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Broadcast Spectrum Consolidation 2021

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1 Executive Summary

Kordia and JedTech were contracted by the Commonwealth Government in April 2021 to provide technical advice on the potential consolidation of spectrum used for television.

The Government has indicated that this advice is intended to inform deliberations by Government and Australia's television broadcasting sector about potential pathways forward for the sector, including such matters as technical standards for receivers and the allocation and design of spectrum used for television broadcasting. While relevant to the broader consideration of the future of television services, there were a number of matters that were outside the scope of this paper. These included detailed consumer impacts and the overall commercial sustainability of the television sector.

The key tasks in the brief were to:

- Identify and evaluate the technical feasibility of two different approaches to the spectrum consolidation.
- Consult with the stakeholders (14) – FreeTV, Broadcasters (9), BAI, TXA, ACMA, and the manufacturers' representatives
- Convene a workshop to seek agreement on the technical parameters for the spectrum consolidation and shared multiplex arrangements.
- Report and present the findings.

Following the workshop it was agreed to consider six Scenarios (and compare these to the status quo which we call Scenario 0). These are summarised on page 12. Scenario 1 is similar to the arrangements considered in the Government's media reform green paper. The Scenarios that have been analysed and compared are the current situation, another three with DVB-T (the current Australian standard), and three with DVB-T2 (a potential future Australian standard). They cover a range of total channels and differing numbers of channels in the metro areas to the regional areas. While potential complexities were identified, all Scenarios are technically feasible.

To compare the program carrying capacity of each Scenario, a base case equivalent to what is being carried today of two high definition, two standard definition and two lower quality programs streams has been used.

There are trade-offs involved, whichever Scenario is chosen. For example, Scenario 1 could be achieved relatively quickly and most consumers would not need to purchase new equipment; however it offers less capacity than some other Scenarios.

Under any consolidation scenario there would be choices to be made, and different options available to broadcasters regarding how they might share multiplexes.

If DVB-T2 were adopted, three RF channels would be sufficient to allow the current number of programs to be broadcast in the current quality with some scope for expansion of services. However, a transition to DVB-T2 is not inevitable and would be disruptive for consumers because of the requirement to purchase new receivers or set-top boxes. More work would be required to determine if a transition away from DVB-T is the optimal approach going forward.

All Scenarios would allow free to air television services to be delivered using less radiofrequency spectrum than is presently used. Some Scenarios achieve a reduction of as much as 84 MHz; others achieve a lower reduction.

Across the Scenarios, the need for a consumer to replace their rooftop antenna is likely to be rare. However, consumers would have to bear the costs if a situation arises that would necessitate the replacement of these antennas with band-appropriate equipment. If this cost was to be borne by the consumer, stakeholders have expressed concerns that this could encourage some households to permanently migrate away from terrestrial TV.

A subset of antennas or receive equipment may need repointing or upgrading due to the greater use of SFNs or wide area SFNs that could be required for some of the proposed Scenarios. Rescanning the channels, moving away from MPEG2, sharing multiplex program information and/or the introduction of DVB-T2 is likely to affect the consumer either in a minor or significant way. This report considers the technical impact on consumers of various Scenarios with respect to the impact on their reception equipment (e.g. antennas and TVs). Broader consumer issues, such as preferences for amount or quality of programming, were outside of the scope of this report.

There appears to be little quantitative data available on the numbers and capability of current receivers in use in Australian households, with new receivers not necessarily replacing the existing receivers but adding to the total number. There has been no recent survey of the receiver population for MPEG-4, which would provide evidence for the number of consumers impacted by a transition to MPEG-4 only broadcasting. Similarly, there is no comprehensive data on the number of DVB-T2 capable receivers in the market.

Regional broadcasters in particular rely on off-air reception from a parent transmitter as the input to their transmitters. If spectrum is consolidated, some of these inputs will need to be replaced with an alternative such as microwave links or fibre, which would have cost implications.

Contribution arrangements (from the studio/playout centre) to the MUX arrangements will change if MUXes are shared by different Networks. To share a MUX, the broadcasters would need to create links to a common physical playout location. If housed by one broadcaster or an independent 3rd party manager, then the other broadcasters would still need to link to it. Location, ownership and management of the shared MUX arrangement would have to be decided and there would be both set up costs and ongoing operational costs to be considered.

