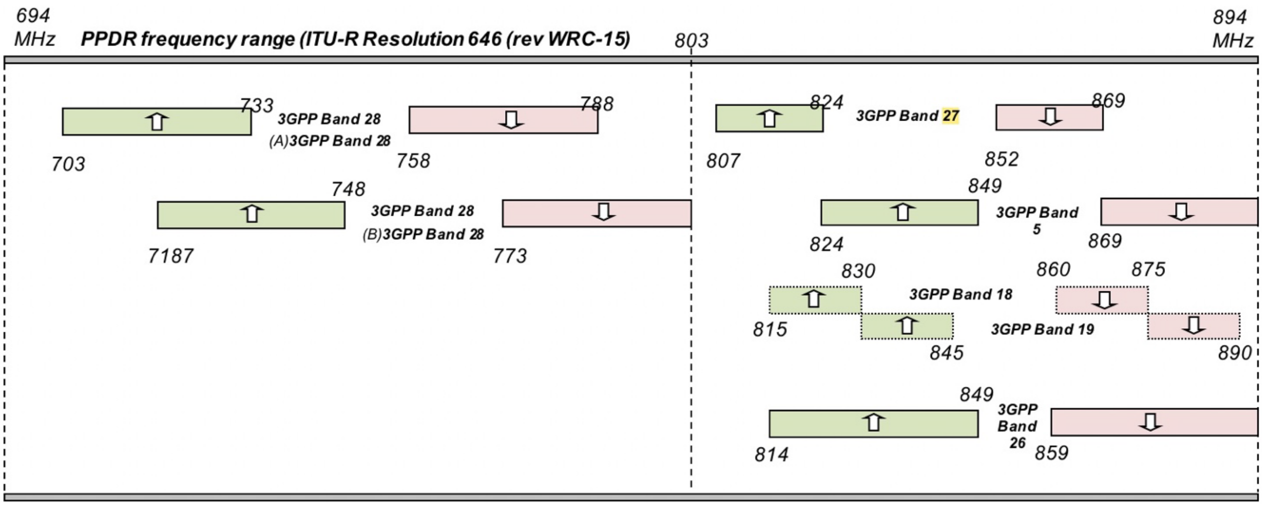
The ITU in a series of Recommendations has sought to promote global and regional harmonization of frequency bands for public protection and disaster relief (‘PPDR’).[59] See Figure 13. They could therefore be considered for use by administrations in relation to deployment of broadband wireless PPDR systems.

The ITU Recommendation followed the APT-AWG unanimous approval for a new recommendation to harmonise 700–800 MHz for LTE-based PPDR. This occurred at the 21st meeting of the APT-AWG in Bangkok on 3-7 April 2017. This decision includes the LTE Band 28 (APT700) and the

56 https://brazilianchamber.org.uk/sites/brazilianchamber.org.uk/files/publications/BBB_SEP14_WEB.pdf
57 www.5gamericas.org/files/1315/0843/7824/700_MHz_y_25_GHz_Oct_2017_Final-EN.pdf
58 www.itu.int/dms_pub/itu-d/opb/stg/D-STG-SG01.08.1-2017-PDF-E.pdf
59 Specifically, in January 2018, it released ITU Recommendation ITU-R M.2015-2 entitled Frequency arrangements for public protection and disaster relief radiocommunication systems in accordance with Resolution 646 (Rev.WRC-15). Resolution 646 (Rev.WRC-15) encouraged administrations including the regulators across ASEAN to consider parts of the frequency range of 694-894 MHz for meeting their PPDR requirements. The 3GPP frequency arrangements (applicable to Region 3) fall within the PPDR frequency range designated by ITU-R Resolution 646 (Rev.WRC-15).
rg.uk/files/publications/BBB_SEP14_WEB.pdf

LTE 800 MHz band 26, which are the two most commonly adopted public safety (PS)-LTE bands in Asia. This move took into consideration the growing communication needs of public protection agencies and organisations that are vital to the maintenance of law and order, protection of life and property, disaster relief and emergency response.

Figure 13 3GPP bands falling within the PPDR frequency range 694-894 MHz



Source: APT, APT Report on Harmonization of frequency ranges for use by Wireless PPDR Applications in Asia-Pacific Region, No. APT/AWG/REP-73(rev.1), edition: September 2017, page 28

The APT-AWG recommendation also takes note of ITU Recommendation M.2009, which identifies radio interface standards applicable to PPDR operations including TETRA, P25 and LTE, and ITU Report M.2291, which provides details of the capabilities of LTE to meet the requirements of applications supporting broadband PPDR operations. Globally and regionally a number of countries have allocated frequency spectrum for PPDR-Broadband as shown in 4.

Table 10 Selected countries allocation of spectrum for PPDR broadband

	PPDR Broadband Allocation
Australia	Will allocate 2 x 5 MHz rising to 2 x 10 MHz in the extended 850 MHz band (i.e. Band 27)
Hong Kong	Hong Kong Police Force has undertaken two LTE trials (at 700 MHz & 400 MHz).
India	TRAI has recommended 2 x 10 MHz in the 800 MHz Band for BB-PPDR.[60]
Malaysia	Allocated spectrum in the 800 MHz LTE Band 26 for PS-LTE.
Myanmar	Considering the 800 MHz LTE Band 26 or 27 for PS-LTE.
Qatar	Allocated dedicated spectrum for PS-LTE in the 800 MHz band.
Singapore	Allocated spectrum in the 800 MHz LTE Band 26 for PS-LTE.
South Korea	Allocated 2 x 10 MHz in 700 MHz for PS-LTE.
Thailand	Allocated dedicated spectrum for PS-LTE - 2x10 MHz in 800 MHz LTE Band 26

60 TRAI, *Recommendations on Next Generation Public Protection and Disaster Relief (PPDR) communication networks*, 4 June 2018

Source: WPC analysis from industry sources, June 2018

Across ASEAN reserving of 2 x 10 MHz for PPDR Broadband in the 800 MHz band rather than in the APT700 Band would seem more consistent with ASEAN regional approaches and maximises usable wireless broadband spectrum at this time. Given implementation issues for PPDR Broadband in the United Kingdom and the high cost estimates from markets like Australia, ASEAN regulators should consider contracting MNOs to use their existing infrastructure for faster and lower deployment costs. Even though additional expenditure will be needed given the need for more “hardened” infrastructure and further route redundancies if MNO networks are to be used for public safety.

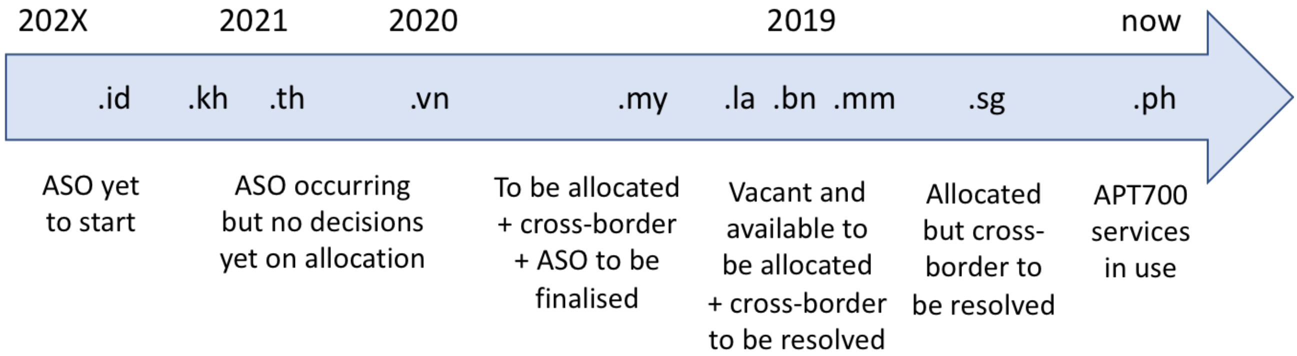
Conclusions and Recommendations

Conclusions

In conclusion, there is strong support across ASEAN for the release of more harmonised IMT spectrum to underpin the very strong growth in regional wireless broadband demand. Unfortunately delays in implementing the ASO and securing the digital dividend in the 700 MHz has meant that generally the deployment of networks utilising APT700 in ASEAN have been slower than was foreseen, and have not meet the expected timetables. It is incongruous that the adoption of APT700 has been more heralded in other parts of the world than in ASEAN – whose markets form a key part of the APT's membership.

The timeline in ASEAN for the availability and allocation of 700 MHz to IMT services and the adoption of APT700 Band plan can be summarised as shown in Figure 14. The three key factors which are holding back the deployment in order of importance are the analogue to digital television migration, cross-border co-ordination issues and how the 700 MHz, once it is available, should be allocated. These three factors can be addressed, by *inter alia* accelerating the ASO, resolving cross-border co-ordination issues to minimise harmful interference and for ASEAN regulators to commence consultations on how the 700 MHz band should be allocated.

Figure 14 ASEAN timeline for availability and allocation for 700 MHz for IMT and APT700 band plan



Source: WPC, August 2018

In the coming 6 to 12 months, the successful resolution of key cross-border co-ordination bottlenecks, will do much to accelerate the adoption of APT700 in ASEAN. Figure 15 highlights the key cross-border co-ordination areas and their likely timing for resolution. Similar to the broader consensus model which underpins ASEAN and the interaction between its members, it is hoped that with considerable goodwill these co-ordination issues can be resolved.

Figure 15 Critical decision points for cross-border co-ordination concerning the implementation of the APT 700 band

There are considerable and compelling benefits for all ASEAN countries to deploy APT700 including improved wide and indoor coverage, speeds and IoT deployments. The ability of multi-RAN LTE network infrastructure to utilise 700 MHz spectrum in the deployment of their networks would have material benefits in terms of operator capex and opex. These benefits have been highlighted by case studies of successful APT700 implementations in the Philippines and in Australia.