Based on views expressed in the workshop and some of the individual consultations, most stakeholders considered that the timeframe expected for migration for the DVB-T Scenarios seems to be no sooner than five years before the spectrum would be available. For the DVB-T2 Scenarios, the timeframe is expected to be five to 10 years depending on take up rates of new receivers and migration methodologies.

Costings for the Scenarios are not well developed due to the variables still to be determined like the transition methodology (simulcast, hard switch etc) however some stakeholders have offered some figures. Converting to DVB-T2 would be more costly. If the 6th channel were used as part of the transition, then more costs would be incurred to establish (and then disestablish) the transmission.

Costs associated with aligning National and Commercial coverage footprints have not been envisaged in any of the stakeholder costings.

1.1 Key Findings

The following is the collated list of key findings presented in the report.

1.1.1 Key Findings from Section 4, Technical Issues in General

F4.1 Key Findings – Single Frequency Networks:

- Greater use of Single Frequency Networks (SFNs), as one possible planning approach, may enhance the possibility of releasing 84 MHz for some of the scenarios.
- Wide area SFNs, as part of the DVB-T2 standard, could increase the amount of spectrum released for some of the scenarios considered, although the use of such wide area SFNs brings its own set of complexities and challenges.
- One of the key disadvantages of the use of more SFNs is the impact to viewers who may need to repoint or upgrade their receive equipment and or installations. This impact could be exacerbated by the introduction of wide area SFNs.
- The use of more SFNs or wide area SFNs are not the only planning approaches available to achieve the consolidation of broadcasting spectrum. Other planning tools or methods will need to be considered as part of a wider evaluation process going forward.

F4.2 Key Findings – Digital TV Transmission Standards:

- If a transition to a new standard is appropriate, then DVB-T2 is the logical choice to transition from DVB-T as its transmitters and receivers are typically backwards compatible and is of the same family of DVB standards.
- The use of DVB-T2 allows greater capacity in a given amount of spectrum, compared to DVB-T, but the use of DVB-T2 in itself would not allow more spectrum to be released as this would be dependent on how much spectrum broadcasters choose to use.
- DVB-T2 is not the only standard available to transition to, although moving away from the DVB family of standards raises greater complexities than staying within it.

F4.3 Key Findings – Compression Standards:

- An efficient compression standards combination, such as transition to exclusive use of MPEG4, would allow additional capacity for the same amount of spectrum used. The adoption of DVB-T2 transmission and HEVC compression would significantly expand the capacity of multiplexes.
- A coordinated approach is key to ensure receivers can use these compression standards.

F4.4 Key Findings – Shared Multiplexing:

- Moving to MUX sharing will require changes to allow the contribution of program content to a centralised location. There would be both set up costs and ongoing operational costs to be considered.

F4.5 Key Findings – Receiver Population and Capability:

- A well-designed consumer survey would provide Government and the broadcasting sector with evidence of the existing capability of household receivers.

F4.6 Key Findings – Spectrum and Logistics Planning:

- Spectrum planning should consider planning for the RF broadcast channels as well as the inputs, but prioritise the RF channels as these are the only means to provide the broadcast services to viewers.
- Should the Government decide to offer broadcasters the choice to move to a consolidation of TV spectrum (as per the green paper proposal), ACMA has noted that it would work to identify the planning approach, in consultation with the industry, based on the high-level objectives set by the Government, once confirmed. This planning approach would then be used by ACMA in preparing the channel plans.
- It is too early for detailed logistics planning to take place.

1.1.2 Key Findings from Section 5, Analysis of Scenarios

F5.2 Key Findings – Spectrum Consolidation:

- All Scenarios would allow free to air television services to be delivered using less radiofrequency spectrum than is presently used. Some Scenarios achieve a reduction of as much as 84 MHz; others achieve a lower reduction.
- Scenario 1 is the most practicable in terms of spectrum planning. Scenario 4 would be similarly practicable from a spectrum planning perspective.

F5.3 Key Findings – Channel Data Capacity:

- Under any consolidation scenario there would be different options available to broadcasters regarding how they might share MUXes.
- The Scenarios have different implications for the data capacity available to broadcasters. For example, one option under Scenario 1 could involve three commercial broadcasters sharing two MUXes and the national broadcasters sharing one MUX with DVB-T. Under this option, the commercial broadcasters would need to share a total capacity of 45 Mb/s and the National broadcasters would need to share a total capacity of 22.5 Mb/s. An alternative option could involve five broadcasters sharing three MUXes. Under this option, broadcasters would need to share a total capacity of 67.5 Mb/s.
- Three RF channels using DVB-T2 would allow the current number of programs and in the current quality.