Recommendations

Based on this Report, a six-step plan is recommended in order to secure the digital dividend across the entire ASEAN. Ministries and national regulators should:

1. Accelerate the DSO process where it is not completed, potentially prioritising those areas of the country where cross-border co-ordination arrangements are required;

2. Review and revise, if necessary, the national frequency allocation table arising from the adoption for the harmonised APT700 Band for 698-806 MHz considering co-existence issues;

3. Undertake internal reviews (and market consultation processes with licensed mobile operators, if required) to determine the optimal allocation processes in accordance with national law for the APT700 spectrum. Such review should address *inter alia* spectrum management, PPDR, competition, and universal service issues;

4. Engage with fellow ASEAN regulators (and non-ASEAN neighbouring regulators as required) in order to establish agreed cross-border co-ordination processes for the allocation of the 700 MHz spectrum band for IMT services and deployment of APT700 compliant network infrastructure and services. Resolution of the key bottlenecks to the implementation of APT700 highlighted in this report (e.g. Singapore /Johor / Bintan and Bantam) should be the focus over the next 6 to 12 months;

5. Make public announcements (including specifically to industry and key equipment distributors) in accordance with national law that the 700 MHz spectrum band will not be available for use by short range devices including wireless microphones after a specified date. This date should be based on the DSO finalisation and assignment process of 700 MHz spectrum; and

6. Address any additional national only spectrum management issues which may slow or restrict the adoption of APT700 in a particular ASEAN market (e.g. Indonesia's court decisions, Cambodia's existing 700 MHz allocations, Thailand's digital television licences and legacy concessions etc). In addressing such issues, the national economic, societal and commercial benefits of making the 700 MHz spectrum band as soon as practicable should be highlighted to decision makers.

APPENDIX A: INDIVIDUAL ASEAN MEMBER SUMMARIES

This Appendix contains the individual ASEAN Member country summaries on the current status of the availability of 700 MHz spectrum band, the issuance of spectrum licences for the spectrum in compliance with the APT700 Band plan and the deployment of LTE networks.

Brunei Darussalam

On 18 June 2013, the Authority for Info-communications Technology Industry of Brunei Darussalam (AITI), the Directorate General Sumber Daya dan Perangkat Pos dan Informatika of Indonesia (DG SDPPI), the Malaysian Communications and Multimedia Commission (MCMC) and the Infocomm Development Authority of Singapore (IDA), jointly announced their commitment to align with the Asia Pacific Telecommunity 700 MHz band plan.[61]

The 15th Frequency Assignment Committee – Singapore, Malaysia, and Brunei Darussalam (FACSMAB)[62] Review Meeting hosted by Singapore on 19 December 2013 the MCMC, the then IDA and AITI signed the Record of Intent (ROI) on the expansion of radio frequency in the 700 MHz digital dividend spectrum.

Analogue television switch-off occurred during 2015 so the digital dividend in the 700 MHz band is currently vacant and ready for mobile broadband services. For 700 MHz, AITI and MCMC has not agreed on any technical parameters yet. However, for any cross-border interference process, AITI with MCMC and IMDA is under the Hetnet and Spillage Coordination Sub-working Group (HSC-SWG) platform, where the regulators address any co-existence of homogeneous/heterogeneous mobile technologies that has been deployed and/or are to be deployed, specifically spillage and interference.

Kingdom of Cambodia

From March to May 2011, the roadmap for transition from analogue to digital terrestrial television in Cambodia was been jointly developed by a team of ITU experts and the National Roadmap Team (NRT) of Cambodia Government.[63] It supported the securing of a digital dividend in the 700 MHz band in line with work then being undertaken by the APT. More broadly, Cambodia has strongly supported the reservation of the 700 MHz band for IMT services. At the Radio Assembly 2015 (RA-15) and World Radiocommunication Conference 2015 (WRC- 15), November 2-27, 2015, Cambodia was supported the propositions and was included in the footnote for using this band for

61 www.imda.gov.sg/about/newsroom/archived/ida/media-releases/2013/brunei-darussalam-indonesia-malaysia-and-singapore-pledge-commitment-to-align-with-the-asia-pacific-telecommunity

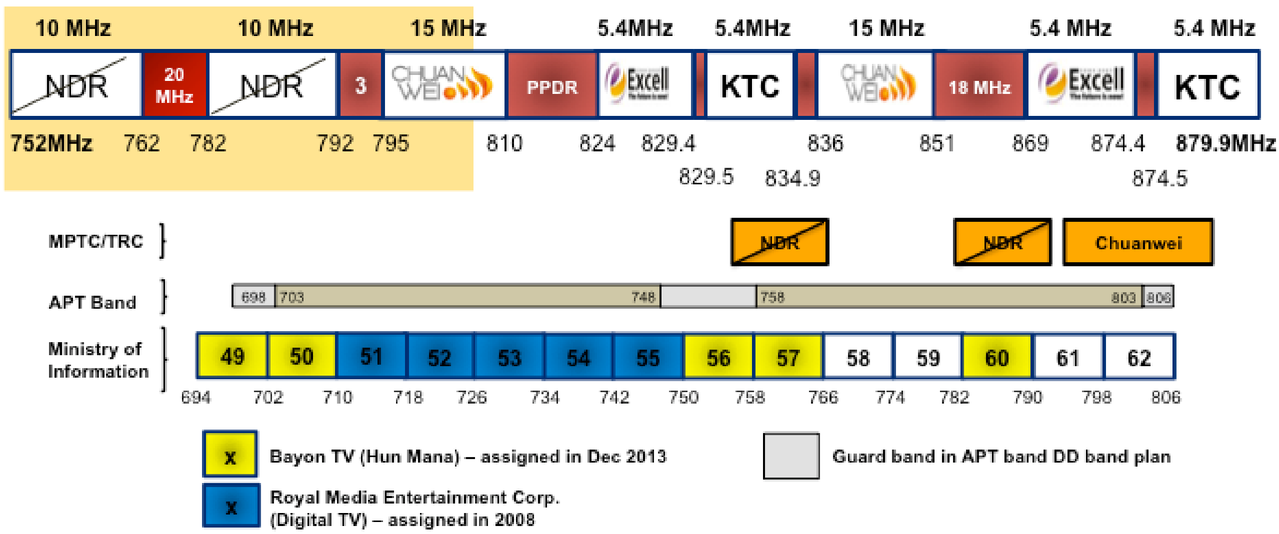
62 FACSMAB is Frequency Assignment Committee, Singapore, Malaysia And Brunei Darussalam. The objective of the committee is to manage coordination of radio spectrum at the border areas of Brunei Darussalam, Malaysia and Singapore since 1948. It was established in 1948 to deal with the day-to-day civil and service frequency assignments in South East Asia, within the sphere of the then British Governor General.

63 www.itu.int/ITU-D/tech/digital_broadcasting/project-dbasiapacific/Roadmaps/db_asp_roadmap_Cambodia.pdf

IMT consistent with its neighbouring countries.[64] It was confirmed by the MPT in a presentation in July 2018, that the 700 MHz band is a key candidate band for refarming.

As Cambodia has both analogue television broadcasting in both the VHF and UHF bands, there will need to be a digital television migration strategy prior to securing the digital dividend in the 700 MHz band. The current allocation and challenges are highlighted Figure 16. It is understood that the MPT has engaged in discussions with existing licence holders in the band in order to handback or acquire the spectrum but thus far they have not been successful.

Figure 16 Current allocation and issues in the 700 and 800 MHz bands



Source: Cambodian industry sources

Republic of Indonesia

While on 18 June 2013, SDPPI, the MCMC, AITI and the then IDA, jointly announced their commitment to align with the APT700 band plan, securing the digital dividend in the 700 MHz band in Indonesia has been great complicated and delayed by the migration to digital television.

On 27 December 2013, the Minister of Communications and Information issued a new Ministerial Regulation No.32/2013 on the digital television broadcasting. It substituted the regulation No.22 of 2011 which was revoked by the Supreme Court after litigation by various parties. The new regulation went through public consultation from 10 to 17 December 2013.

Under the new regulation:

1. There is no deadline for the migration of analogue TV to digital as the previous regulation.

[64] Cheang Sopheak, MPT, *Results of Cambodia's participation in the Radio Assembly 2015 (RA-15) and World Radiocommunication Conference 2015 (WRC- 15),* November 2-27, 2015. Available at www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/Documents/Events/2015/Dec-OTT/Presentations/Result%20of%20WRC-15-Cambodia.pdf

2. A new zonal system set by provinces; and
3. A new initial date for the commencement of digital TV broadcasting.

The conversion to digital represents a significant investment in studio equipment for all existing operators. In addition, completely new transmission networks will be required to support digital transmissions.

While various approaches to resolve this deadlock have and are being considered, including amendments to the *Broadcasting Act*, assessing the ability to reactivate the digital multiplexor licences in multiple regions of Indonesia issued in 2012, considering public private partnerships on the deployment of digital muxes etc., and increasing the licensing fees for analogue services and considering regional licences there is not a simple and straightforward way to secure the digital dividend in Indonesia.

As such there is no confirmed date for the deployment of APT700 compliant networks in Indonesia.

To address the cross-border coordination issues, bilateral meetings have been scheduled with Singapore and Malaysia in July 2018, and special trilateral meeting regarding analogue TV switch-off between IMDA, MCMC and MCIT in September 2018. The focus of such meetings is particularly on services in Batam and Bintan areas where there is a common border with three countries. These areas currently have analogue and digital television services with some of the digital multiplexors currently switched off as a result of the Supreme Court decision.

Lao PDR

In Lao PDR, the Ministry of Post and Telecommunications has had a Ministerial decision supporting the allocation of 700 MHz band for IMT since 2015,[65] and the frequency arrangement of this band is in accordance with the APT700 band plan. However, the MPT has not yet issued any spectrum licence for the 700 MHz band, even though the MPT is keen to do so and the ITU has recommended the use of 700 MHz band for wireless broadband especially in regional areas.

The MPT has not done so, because of concerns about possible interference to LTE services[66] especially in Vientiane which would utilise the 700 MHz spectrum band given the high power digital TV transmitters on the Thai side of the Mekong River.

Malaysia

On 18 June 2013, the MCMC, along with AITI (Brunei Darussalam), SDPPI (Indonesia) and the then Infocomm Development Authority (Singapore), jointly announced their commitment to align with the APT700 band plan.

On 11 October 2017, the MCMC, in accordance with Ministerial Determination on 700 MHz Spectrum Reallocation, Determination No. 1 of 2017, released Applicant Information Package No.

65 MPT, *Circular on Approving the 700 MHz band for IMT, No. 3105*, 25 December 2015

66 Presentation by Monesili Douangmany, MPT, *Current Status of the 700 MHz Band in Laos*, 4th Annual Spectrum Management Conference, Bangkok, 17 July 2018

1 of 2017 (AIP No1 of 2017) pursuant to regulation 8 of the *Communications and Multimedia (Spectrum) Regulations 2000* commenced a tender or "beauty contest" to allocate 2 x 40 MHz. Eight lots of 2x5 MHz is up for tender with a spectrum cap of 4 lots on any one bidder. The total spectrum fee for each block of 2x5 MHz is fixed at RM494m (comprising one-off payment of RM216m and annual payment of RM18.5m for 15 years) (approximately USD124 million). Bidders are required to submit a Business Plan and the selection criteria and weightage detailed in Figure 17.

Figure 17 Selection criteria for 700 MHz beauty contest in Malaysia

No.	Criteria	Weightage (%)
1.	Service rollout and planned coverage	25
2.	Infrastructure sharing	15
3.	Services to be offered, retail prices and quality of service	25
4.	Past experience and track record	10
5.	Financial and funding	20
6.	Management and technical experience	5
	TOTAL	100

Source: MCMC, AIP No1 of 2017, page 11

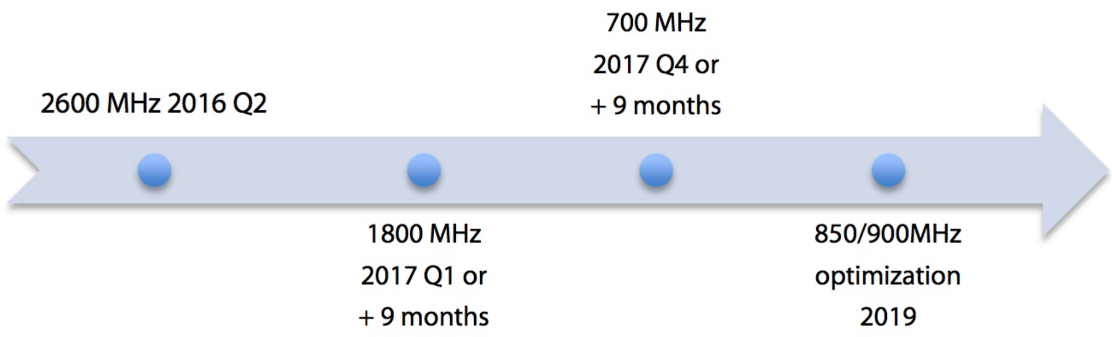
Subject to confirmation with the incoming Government, the spectrum will be made available from 1 January 2019 after analogue TV broadcasting is scheduled to be switched off in Malaysia. The 700 MHz spectrum will be mainly used to provide mobile broadband services (utilising LTE technology) to achieve higher speed and the broadband penetration target by 2020. It should be noted that there remains 2 x 5 MHz in the 700 MHz spectrum band which would not be allocated via this process. While it is not being reserved for PPDR broadband or similar, how it will be allocated has not be announced.

The use of spectrum assignment in areas located within Malaysia's border coordination zones will be shall be subject to any agreement with Malaysia's neighbouring countries in accordance with international law and/or regulations. It is understood that the MCMC is currently in discussions with the IMDA and SDPPI concerning cross-border co-ordination issues – meetings are scheduled for July to September 2018.

Republic of the Union of Myanmar

The *MCIT's Spectrum Roadmap: Meet the Needs Over Next 5 Years issued on 8 April 2016* outlined the plans of Posts and Telecommunications Department (PTD) for the release of 700 MHz spectrum in Myanmar in the 2017/18 period. Specifically, the Spectrum Roadmap as shown in Figure 18, notes that 700 MHz spectrum band which is currently unassigned, is scheduled to be allocated in accordance with the APT700 band plan by 30 September 2018.

Figure 18 Proposed release schedule of available spectrum in Myanmar



Source: Myanmar Spectrum Roadmap 2016, page 57.

In a more recent update on 17 May 2018, the PTD stated that "The sought after 700 MHz spectrum band will be considered by the Government later in 2018/2019 in accordance with Myanmar's *Spectrum Roadmap*. The views of the industry and the public on spectrum availability in this and other IMT capacity spectrum bands will be sought in a future consultative process."[67]

It is expected therefore that 700 MHz spectrum band will be made be available in Myanmar by early 2019. Importantly, the use of this spectrum could extend the coverage beyond the 95 percent population coverage expected by early 2019 and bridge the gap between voice and wireless broadband connectivity – the latter is currently estimated at 80 percent.[68]

Republic of the Philippines

In the 1990s, the bulk of the 700 MHz band was owned by Liberty Broadcasting Network Inc. (LBNI), a local company which provided voice and data communication services as well as trunk radio services. LBNI was acquired by Liberty Telecom Holdings Inc. (LTHI). Through a series of acquisitions, LTHI became a subsidiary of San Miguel Corporation.

In May 2016, San Miguel Corporation, with the approval of the National Telecommunications Commission (NTC) sold its telecommunications assets to Smart and Globe Telecom for P69.1 billion (approx. USD1.3 billion). Each mobile operator secured 2 x 17.5 MHz of 700 MHz while 2 x 10 MHz (namely 738.0 to 748.0 MHz paired with 793.0 to 803.0 MHz) is reserved for the new market player. The Department of Information and Communications Technology (DICT) and the NTC via an Oversight Committee are scheduled to select a congressional franchise holder and allocate a number of IMT frequencies including the 700 MHz to the new market player later in 2018.

In early June 2016, both Smart and Globe Telecom launched LTE services using the 700 MHz spectrum band. In May 2018, it was reported that Globe has close to 1,700 LTE sites using the

67 www.motc.gov.mm/my/news/all-1800-mhz-wireless-broadband-spectrum-blocks-allocated-myanmar

68 Ministry of Transport and Communications, Post and Telecom Department, *Universal Service Strategy for Myanmar (2018 to 2022),* pages 4 and 12

700 MHz spectrum band. In Q1, 2018, Smart installed over 1,300 additional LTE e-node B's across the country. These base stations use various radio frequency bands, specifically the 700 MHz band for better coverage and indoor penetration, and the 1800 MHz and 2100 MHz bands for additional capacity. These are in addition to reported over 2,000 LTE e-node Bs on the Smart network using 700 MHz spectrum at the end of 2017. LTE-A has now been deployed including 3 Component Carrier (3CC) to 4CC aggregation across Metro Manila.

As the current 700 MHz spectrum allocations to Smart and Globe Telecom are 2 x 17.5 MHz, 2 x 2.5 MHz for each mobile network operator is unusable because of the nature of LTE technology. It is likely therefore that the NTC will ask each operator to return 2 x 2.5 MHz of 700 MHz spectrum in the future.

Republic of Singapore

On 18 June 2013, the then Infocomm Development Authority of Singapore (IDA), along with AITI (Brunei Darussalam), SDPPI (Indonesia) and the MCMC (Malaysia) jointly announced their commitment to align with the APT700 band plan.

On 4 April 2017, the Info-communications Media Development Authority (IMDA) concluded the first stage of the General Spectrum Auction on the amount of spectrum to be awarded to interested bidders for the provision of high-speed mobile broadband services. A total of 175 MHz of spectrum in the 700 MHz, 900 MHz and 2.5 GHz spectrum bands was successfully auctioned for SGD1.145 billion. The winning bidders were able to use of the spectrum from as early as 1 July 2017 with the exception of 700 MHz which will commence on 1 January 2018 at the earliest.[69]

On 6 November 2017, the IMDA announced that the cessation of analogue TV broadcasting had been shifted from end-2017 to 31 December 2018 to allow more time for households to switch over to digital TV.[70] In addition, IMDA indicated that studying enhancements to the DTV Assistance Scheme (DTVAS) with a view to assist more HDB Singaporean households with the switchover. Mediacorp will continue to broadcast in both analogue and digital formats until 31 December 2018. The IMDA announced on 6 April 2018, that IMDA) will offer a DTV Starter Kit to all Singaporean HDB households which do not subscribe to Pay-TV, thereby helping these households continue to enjoy local free-to-air TV programs after analogue TV signals are switched off.

Unless there are further delays, it is expected that the successful bidders for the 700 MHz spectrum, namely M1 Limited (2 x 10 MHz), Singtel (2 x 20 MHz) and StarHub Mobile (2 x 15 MHz) would commence LTE service on or after 1 January 2019 if cross-border co-ordination issues can be solved.