F5.5 Key Findings – Impact on Consumers:

- Minimising the change and effort that consumers need to make to receive a suitable service is viewed by broadcasters as paramount in order to maintain their audience numbers. All Scenarios (other than Scenario 0 – the current situation) would have some impact on the consumer (as noted in key finding 5.6).
- From a technical perspective, consumers could be affected by changes in band, rescanning, repointing antennas and or upgrading equipment to receive SFN signals, moving away from MPEG2 etc.

F5.6 Key Findings – Implementation Logistics:

- All Scenarios (other than Scenario 0 – the current situation) would have some impact on the consumer, and both the Government and the broadcasters attach a high priority to minimising this impact.
- Further work would be required to better understand specific implementation logistics to transition to a new Scenario. However, a five to 10 year transition timeframe to free up the spectrum was deemed reasonable by all participants in the workshop.

F5.7 Key Findings – Costs:

- Costings for the Scenarios are not well developed because the variables are still to be determined, including the transition methodology (simulcast, hard switch etc.). However, some stakeholders have offered some figures. While no in-depth costings have been completed, the costs to implement Scenario 1 are likely to be the lowest. The highest costs would likely be for the Scenarios with more RF channels and use of DVB-T2.

1.1.3 Other Key Findings from Appendices 2 and 3

AF2.1 Key Findings – National vs Commercial Broadcast Licence Areas:

- Nationals and Commercials sharing a MUX could be complicated for areas where the coverage footprints differ significantly between the services, typically for high powered sites (Nationals do not have licence areas, Commercials do), noting that under any consolidation scenario there would be choices to be made, and different options available to broadcasters regarding how they might share multiplexes.

AF2.2 Key Findings – Contribution to a Shared MUX:

- All broadcasters' uncompressed signals need to come to a central location, encoded/compressed and statistically MUXed.
- Centralising a shared MUX would give rise to business decisions for stakeholders opting into a shared MUX arrangement, and there would be costs involved to get streams to a central location. There are differing views as to whether operating costs would increase or decrease. More work is required on the cost issues.

AF2.3 Key Findings – Distribution of a Shared MUX Output:

- The current distribution chains are the most efficient solution, technically and economically.
- The distribution arrangements need to be carefully considered for a shared MUX. These issues are more related to business decisions for stakeholders opting into a shared MUX arrangement, rather than technical impediments that make the distribution side of MUX sharing unfeasible.
- A number of off-air inputs may no longer work and would require direct microwave links or fibre, increasing CAPEX and ongoing costs to upgrade.
- A rebuild of some of these distribution chains could be complex and expensive.
- Satellite distribution could be considered as an option for remote transmitters.

AF3.1 Key Findings – Considerations in Regards to Adjacent Users:

- There is potential for coexistence issues from mobile phone transmissions that are adjacent to the TV spectrum for any proposed consolidation, but this is not an assumed outcome.
- Band replanning activities would be expected to look at supporting the coexistence of spectrum users and could help mitigate the issue, should it be significant.
- Coexistence would need to be managed and coordinated between broadcasters, mobile phone operators and the Government.

AF3.2 Key Findings – Wireless Microphone/Audio Device Spectrum Availability

- There would be impacts on the spectrum available for wireless microphones and other wireless audio devices as part of any potential consolidation.

1.2 Areas for Further Work

The following are suggested areas for further work, collated from the report, for Sections 4 – Issues, Section 5 – Analysis of Scenarios, and other Areas for Further Work presented in the Appendices. Note that not all areas or topics will have suggestions, with the aim being to capture some areas that could benefit from more work as a priority.

1.2.1 Areas for Further Work from Section 4, Issues

W4.1 Possible Area for Further Work – Single Frequency Networks:

- More work is needed to understand the practical use and implementation of wide area SFNs, should this be one of the planning approaches used for any potential consolidation of broadcasting spectrum.

W4.2 Area for Further Work – Digital TV Transmission Standards:

- Should it be determined that a new transmission standard is appropriate it would be important to have the Australian DVB-T2 standard finalised, which the broadcasting industry is currently progressing.