69 www.imda.gov.sg/about/newsroom/media-releases/2017/175-mhz-of-spectrum-allocated-to-four-winning-bidders-through-the-general-spectrum-auction

70 www.imda.gov.sg/about/newsroom/media-releases/2017/analogue-tv-broadcast-to-cease-from-1-january-2019

Kingdom of Thailand

Among one of seven strategies under the first Broadcasting Master Plan (2012-2016) effective on 4 April 2012, the NBTC was given the mandate to implement the transition from analogue to digital terrestrial broadcasting in Thailand. With ITU support and consistent with global recommendations, Thailand agreed to adopt DVB-T2 specification for digital television standard in line with most ASEAN countries. Analogue television switchoff was scheduled to be completed in 2020.

On 26-27 December 2013, the NBTC auctioned 24 commercial television licences raising some THB50.9 billion (approximately USD1.6 billion). The winning bids were approximately 2.3 times the starting price. Digital television was launched in early 2014.

Things have not gone to plan however. Individual licensees and the Association of Digital Broadcasting have sought Government assistance especially in relation to the applicable fees. On 23 May 2018, the National Council for Peace and Order invoked Section 44 (Order No 9/2018) to impose a three-year debt moratorium to help digital TV operators who have been struggling to pay their licence fees to NBTC. Digital TV operators have already paid licence fees of THB34 billion, or 68 percent of the licence payment total. There are currently 22 digital TV channels run by 15 companies, down from the initial 24 channels and 17 companies, after two Thai TV channels exited the business and are in disputes with the NBTC at the Supreme Administrative Court.

The financial health of the digital television licensees, the end date of the analogue television concessions and the NBTC's view that it has been necessary to use the 700 MHz band for digital terrestrial television, especially during the transition period has slowed the making available of the digital dividend.

The NBTC is committed to the making the 700 MHz available for IMT services but it may take until 2022. This period may be shortened depending on the negotiations with Channel 3 whose concession will be the only one left (it expires on 25 March 2020) after June/July 2018.[71] While detailed steps planned by the NBTC to release the 700 MHz band for IMT are detailed in Figure 19, in July 2018, it announced that it was accelerating the transition process including:

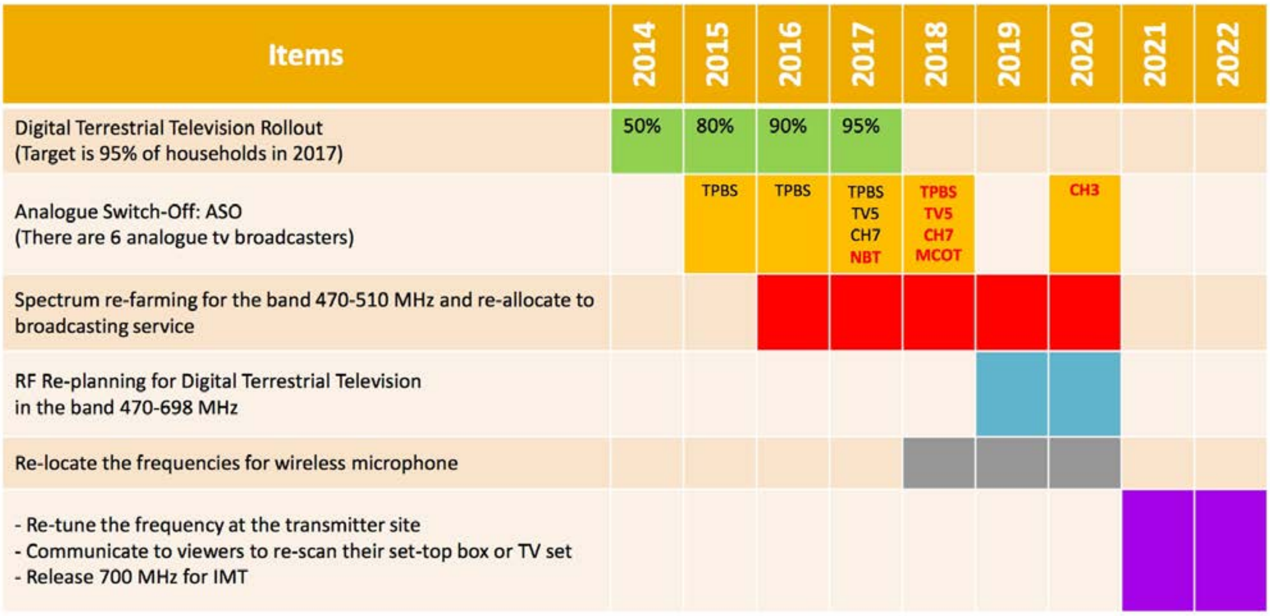
- Wireless microphone re-location being moved forward from 2023 to Q1, 2021;
- Land Mobile Services re-location being changed from 2020 to Q2, 2019;
- Bringing forward the analogue switch off and a new digital TV plan from 2020/2023 to 2019/2020; and
- Valuing the APT700 spectrum from 2023 to Q1, 2021.[72]

71 RTA TV5, TPBS, Channel 7 and MCOT analogue TV concessions all expire in June and July 2018.

72 Presentation by Nattawut Ard-Paru, NBTC, *Thailand 700 MHz Implementation: Opportunities and Challenges,* 4th Annual Spectrum Management Conference, Bangkok, 17 July 2018.

These accelerated plans may also be further brought forward, given the recent speech by the Secretary General of the NBTC that the NBTC plans to auction 45 MHz of paired FDD spectrum in the 700 MHz band for IMT services. The auction preparation is expected to begin in 2019 and to be finished by 2020.[73]

Figure 19 Steps to release 470 MHz for digital TV and 700 MHz for IMT in Thailand[74]



Items	2014	2015	2016	2017	2018	2019	2020	2021	2022
Digital Terrestrial Television Rollout (Target is 95% of households in 2017)	50%	80%	90%	95%					
Analogue Switch-Off: ASO (There are 6 analogue tv broadcasters)		TPBS	TPBS	TPBS TV5 CH7 NBT	TPBS TV5 CH7 MCOT		CH3		
Spectrum re-farming for the band 470-510 MHz and re-allocate to broadcasting service									
RF Re-planning for Digital Terrestrial Television in the band 470-698 MHz									
Re-locate the frequencies for wireless microphone									
- Re-tune the frequency at the transmitter site - Communicate to viewers to re-scan their set-top box or TV set - Release 700 MHz for IMT									

Source: NBTC, 2017

Socialist Republic of Vietnam

Vietnam has made excellent progress on the way to securing the digital dividend in the 700 MHz band. The Ministry of Information and Communications ('MIC') promulgated its Plan on Terrestrial TV channel transition in the band (470-806) MHz:

- Decision 80/QD-BTTTT (2014) for 2014-2017; and
- Decision 1761/QD-BTTTT (2017) for 2018-2020.

Analogue television was switched off in Da Nang on 1 November 2015, making it the first ASEAN city to be switched off. Vietnam's major cities of Hà Nội, HCMC, Hải Phòng and Cần Thơ were switched off in mid-2016. As at April 2018, analogue television has been switched off in 34 cities and provinces (5 major cities and 29 provinces). See Figure 20. An estimated 65 percent of the population has digital TV.

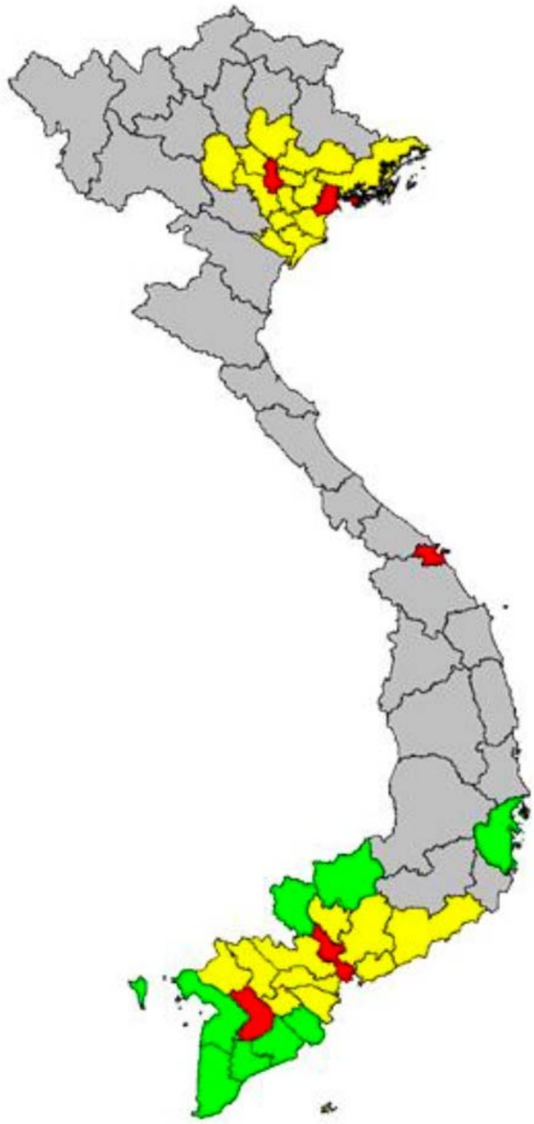
73 Takorn Tantasith, *Welcome speech*, 4th Annual Spectrum Management Conference, Bangkok, 17 July 2018, page 4
74 Supatrasit Suansook, NBTC, *Spectrum for Television Broadcasting and IMT 700 MHz in Thailand*, 21 August 2017

Television digitalization will be completed in delta areas by end of 2018.[75]

In 2013, MIC promulgated Circular 26/2013/TT-BTTTT on TV channel usage plan in the band UHF (470-806) MHz by 2020. All TV stations operating in the 700 MHz band will be moved to below 694 MHz or stopped by 2020.[76] This process is going very well and according to the Authority of Radio Frequency Management ('ARFM') it may be able to completed slightly earlier than planned.

Band 694-806 MHz will be refarmed to permit IMT. While now Vietnam permits technology neutrality[77] it is supportive of APT700 FDD plan. The MIC, ARFM, Viet Nam Telecommunications Authority ('VNTA') and other stakeholders are determining the best way forward on how to assign the 700 MHz. 2 x 5 MHz may be reserved for PPDR Broadband as shown in Figure 21.

Figure 20 TV digitalisation in Vietnam

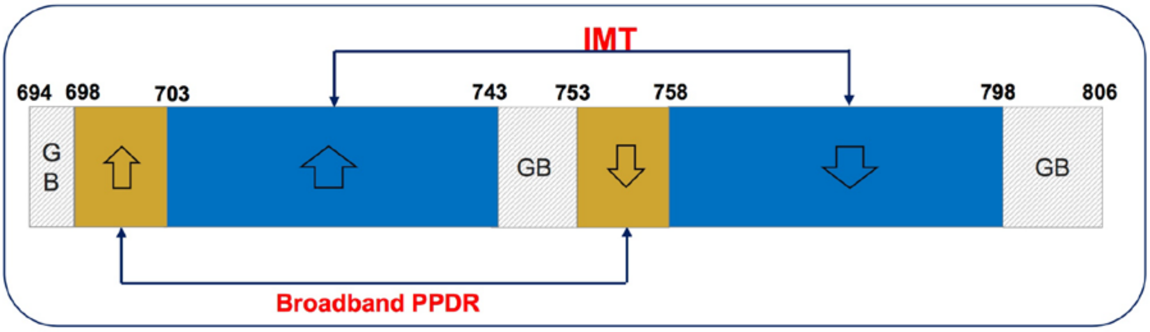


75 For a more complete summary of Vietnam's transition to digital television see GSMA, *Practical Recommendations to Digital Migration in ASEAN: Vietnam case study and regional comparisons,* 2017.

76 Doan Quang Hoan, ARFM, *700 MHz Band Plan in Vietnam*, Hà Nội, 2018

77 See Circular 04/2017/TT-BTTTT allows operators to deploy IMT systems in their licensed bands with WCDMA, LTE, LTE-A standards

Figure 21 Possible assignment of 700 MHz spectrum band in Vietnam



Source; ARFM, 2018

APPENDIX B: INTERNATIONAL CROSS-BORDER FREQUENCY CO-ORDINATION

International and regional spectrum management on releasing spectrum for IMT

Cross-border frequency coordination cannot be addressed without considering the results of international and regional spectrum management and harmonisation. These spectrum management results provide important guidelines and restrictions on the implementation of IMT (in the 700 MHz Band) and consequently on the cross-border frequency coordination between countries (who ultimately assign spectrum and implement IMT).

Figure 22 provides an overview of the three different levels in spectrum management and harmonisation, including cross-border frequency coordination. Figure 23 also shows the key results for allocating IMT spectrum.

Figure 22 Spectrum management and harmonisation on releasing spectrum

Spectrum Management levels	Key items relevant for DTTB and IMT in the 700 MHz Band
I. International Spectrum Management & Harmonisation (all Regions)	1. WRC-07,12 and 15 IMT Allocations, ITU-RR Footnotes 5.313A & 5.317A 2. ITU-RR, Article 6 (Special Agreements for cross border coordination) 3. CPM report for WRC-15, compatibility studies on DTTB/IMT 4. ITU-R Rec. M.1036.5, Frequency arrangements for IMT
II. Regional Spectrum Management & Harmonisation (Region 3)	5. APT Harmonised frequency arrangements for 698-806 MHZ Band (APT/AWF/REP-14)
III. Cross-Border Frequency Coordination	6. Bi- and multi-lateral frequency coordination Agreements 7. ITU Rec. & Rep. on planning method and criteria for DTTB and IMT

At a global level, the International Telecommunication Union (ITU) manages the global spectrum resources through its World Radio Conferences (WRC), open to and attended by all ITU members[78]. The results of these WRCs are incorporate in the ITU Radio Regulations (ITU-RR) and

[78] Comprising 193 Member States (as of 25 May 2018) and more than 700 Sector Member, Associates and Academia. The Member States are often represented by their National Regulatory Authority (NRA) or Administration. The ITU Radiocommunication Bureau (ITU-R) is responsible for managing the global spectrum resources and organising the WRCs.

more specifically in Article 5 (Frequency Allocations). The latter also referred to as the International Table of Frequency Allocations (ITFA).

Figure 23 includes the following key results, directly relevant for allocating IMT (in the 700 MHz Band):

1. The WRC-07, 12 and 15. These successive WRCs established the international framework for enabling countries to assign spectrum to IMT. For the 700 MHz Band in Region 3, the IMT allocation is reflected in the co-primary allocation of MOBILE services[79] in the ITFA and Footnotes 5.313A and 5.317A[80]. These two Footnotes *identify* IMT, allowing Administrations to implement IMT. However, this identification does not preclude the use of this spectrum by any application already allocated in the band. Neither do these Footnotes establish priority in the Radio Regulations. Consequently, as spectrum has been assigned to broadcasting services before any IMT service, Administrations planning for IMT will have to protect the broadcasting services (from harmful interference). The protection of broadcasting services is therefore a key factor, also in cross-border frequency coordination;
2. ITU-RR Article 6. It is important to note that according to the decision of WARC-79[81], cross-border coordination of frequency assignments between Administrations is excluded from the ITU-RR. However, Article 6 of the ITU-RR promotes Administrations to pursue special agreements and conclude bi- or multi-lateral frequency coordination agreements (see level III in Figure 22). These frequency coordination agreements should not conflict with any of the provisions of the ITU-RR. The ITU may also be invited to send representatives to participate in an advisory capacity to the preparation of such bi- or multi-lateral agreements;
3. Conference Preparatory Meeting (CPM) report for WRC-15. This report includes results from compatibility studies between IMT and other services in the range 470 to 694/698 MHz. Most notably, broadcasting services (DTTB), Fixed Services (FS), Radio astronomy service (RAS) and Services Ancillary to Broadcasting/ Programme making (SAB/SAP)[82]. The studies showed under what conditions these other services (Including DTTB in the 700 MHz Band) can co-exist with IMT. Subsequently, these findings were incorporated in further ITU-R Recommendations and Reports. As the section ***Detailed overview of cross-border interference cases between IMT and DTTB*** also addresses, these Recommendations and Reports can be used in cross-border frequency coordination between countries;
4. ITU-R Recommendation M.1036.5. This Recommendation provides guidance on the selection of transmitting and receiving frequency arrangements for the terrestrial component of IMT systems as well as the arrangements themselves, in the bands identified in the ITU-RR (see item 3 above). For the 700 MHz Band, Section 2 of this Recommendation provides 11 frequency arrangements in the band 694-960 MHz. Frequency arrangement A5 and A6 (i.e. respectively Frequency Division Duplex, dual

[79] MOBILE (including IMT) services have primary status, next to FIXED and BROADCASTING services. A primary service has priority over a secondary service. As any secondary services shall not cause harmful interference to stations of primary services to which frequencies are already assigned or to which frequencies may be assigned later.

[80] It is noted that (a) Footnote 5.313A covers the IMT identification in Region 3 for 27 countries, including all 10 ASEAN countries, for the band 698-790 MHz, and (b) Footnote 5.317A covers the IMT identification in Region 3 for the band 790-960 MHz.

[81] Predecessors of WRCs were called World Administrative Radio Conference (WARC).

[82] Also know under the CEPT terminology of Programme Making and Special Events (PMSE).

duplex arrangement and Time Division Duplex arrangement[83]) are the selected arrangements by the Asian-Pacific Telecommunity (APT). It is noted that Public Protection and Disaster Relief (PPDR) systems, such systems having considerable attention in Region 3, can be deployed on IMT technology. The frequency arrangement for these PPDR systems can be found ITU-R Recommendation M.2015-2;

5. APT 700 MHz band plan. As included in the ITU-R Recommendation M.1036.5 (see item 4 above) the Asian-Pacific Telecommunity agreed the frequency arrangements for the band 698-806 MHz. In its report on "*Harmonised Frequency Arrangements for the band 698-806 MHz*", dated September 2010, the APT stresses the importance of further studies as to determine appropriate LTE User Equipment (UE) out of band emission limits. These studies were needed to further ensure the coexistence of mobile services with adjacent broadcasting services below 698 MHz. Several studies have been conducted since, resulting in additional ITU-R Recommendations on unwanted emission characteristics of IMT(-A) base station and UE (e.g. ITU-R Recommendations M.2070-1 and M.2071-1).

As indicated above, the APT 700 MHz band plan includes the frequency arrangements for respectively Frequency Division Duplex (FDD) and Time Division Duplex (TDD)[84]. For most NRA's around world, the LTE-FDD is the natural choice, since in most markets mobile operators are adopting LTE by transforming their existing 2G/3G FDD networks[85].

Figure 24 shows the APT frequency arrangements for FDD in the 700 MHz Band. Figure 20 illustrates how the APT frequency arrangement compares to an 8 MHz (bandwidth) television channel arrangement, applied in the ASEAN countries in the UHF band. For example, in Cambodia and Thailand, where respectively the digital television standards DVB-T and DVB-T2 are deployed in an 8 MHz channel arrangement.