W4.5 Area for Further Work – Receiver Population and Capability:

- Conduct a survey to gain an understanding of the technical capability of the receiver population and gauge the impact on consumers.

W4.6 Area for Further Work – Spectrum and Logistics Planning:

- Should the Government decide to offer broadcasters the choice to move to a consolidation of TV spectrum, comprehensive spectrum planning would need to be undertaken once associated policy decisions had been made.

1.2.2 Areas for Further Work from Section 5, Analysis of Scenarios

W5.2 Area for Further Work – Spectrum Consolidation:

- Detailed spectrum planning would need to be completed to understand the potential amount of spectrum that may be released for each Scenario.

W5.7 Area for Further Work – Costs:

- Suggest further work be undertaken to better understand the overall end-to-end costs to consolidate the spectrum.

1.2.3 Areas for Further Work from Appendices 2 and 3

AW2.1 Area for Further Work – National vs Commercial Broadcast Licence Areas:

- Assess the scale and impact of sharing National and Commercials on the same MUX.

AW2.2 Area for Further Work – Contribution to a Shared MUX:

- Undertake further analysis to understand the contribution complexities involved, and the added costs, plus any potential offsets in costs that arise from a centralised shared MUX arrangement.

AW2.3 Area for Further Work – Distribution from a Shared MUX:

- Undertake further work to understand the distribution complexities involved and the added costs, that takes into consideration the outcome of the spectrum plan and MUX sharing arrangements.

AW3.1 Area for Further Work – Considerations in Regards to Adjacent Users:

- Examine the impact of mobile phone carriers on adjacent channels to understand the interference potential and scale of problem (adjacent spectrum and intermodulation) once there is direction on the preferred approach to spectrum consolidation.

AW3.2 Area for Further Work – Wireless Microphone/Audio Device Spectrum Availability:

- Undertake further work to understand the impact to wireless microphones/audio devices once there is direction on the preferred approach to spectrum consolidation.

2 Introduction

2.1 Scope

Kordia and JedTech were contracted to provide technical advice on the proposal for a possible consolidation of the TV spectrum in April 2021 after responding to an "Approach to Market" (ATM) (Reference ID:10021653).

The key tasks for this brief as described in the ATM's document Statement of Works were to:

1. Identify and evaluate the technical feasibility of at least two different approaches to television broadcasting spectrum consolidation;
2. Conduct consultations with individual broadcasters and facilitate a workshop or workshops with commercial and national broadcasters to develop an agreed set of facts concerning the technical parameters relevant to the potential spectrum consolidation and shared multiplex arrangements;
3. Consider the possibility of planning a different number of services in metropolitan and regional areas to achieve the same or greater consolidation of spectrum;
4. Consider the differences between metropolitan and regional television services that might result from the technological and policy options;
5. Consider the impact on consumers of the two approaches including changes to coverage, and viewer cost and disruption associated with the transition.
6. Consider how costs to commercial and national broadcasters would be minimised, and whether there would be an impact to the digital radio allotment plan;
7. Detail the assumptions made in the analysis and the implications of these assumptions for national broadcasters, commercial broadcasters, consumers and technical planning;
8. Present your findings in a written report; and
9. Present your findings in a verbal briefing and presentation.

2.2 Consultation and Workshop

Initially two approaches (three channels everywhere and alternatively three channels in the regional areas with more in the metros) were specified and examined however after consulting with the stakeholders, review of the Green Paper submissions and the workshop, six different approaches or Scenarios as well as the current situation have been analysed.

Consultation sessions with individual stakeholders were held with 13 of the 14 specified (one declined). They were all constructive and informative with the stakeholders keen to participate, contribute and add value.

A workshop was held on 17th June 2021 with nearly all stakeholders (one declined) participating. The six Scenarios plus the current arrangement were discussed, and the technical parameters compared for each scenario.

This following report presents the findings from all the key tasks.

3 Background

This section provides a high-level background on the technical aspects in relation to this proposed spectrum consolidation. Further descriptions of the relevant technical aspects are provided in the Appendices, and further commentary and analysis of these aspects are provided in Sections 4 and 5. A Glossary of key technical terms are provided in Section 8.

3.1 Overview

Digital Television (digital TV or DTV) is a means whereby broadcast services are transmitted to viewers via the use of digital transmissions, that utilise digital encoding and file compression. Digital TV has superseded Analogue TV in Australia.

This background section is divided into the following topics:

- A discussion on the spectrum used to broadcast digital TV.
- An overall description of the network topologies that make use of this spectrum.
- The various digital TV transmission standards and compression standards.
- A description of the use of multiplexes to combine content for broadcasting.
- Brief descriptions on the overall contribution and distribution concepts that utilise the standards, technologies and network topologies to form the overall digital TV system.

3.2 Digital TV Spectrum

Currently the digital TV broadcast spectrum is made up of a Very High Frequency (VHF) channel block and four Ultra High Frequency (UHF) channel blocks. A channel block is a grouping of six RF channels used in the block planning approach adopted in Australia. This translates to RF channels 6 to 12 in the VHF band (174 MHz to 230 MHz, minus the digital radio allocation on RF channels 9 and 9A) and RF channels 28 to 51 in the UHF band (526 MHz to 694 MHz). Each RF channel is 7 MHz wide. The Government has been consulting on a proposal that would offer broadcasters the choice to use less radiofrequency spectrum, which could potentially release up to 84 MHz of spectrum Australia-wide through consolidation of TV services onto shared multiplexes (MUX) which would mean TV services would cease using RF channels 40 to 51.

Each VHF or UHF channel is used by a TV network to transport services via a MUX containing various streams of video and audio services, such as HD or SD TV services, radio programmes and Service Information (SI). Currently 5 of the 6 channels in each block are each allocated to ABC, SBS, Seven, Nine and Ten in metropolitan areas, and ABC, SBS, Prime, SCA, WIN, Imparja, Seven (Seven Queensland) and Nine (NBN) in regional or remote areas, with the 6th channel currently used by community television services in Melbourne and Adelaide[1]. This makes up the National (ABC, SBS), Metropolitan Commercial (Seven, Nine and Ten) and Regional/Remote area Commercial (Prime, SCA, WIN & Imparja) networks.

The spectrum blocks model is used to aid planning of the spectrum allocations across geographical regions, allowing for uniform planning based on RF channel groups that can be reused where available. For example, Block A is allocated to each of the capital city metropolitan areas, made possible by the large geographical isolation and channels from other blocks are used for infill services. Typically, a single channel block is allocated to each transmission area, except for overlapping licence areas. The spectrum consolidation is targeted to retain

[1] except for 14 MHz in Melbourne and 7 MHz in Adelaide used for community television services. The community television services will continue to have access to this spectrum until 30 June 2024 (see Section 96A of the *Radiocommunications Act 1992*). Also, broadcasting technology trials have been undertaken using this vacant spectrum.

3 RF channels in each UHF block, while retaining the 4 UHF blocks. However, the number of RF channels retained per block will depend on the final scenario agreed, as discussed later in this report.

Figure 1 shows the current allocations in both VHF and UHF bands (top row), how the spectrum is divided into channel blocks (second row down), how the channel blocks are divided into RF channels (third row down) and the potential spectrum release (bottom row). Note, this diagram shows the current channel blocks made up of 6 RF channels consolidating down to 3 RF channels per block; this has been referred to as the simple concertina model during this consultation period and is one of the proposals laid out in the 'Media Reform Green Paper – November 2020', it is not necessarily the final planned/agreed scenario.