Figure 24 APT frequency arrangements and an 8 MHz TV channel raster in the 700 MHz band

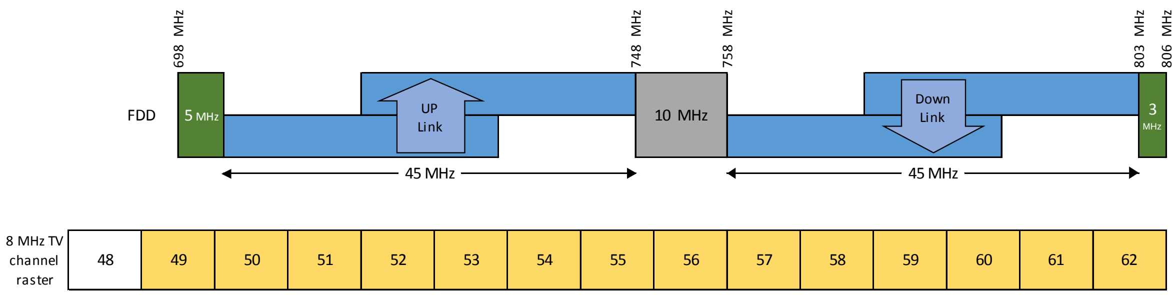


Figure 24 shows at the low end of the frequency arrangement a 5 MHz guard band. This can be considered as a minimum guard band. Because countries migrating their television services from the 700 MHz band (i.e. TV channel number 49 and up) to the 600 MHz band (48 and below) and

83 Two main types of frequency arrangements are possible Time Division Duplex (TDD) and Frequency Division Duplex (FDD) with both their pros and cons. The dual duplex arrangement is variant of FDD, considering implementation aspects (such equipment sharing between mobile operators).

84 These channel arrangements can also be found in the 3GPP technical specifications on LTE. Latest "frozen" release to date is: ETSI TS 136 101 V14.3.0 (2017-04). The 3rd Generation Partnership Project (3GPP) unites seven telecommunications standard development organizations; ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC.

85 Although some industry analysts state that in the future the TDD frequency arrangement may receive more attention of it being more spectrum efficient and spectrum becoming increasingly scarcer.

keeping their 8 MHz channel raster, would only include channel 48 and below in their new television frequency plan. In principle this would create an extra 4 MHz frequency separation distance between LTE and the broadcasting services (ATV and DTTB).

It is important to note however, that television frequency arrangements differ between countries, also between the ASEAN countries. For example, the Philippines applies a 6 MHz television raster in the UHF band and uses the Japanese ISDB-T digital television standard. Hence, frequency separation distances between LTE and broadcasting services needs to be carefully considered when re-planning the broadcasting services, an aspect which is also relevant for cross-border frequency coordination.

Cross-border frequency coordination

The ITU-RR (Article 5, Frequency Allocations) indicate that resources of the same frequency range can be utilised for different telecommunication services in countries. Particularly the co-primary allocation of mobile and broadcasting services in the 700 MHz Band (in Region 3). This fact leads to the necessity of frequency coordination in bordering territories of neighbouring countries[86]. A key principle in this cross-border frequency coordination is *equal access* to spectrum. This principle, as well as ITU-RR Article 6, asks from countries to enter into coordination talks and come to an agreement on spectrum usage.

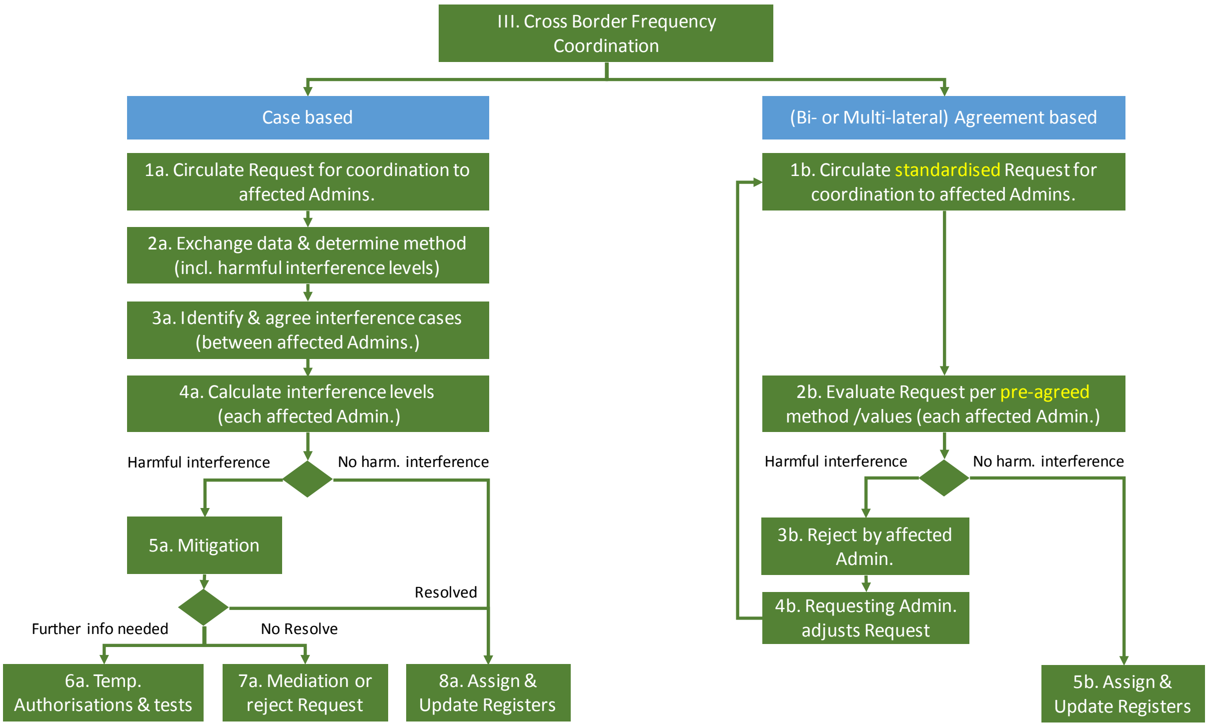
Figure 25 shows the two elementary types of cross-border frequency coordination; case- and Agreement-based. It is noted that variants and combinations of these two process types can be found across the world.

Case-based frequency coordination is in principle applied in the absence of bi- or multi-lateral Agreements. Case-based refers to the situation of one country (i.e. Administration) in the need of coordinating a frequency (or a set of frequencies) as it would like to protect this frequency from harmful interference or it expects this frequency to cause harmful interference. Case-based coordination would ultimately result in an agreement on the frequency usage of the frequencies involved in the case.

Bi- or multi-lateral Agreements are agreed well in advance of the actual (detailed) planning and assignment of frequencies. These Agreements include, in varying degrees, the process or method of frequency coordination (such as procedures, data sets, registers, propagation models and planning software) and the key applied parameters (such as specified levels of harmful interference, coordination zones and distances). These Agreements can cover large parts of the spectrum and may include a range of telecommunication services. Following the conclusion of such an Agreement, any Administration (part of the Agreement) in the need of frequency coordination will following the agreed process or method.

86 This not necessarily only involves directly adjacent countries. Especially for broadcasting services, characterised by high towers and high-power transmitters, countries beyond directly adjacent countries can be involved. For example, this is often the case with countries with relatively small territories and/or with sea-paths being involved (as frequencies propagate longer distances over water).

Figure 25 Case- and agreement-based cross-border frequency coordination processes



A well-known example of a multi-lateral agreement is the Harmonized Calculation Method (HCM) Agreement between 17 European countries, covering the co-ordination of frequencies between 29.7 MHz and 43.5 GHz for the Fixed Service (FS) and the Land Mobile Service (LMS). This Agreement is applicable for IMT to IMT frequency coordination in the 700 MHz band between the involved Administrations[87].

Another example is the Geneva 2006 (GE-06) Agreement which governs the use of frequencies by the broadcasting service (ATV and DTTB) and other primary terrestrial services in the frequency bands 174-230 MHz and 470-862 MHz in parts of Region 1 (i.e. except Mongolia and including the Islamic Republic of Iran)[88]. Although these Agreements are not directly applicable to Region 3 and the ASEAN countries, they included important planning criteria and maximum permissible interference field strengths for IMT and DTTB.

Between the ASEAN countries some cross-border frequency coordination Agreements have been concluded, with different scopes and varying degrees of process and technical detail. Table 11 provides an overview.

[87] Table 1 of Annex 1 of the HCM Agreement includes the maximum permissible interference field strengths and maximum cross-border ranges of harmful interference for land mobile services, also for the range 694 – 862 MHz (for IMT only).

[88] For more details on the GE-06 Agreements, see Annex A of the *ITU Guidelines on the transition from analogue to digital broadcasting,* edition 2014.

Table 11 An overview of some cross-border frequency coordination agreements in ASEAN

Administrations	Telecommunications services	Frequency ranges/bands	Key agreement elements
1. Joint Technical Committee Agreement on Coordination and Assignment of Frequencies, April 2015[89]			
Malaysia **Thailand**	Broadcasting services Non-broadcasting services	VHF Band I/III, UHF Band IV/V, L Band Large number of ranges within 47 MHz – 86 GHz	Agreed bands (allowing Administrations to assign frequencies in these bands) Coordination parameters (including minimum frequency separation distances, maximum permissible interference levels and coordination distances) Notification and registration procedure (including data format and types of spectrum rights)
2. Joint Technical Committee (JTC-5) partial agreements on Coordination and Assignment of Frequencies, October 2014[90]			
Thailand **Lao PDR**	Not specified yet	Not specified yet	Agreed frequency registration procedure, data forms and information exchange every 3 months (JTC-4) Ad-hoc frequency coordination on specific interference cases for example for land mobile services and aeronautical services Ad-hoc Information exchange on DTTB and mobile network deployments Proposal to designate common frequencies for PPDR
3. Frequency Assignment Committee of Singapore, Malaysia And Brunei Darussalam (FACSMAB)[91], established in 1948			
Singapore **Malaysia** **Brunei Darussalam**	All services, non-specified	All frequency ranges, non-specified	FACSMAB is a coordination forum for reaching agreements on sharing spectrum as to avoid harmful cross-border interference

89 It is important to note that this Agreement also includes assignment of frequencies, allowing the Administration to directly assign frequencies in the specified bands and under the stipulated conditions. This may still entail that case-based frequency coordination is necessary (for adjacent channel interference).