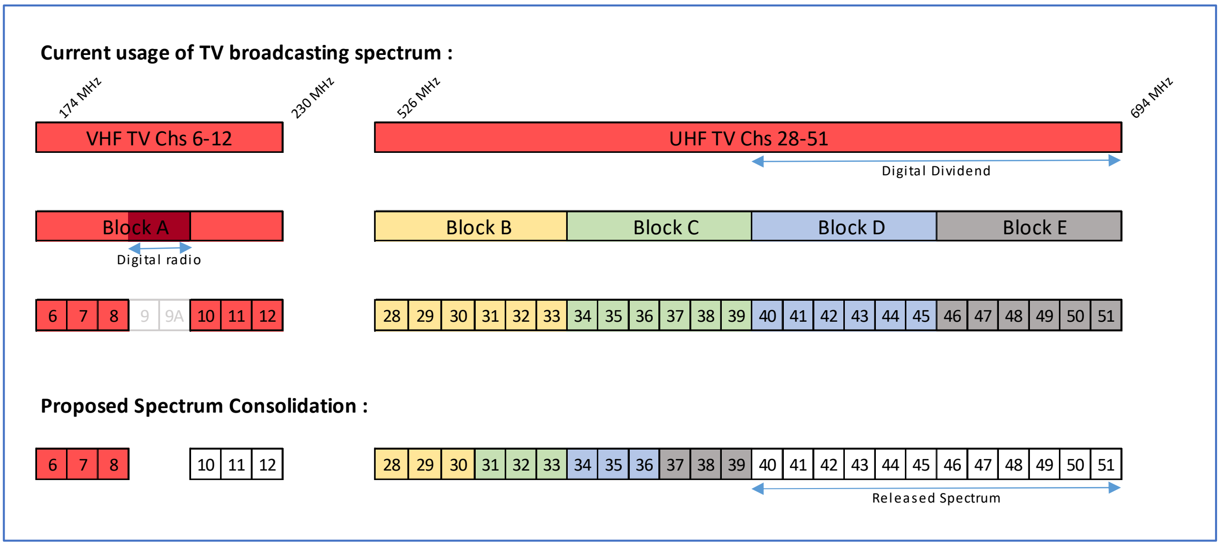

Figure 1: Digital TV Broadcasting existing and proposed allocations with the potential spectrum release. Note, the proposed spectrum release scenario shown in this figure is one of the proposals laid out in the Green Paper and not an agreed or fixed final consolidation arrangement.

Each transmitting station's use of a channel requires an individual transmitter (apparatus) licence under the *Radiocommunications Act 1992*, providing the right to broadcast their transmissions. A channel is assigned to a broadcaster for a specified area served; the formal allocation process is via a Television Licence Area Plan (TLAP), an ACMA legislative instrument. The current digital TV allocated spectrum is represented by 2,828 existing apparatus licences; of these, 326 are in the VHF block and 2,502 are in the UHF blocks. Of the UHF spectrum proposed to be released, from channel 40 to 51, there are 1,593 apparatus licences (made up of broadcasters in the commercial, national, retransmission and community/HPON/trial categories).

All services currently operating in Block D and E would require rechannelling as part of the proposed spectrum consolidation and the rechannelling process will have a knock-on effect also requiring rechannelling of many services in Blocks B and C. The implication of this process to viewers is that most, if not all, viewers would need to retune their receivers at some point.

3.2.1 Transmitter Hierarchy

Higher powered digital TV broadcasting sites typically operate as the primary transmitter in any given market area and the lower powered or retransmission sites typically receive an off-air feed (input DTV signal is received over the air path from another transmitting service) to operate as gap filler services for any isolated or uncovered communities.

An example is a main site might operate on Block B serving as the primary transmitter for the area. Multiple other sites would receive their input signal from the main site off-air, and regenerate the broadcast at a lower power on other blocks such as Block C, D or E. In some areas depending on the geographical separation of reception areas, the secondary sites may broadcast on the same Block of channels providing a synchronised service.

In the metropolitan areas the main high-powered broadcasting site operates on Block A in the VHF band. Operating in this band allows for the maximum range and penetration into coverage areas. This is because the propagation characteristics of the VHF band allows it to travel further, in comparison to a service operating in the UHF band. Historically the existing reception rooftop antennas in these metropolitan areas will primarily be designed for the VHF band, and not for UHF (although this will not always be the case, such as situations where a UHF metro gap filler translator is in operation).

3.2.2 Scenario Introduction

As part of this consultation process a number of Scenarios have been identified in conjunction with the stakeholders, review of the Green Paper submissions, and during the workshop, which would enable a consolidation of spectrum used for television broadcasting. Six different approaches or Scenarios as well as the current situation have been analysed. A brief outline of those scenarios is introduced here:

- Scenario 0 – this is the current situation, a 5/5 RF channel arrangement using DVB-T which refers to 5 RF channels in metro areas and 5 RF channels in regional areas.
- Scenario 1 – a 3/3 RF channel arrangement using DVB-T which refers to a consolidation to 3 RF channels in metro areas and 3 RF channels in regional areas. A release of 84 MHz expected. This is the scenario depicted in the bottom row of Figure 1.
- Scenario 2 – a 4/3 RF channel arrangement using DVB-T which refers to a consolidation to 4 RF channels in metro areas and 3 RF channels in regional areas. A release of 84 MHz or 77 MHz expected.
- Scenario 3 - a 5/3 RF channel arrangement using DVB-T which refers to a consolidation to 5 RF channels in metro areas and 3 RF channels in regional areas. A release of 77 MHz or 70 MHz expected.
- Scenario 4 - a 3/3 RF channel arrangement using DVB-T2. A release of 84 MHz expected.
- Scenario 5 – a 4/4 RF channel arrangement using DVB-T2. A release of 84 MHz (probably) expected.
- Scenario 6 – a 5/4 RF channel arrangement using DVB-T2. A release of 77 MHz or 70 MHz expected.

Each of the above scenarios, apart from Scenario 0, require additional consideration of the compression standard used, MUX sharing, network topology, changes to the contribution and distribution chain and consumer impact to gain a spectrum release. These factors are assessed in more detail in this report.

3.3 Multi-frequency and Single Frequency Networks

Digital terrestrial TV uses two main types of frequency use topologies - Multiple Frequency Networks (MFNs) and Single Frequency Networks (SFNs). A network can be implemented using a mixture of MFNs and SFNs to serve different coverage areas.

Both MFNs and SFNs are currently used in Australia to provide terrestrial digital TV services, as part of the DVB-T standard. SFNs are already extensively used in Australia including in remote areas, for example there are 10 SFNs off the East Coast with four to six sites off each of those SFNs. Metro areas have two or three SFNs, except for Adelaide.

The industry has extensive experience in SFN deployments, including wide area SFNs, but not as part of the DVB-T2 standard. SFNs deployed as part of the current digital TV services provide the most efficient technical solution; and are deployed to optimise spectrum and provide interference management.

This report discusses the use of SFNs and wide area SFNs in more detail than MFNs, as the *greater* use of SFNs or introduction of wide area SFNs are two of the possible planning approaches that can help realise the consolidation of spectrum in some of the scenarios.

Considering the current proposed digital TV consolidation with respect to SFN use: in Scenarios 1 and 4 the same number of SFNs as in operation today would be necessary, Scenarios 2, 3, 5 and 6 are expected to require additional SFNs and investigation of very wide area SFN capability and use (in the case of the DVB-T2 standard) would be needed for Scenarios 5 and 6.

See Appendix 1 for more details on SFNs in general; and the differences, pros and cons between the SFNs currently used in Australia as part of the DVB-T standard (an appendix in the Australian transmission standard, AS 4599, describes the implementation of DVB-T SFNs in Australia), and the potential use of wide area SFNs as part of the DVB-T2 standard (noting that SFNs are also used in other digital TV standards and are not exclusive to the DVB family of standards).

3.4 Digital TV Transmission Standards

Note, though this section focuses on describing the DVB family of digital TV standards, they are not the only family of digital TV standards used around the world. The DVB standards are described here as Australia currently uses DVB-T, hence this family of standards merit discussion. DVB-T2 is logical transition choice for DVB-T, but this report does not assume that DVB-T2 will be the chosen standard to transition to (as that would be a technical choice weighting up all the pros and cons), should transitioning from the current DVB-T standard be the appropriate approach as part of the potential spectrum consolidation.

See Appendix 1 for more details on transmission standards and a comparison of DVB-T and DVB-T2, as well as general commentary on other standards.

3.4.1 DVB-T

DVB-T is a standard for the broadcast of digital terrestrial TV. DVB-T transmits compressed digital video, digital audio and other digital data in an MPEG transport stream. The transmission uses a modulation scheme called Orthogonal Frequency Division Multiplexing (OFDM), which is a method of encoding digital signals onto a carrier signal for broadcasting. The DVB standard was developed by the European Telecommunications Standards Institute (ETSI).

Viewers receive this transmission using TV sets or Set Top Boxes (STB/s) equipped with a DVB-T capable receiver.

DVB-T is currently the digital TV broadcast standard used in Australia. DVB-T coverage is provided by a large number of transmitter sites broadcasting in both VHF and UHF Bands, using a 7 MHz RF channel. The Australian digital TV transmission standard is Australian Standard AS 4599 and the receiver standard is AS 4933[2].