90 It is noted that between Thailand and Cambodia an agreement is reached on a common frequency registration procedure but that the actual cross-border coordination is (still) case-based.

91 See also FACSMAB website: https://www.facsmab.org.

Administrations	Telecommunications services	Frequency ranges/bands	Key agreement elements
			Agreed Radio Frequency Interference (RFI) resolution procedure; Agreed exchange of information and monthly coordination meetings
4. Agreed Trilateral Coordination Meeting between Singapore, Malaysia and Indonesia			
Singapore **Malaysia** **Indonesia**	All services, non-specified	All frequency ranges, non-specified	Agreed annual meetings to discuss matters related to: Radio frequency coordination along border areas Coordination of future planned radio-communication services Resolution of radio frequency interference along border areas
5. Agreement and execution on interference mitigation for land mobile services, with the assistance of ITU, project based, 2013			
Malaysia **Singapore** **Indonesia (mobile operators only)**	Land mobile services (E-GSM and CDMA)	880 – 890 MHz	To have a fair, transparent and accountable assessment of the 880-890 MHz band spectrum usage Study mutually favourable possibilities of spectrum utilisation (including field measurements) Provide non-binding recommendations, based on the field measurements, for frequency arrangement between the countries in the specified band

Table 11 clearly shows the many different types and forms of frequency coordination agreements between the ASEAN countries.

APPENDIX C: CASE- AND AGREEMENT-BASED COORDINATION

The steps as included in Figure 25 (in Appendix B) are further detailed in this Annex.

Case-based cross-border frequency coordination

Case-based cross-border frequency coordination refers to a situation of one country in the need of frequency coordination for a specific set of frequencies and coordination talks are needed to avoid harmful interference. As Figure 25 in Appendix B shows, these talks may take place in the framework of an already agreed forum or coordination-meetings calendar (see for example items 3 and 4 in Table 11).

As Figure 26 shows, the following process steps are included for case-based frequency coordination:

1a. Circulate request for coordination to affected Administrations. This request is often initiated by an Administration planning to introduce or change a station (for example, for IMT or DTTB). The request letter and accompanying data, although not pre-defined, includes often the station coordinates, affected services, system parameters and frequency characteristics and planned introduction date. The request is sent to all affected Administration[92]. For determining which Administrations could be affected, the requesting Administration should make a first assessment of the interference cases (see also item 3a below) at a determined coordination area, i.e. the area in which harmful interference is expected[93];

[92] An affected Administration can be defined as any Administration whose station could suffer from harmful interference because of the planned use of a frequency, or whose station could cause harmful interference to a planned receiving station of the requesting Administration.

[93] In cross-border frequency coordination Agreements, this area is often defined as the Coordination Zone, i.e. the area along the border in which a coordination agreement applies.

2a. Exchange data and determine calculation method. Following the request letter, the affected Administrations exchange data needed for determining the interference levels between the affected services. Often the requesting Administration does not hold a comprehensive and up-to-date set of the involved stations of the affected Administrations[94]. The calculation method should also be determined and agreed between the Administrations, for carrying out the interference calculations. A range of methods are available, each with its pros and cons, and internationally not a single method is recommended or commonly agreed[95];

3a. Identify and agree interference cases. In this process step the different interference cases are identified and agreed between the affected Administrations. This is an elementary part of cross-border coordination and deals with unwanted signals from either IMS and broadcasting stations interfering the wanted signals from both services, under different reception and transmission conditions. For example, the unwanted signals from an IMT base station in country A may cause harmful interference[96] to the rooftop or indoor reception of DTTB wanted signals in country B (or the other way around);

4a. Calculate interference levels. In this step the interference field strength levels are calculated based on the exchanged data, the agreed calculation method and for the identified and agreed interference cases. These calculations are normally carried out independently by each affected Administration. Different calculation results between the affected Administrations may need to be resolved before it can be determined whether the (agreed) calculated field strengths are above the permissible interference field strength levels;

5a. Mitigation. When finding interference cases with interference field strength levels above the permissible levels, mitigation should be pursued. Several mitigation options are generally available, ranging from power reductions (ERP), antenna diagram changes (e.g. more directed antenna diagrams away from the border), antenna tilting and possibly frequency changes. When working with advanced planning software, the effect of these mitigation options can be calculated relatively quickly. Applying, (additional) filtering, for example at the IMT base station or at the broadcaster receiver, may be a mitigation option. These options may have far-reaching consequences in the operational domain and are general applied for resolving interference between IMT and DTTB in adjacent channels, within a country;

6a. Temporary authorisations and tests. After mitigation, it may that the affected Administrations cannot agree on a shared solution, due to missing information on specific interference cases. The Administrations may then agree to issue a temporary authorisation,

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94 For lists of data to be exchanged, see the examples included in ITU-R Recommendation SM.1049-1.

95 Calculation methods can range from simple free-space propagation models to methods that incorporate terrain and clutter data. The first methods can be carried out by hand, whilst the latter methods need computer-based planning software. For example, the ITU defined the following propagation models ITU-R P.526-11, ITU-R P.1546-4, ITU-R P.1546-GE06, ITU-R P.370-7 and ITU-R P.1812-2. In addition, also CRC-predict and Okumura Hata are commonly applied methods.

96 ITU-RR definition 1.169 defines harmful interference as: Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with Radio Regulations. In cross-border Agreements harmful interference is often further defined in terms of a defined harmful or permissible interference field strength level (expressed in dBμV/m).

allowing the requesting Administration to temporarily assign the frequency to the station (or set of stations). In this grace period, further field tests or calculations can be carried out to gather more information on the specific interference cases and to provide comfort for a permanent solution (and ultimately the assignment of frequencies)[97];

7a. Mediation or reject coordination request. After mitigation, it may that the affected Administrations cannot agree on a commonly agreed solution, due to disagreement on the calculation results and their impact on the involved services. Mediation could resolve matters. As the ITU-RR (Article 6) and Table 11 (item 5) shows, the ITU may be invited to send representatives to participate in an advisory capacity, for resolving interference cases. Ultimately, if no resolve can be agreed the coordination request may be rejected and the requesting Administration should make alternative plans (and may start a new request);

8a. Assign and update registers. After calculating the interference field strength levels, it may that no harmful interference can be found for the defined interference cases. The Administrations may then agree that the requesting Administration can assign the frequency to the station (or set of stations)[98]. Following the agreement or assignment the affected Administrations should update their registers containing their assignments and/or frequencies under coordination. Their National Table of Frequency Allocations (NTFA) is often accompanied with a national register containing the frequency assignments (with their specified spectrum rights). Following the update of the NTFA the Administration should also record the assignment (i.e. station) in the Master International Frequency Register (MIFR) of the ITU. The Administration notifies the ITU (i.e. Radiocommunication Bureau) of the new or changed station taken into operation. The ITU will check the station's conformity with ITU-RR and will, after approval, record the station in the MIFR.

In the following Section the Agreement-based cross-border frequency coordination is addressed, which contains several process steps as discussed in this Section, although with pre-agreed procedures and parameters.

Agreement-based cross-border frequency coordination

As Table 11 shows, many different forms of cross-border frequency coordination Agreements exist in ASEAN (and the world). ITU-R Recommendation SM.1049.1 outlines a general method for aiding frequency assignment for terrestrial services in border areas and includes some examples or templates for cross-border frequency coordination agreements. In this Section the general process steps of the more advanced type of agreement is outlined, involving multiple countries.

[97] For more details on setting up field measurements and analysis of compatibility between DTTB and IMT, see ITU-R Report BT.2247-3 (07/2015).

[98] ITU-RR definition 1.18 defines frequency assignment as: Authorization given by an administration for a radio station to use a radio frequency or radio frequency channel under specified conditions. The specified conditions are in the case of cross-border coordination derived from the planning conditions under which the interference levels are calculated for the specified interference cases.

As Figure 25 shows, the following process steps are included for Agreement-based frequency coordination:

1b. Circulate standardised request for coordination to affected Administrations. The standardised request is often initiated by an Administration planning to introduce or change a station. The request form is accompanied with a standardised data set[99]. The request is sent to all affected Administration[100]. For determining which Administrations are affected, the requesting Administration calculates, based on the pre-determined calculation method, and using the data in the agreed frequency register (see also step 5b). The requesting Administration will include those stations located in the applicable coordination zone[101]. This calculation will show which stations in the coordination zone will suffer from harmful interference (i.e. where the interference field strength is above maximum permissible interference field strength). By applying the pre-agreed coordination zone, calculation method and maximum permissible interference field strengths (also referred to as trigger values), the interference cases are defined;

2b. Evaluate request per pre-agreed method and values. In this step the interference field strength levels are calculated based on the pre-defined data/frequency register, the agreed calculation method and for the identified interference cases. These calculations are carried out independently by each affected Administration[102]. Different calculation results between the affected Administrations may need to be resolved before it can be determined whether the (agreed) calculated field strengths are above the permissible interference field strength levels. In this evaluation process, the affected Administration may have to consider preferential rights of certain frequencies or shared frequencies[103]. These preferential rights or shared frequencies may have been established, based on previous bi- or multi-lateral coordination Agreements;

3b. Reject by affected Administration. Following the commonly agreed calculation results, the affected Administration can reject the request if the calculations show that the interference field strength is above the maximum permissible interference field strength. Or in other words, the interference field strength is above the trigger value and there is harmful interference. Mitigation between the affected Administrations for resolving the harmful interference may follow, but is often not part of the formal procedure of the Agreement;

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99 For the HCM Agreement the standardised data sets of respectively land mobile and fixed services can be found in Annex 2A and 2B. Also, the coordination Agreement between Thailand and Malaysia includes agreed data sets

100 See footnote 92.

101 In the HCM Agreement the coordination zones for respectively land mobile and fixed services can be found in Annex 1A and 1B. The GE06 Agreement also includes procedures for determining coordination areas. By the construction of coordination contours and determination of coordination trigger field strengths (i.e. the maximum permissible field strength). See Annex 4, figure 1 (*Limits and methodology for determining when agreement with another administration is required*) of the Final Acts of the GE06 Agreement.

102 The HCM agreement defines and made available the HCM software program, to be used by all Administrations, part of the Agreement. This program also includes the necessary databases such as topographical and border line databases.

103 Shared frequencies are frequencies which can be assigned without prior co-ordination, based on bi- or multilateral agreements under the terms laid down therein. See also footnote104.

4b. Requesting Administration adjusts request. Following mitigation between Administrations or the requesting Administration adjusting its request, the requesting Administration may circulate a renewed or adjusted coordination request;

5b. Assign and update registers. Following the commonly agreed calculation results, the affected Administration can accept the request if the calculations show that the interference field strength is below the maximum permissible interference field strength. Following this acceptance, the requesting Administration is then permitted to assign the frequencies to the station (or set of stations)[104]. Following the agreement or assignment the affected Administrations should update their registers (NTFA and register), which data also feeds into the frequency register as defined by the Agreement[105]. Again, the Administrations should also have the assignments recorded in the MIFR by ITU-R.

104 It is noted that direct assignment, without cross-border coordination, may even be possible under certain frequency coordination Agreements. See for example the cross-border frequency coordination Agreement between Thailand and Malaysia. In this Agreement both Administrations agreed that frequency assignment is possible if Malaysia only assigns odd numbered frequencies and Thailand even numbered frequencies (i.e. respectively television CH51/CH53 and CH52/CH54) in the agreed coordination zone. Resolving adjacent channel interference may however still be required.

105 The HCM Agreement defines the Frequency Register, made up of the lists set out by every Administration including its co-ordinated frequencies, its assigned (preferential) frequencies and its shared frequencies.

APPENDIX D: ITU-R RECOMMENDATIONS AND REPORTS

In Figure 10, an overview is provided of the ITU-R Recommendations and Reports relevant for IMT and BS (DTTB/ATV) interference calculations and cross-border frequency coordination. In this Appendix a detailed list is included of these Recommendations (Rec.) and Reports (Rep.) in Table 12.

Table 12 List of ITU-R Rec/Rep for IMT and BS interference calculations and cross-border frequency coordination

Rec / Rep	Ref.no	Title	Radio Category	Services
Rec.	BT.417-5 (10/2002)	Minimum field strengths for which protection may be sought in planning an analogue terrestrial television service	N/A	BS
Rec.	BT.1368-13 (06/2017)	Planning criteria, including protection ratios, for digital terrestrial television services in the VHF/UHF bands	N/A	BS
Rec.	BT.2033-1 (02/2015)	Planning criteria, including protection ratios, for second generation of digital terrestrial television broadcasting systems in the VHF/UHF bands	Sharing/compatibility issues; Technical/operational characteristics or parameters	BS; LMS
Rec.	BT.2036-2 (03/2018)	Characteristics of a reference receiving system for frequency planning of digital terrestrial television systems	Technical/operational characteristics or parameters	BS
Rec.	M.1036-5 (10/2015)	Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications (IMT) in the bands identified for IMT in the Radio Regulations	Frequency arrangements; IMT	LMS
Rec.	M.1580-5 (02/2014)	Generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT-2000	Technical/operational characteristics or parameters; IMT	LMS

Rec / Rep	Ref.no	Title	Radio Category	Services
Rec.	M.1581-5 (02/2014)	Generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT-2000	Technical/operational characteristics or parameters; IMT	LMS
Rec.	M.1635-0 (06/03)	General methodology for assessing the potential for interference between IMT-2000 or systems beyond IMT-2000 and other services	IMT	LMS
Rec.	M.1767-0 (03/06)	Protection of land mobile systems from terrestrial digital video and audio broadcasting systems in the VHF and UHF shared bands allocated on a primary basis	Sharing/compatibility issues	LMS; BS
Rec.	M.2015-2 (01/2018)	Frequency arrangements for public protection and disaster relief radiocommunication systems in accordance with Resolution 646 (Rev.WRC-15)	Frequency arrangements	MS
Rec.	M.2070-1 (02/2017)	Generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT-Advanced	Technical/operational characteristics or parameters; IMT; Vocabulary	LMS
Rec.	M.2071-1 (02/2017)	Generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT-Advanced	Technical/operational characteristics or parameters; IMT; Vocabulary	LMS
Rec.	M.2090-0 (10/2015)	Specific unwanted emission limit of IMT mobile stations operating in the frequency band 694-790 MHz to facilitate protection of existing services in Region 1 in the frequency band 470-694 MHz	IMT; Sharing/compatibility issues	LMS, BS
Rec.	SM.329-12 (09/2012)	Unwanted emissions in the spurious domain	Vocabulary	All
Rec.	SM.1049-1 (10/95)	A method of spectrum management to be used for aiding frequency assignment for terrestrial services in border areas	Sharing/compatibility issues; National Spectrum Management issues	BS; FS; MS; RDS
Rec.	SM.1541-6 (08/2015)	Unwanted emissions in the out-of-band domain	Vocabulary; Sharing/compatibility issues	All

Rec / Rep	Ref.no	Title	Radio Category	Services
Rec.	BT.1206-1 (01/2013)	Spectrum limit masks for digital terrestrial television broadcasting	N/A	BS
Rep.	BT.2254-3 (03/2017)	Frequency and network planning aspects of DVB-T2	N/A	BS
Rep.	BT.2215-6 (2016)	Measurements of Protection Ratios and Overload Thresholds for Broadcast TV Receivers	Sharing/compatibility issues; IMT	BS; LMS
Rep.	BT.2247-3 (07/2015)	Field measurement and analysis of compatibility between DTTB and IMT	Sharing/compatibility issues; IMT	BS; LMS
Rep.	BT.2301-2 (10/2016)	National field reports on the introduction of IMT in the bands with co-primary allocation to the broadcasting and the mobile services	Sharing/compatibility issues; IMT	BS; LMS
Rep.	BT.2337-0 (2014)	Sharing and compatibility studies between digital terrestrial television broadcasting and terrestrial mobile broadband applications, including IMT, in the frequency band 470-694/698 MHz	Sharing/compatibility issues; IMT	BS; LMS
Rep.	BT.2339-0 (11/2014)	Co-channel sharing and compatibility studies between digital terrestrial television broadcasting and international mobile telecommunication in the frequency band 694-790 MHz in the GE06 planning area	Sharing/compatibility issues; IMT	BS; LMS
Rep.	M.2291-1 (11/2016)	The use of International Mobile Telecommunications for broadband public protection and disaster relief applications	IMT	LMS
Rep.	SM.2353-0 (06/2015)	The challenges and opportunities for spectrum management resulting from the transition to digital terrestrial television in the UHF bands	National Spectrum Management issues	All

Glossary of Abbreviations

3GPP	3rd Generation Partnership Project (uniting 7 standardisation bodies)
APT	Asia-Pacific Telecommunity
ARNS	Aeronautical Radio Navigation Service
ASEAN	Association of South East Asian Nations
ATV	Analogue Television
BS	Broadcasting Service
CPM	(ITU) Conference Preparatory Meeting (for WRC)
DSO	Digital television switch-over
DTMB	Digital Television Multimedia Broadcast a Chinese digital television standard
DTTB	Digital Terrestrial Television Broadcasting
DVB-T	Digital Video Broadcasting-Terrestrial
DVB-T2	Digital Video Broadcasting-Terrestrial, 2nd generation
ERP	Effective Radiated Power
FDD	Frequency Division Duplex
FS	Fixed Services
HCM	Harmonized Calculation Method
IMT	International Mobile Telecommunications
IMT BS	IMT Base Station
IoT	Internet of Things
ISDB-T	Integrated Services Digital Broadcasting - Terrestrial
ITFA	International Table of Frequency Allocations
ITU	International Telecommunications Union

ITU-RR	ITU Radio Regulations
LMS	Land Mobile Service
LTE	Long Term Evolution
LTE BS	LTE Base Station (e Node B)
LTE-M	LTE-Cat M1 or category M1 for Internet of Things
MIFR	Master International Frequency Register
NRA	National Regulatory Authority
NTFA	National Table of Frequency Allocations
PAL	Phase Alternating Line – an analogue television standard
PMSE	Programme Making and Special Events (CEPT terminology)
PPDR	Public Protection and Disaster Relief (service/system)
PR	Protection Ratio
RAS	Radio astronomy service
RX	Receiver
SAB/SAP	Services Ancillary to Broadcasting/Programme making
Secam	A French analogue television standard
TDD	Time Division Duplex
TX	Transmitter
UE	User Equipment
WARC	World Administrative Radiocommunication Conference (predecessors of WRCs)
WRC	(ITU) World Radiocommunication Conference

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