3.4.2 DVB-T2

DVB-T2 is the second generation terrestrial standard for digital terrestrial TV developed and standardised by ETSI. This extension of the DVB-T standard was developed to provide advanced modulation scheme for digital terrestrial broadcasting. DVB-T2 has the same baseline principles as the DVB-T standard, but can be seen as a more efficient version of the original DVB-T standard, with new forward error correction, higher modulation constellations, reduction in overheads etc. The higher bit rate of DVB-T2 in comparison to DVB-T makes it capable of delivering a larger number of HD streams as well as Ultra HD (UHD) TV signals, although the Australian broadcasters have been providing HD services with the existing DVB-T, along with SD services. Work is currently underway to determine a DVB-T2 standard in Australia through Standards Australia's committee, CT-002 Broadcasting and Related Services.

3.5 Compression Standards

Moving Pictures Experts Group (MPEG) is an alliance of working groups that set standards for media coding. In the case of digital TV broadcasting in Australia, MPEG2 and MPEG4 are the compression standards for video encoding. MPEG4 was created as a standard capable of providing good video quality at substantially lower bit rates compared to MPEG2 and all receivers since 2015 are MPEG4 compatible.

[2] Standards developed by Standards Australia are not automatically mandated by the ACMA under Section 158 of the *Radiocommunications Act 1992*.

Australia currently broadcasts digital terrestrial TV services in MPEG2 and MPEG4 format, in Standard Definition (SD) at 576i[3] and High Definition (HD) at 1080i format.

High Efficiency Video Coding (HEVC) was created to provide high efficiency coding rates for resolutions above HD (4K, 8K) and is more efficient for progressive[4] scanning rates.

See Appendix 1 for more details on compression standards.

3.6 Multiplexing

A MUX is a method that combines together multiple digital streams, for example digital TV programmes, audio or data streams, into a single transport stream for modulation into a single RF channel. Each MUX's total capacity depends on the modulation and coding parameters. The broadcasters then determine how best to utilise the available capacity of the MUX by employing various factors when encoding the video/audio content. The use of the capacity is a trade-off between picture quality and encoding performance.

There are two key approaches to combining services into a MUX:

- Services are combined into a MUX with fixed bit rate allocations. This can prove to be inefficient, as a fixed bit rate will be used to encode a complex picture as well as a predominately static picture where the overall background is less complex and static. The impact of fixing the capacity allocation can lead to degradation of service quality and potentially wasted capacity.
- Statistical Multiplexing, which is used by Australian broadcasters, is a way to combine services into a MUX where the shared capacity of the MUX is dynamically allocated between the services with varying bit rates based on their real-time needs. For example complex video scenes will be dynamically allocated more bandwidth for that time period compared to another video stream on the same MUX that may have less complexity. The benefits of Statistical MUX include being able to allocate the highest number of services for a given capacity with the best quality for the given bandwidth. Broadcasters determine the quality of their content – where premium services such as sports are assigned high quality whereas less premium services for example 'talking head' studio news or discussion programs could be assigned a lower quality.

3.7 Contribution

Contribution in the digital TV system refers to the studio to playout portion of the broadcasting chain. In the current scenario, where each broadcaster has the independent use of an individual MUX, each broadcaster manages their own contribution in-house; uncompressed video feeds of content follows through to Presentation, SI Generation, Compression and Statistical Multiplexing stages. This multiplexed stream is then passed onto the distribution network all from the same physical location. Any MUX sharing scenario will require changes to the current contribution/playout arrangements. A central playout location would be most efficient and therefore any scenario with MUX sharing will require consideration of linking to a common playout centre.

For example, Broadcaster A will need to link their uncompressed video feed content along with service information to a common physical location at which their transport streams are encoded/compressed and combined via statistical multiplexing with Broadcaster B's feeds. This is depicted in the block diagram provided by the ABC in the Consolidation Workshop, 17th June 2021 (Figure 2).

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[3] Interlaced scanning is denoted with a lower-case *i* after the number of lines (for example 1080i) meaning for each picture frame, only alternate lines of pixels are refreshed with each scan. In this mode the frame is refreshed 50 times per second, while each pixel is refreshed every 25 times per second. This is the traditional method used for analogue TV. This reduces the capacity required to provide content.

[4] Progressive scanning is denoted with a lower-case *p* after the number of lines (for example 1080p) and differs by refreshing each pixel 50 times per second, which is twice as often as the interlaced mode. This mode requires more capacity than interlaced and delivers a higher perceived quality, although tests have shown that there is only minor increase in capacity for compressed progressive scanning mode compared to compressed interlaced scanning mode, for the similar perception of quality.

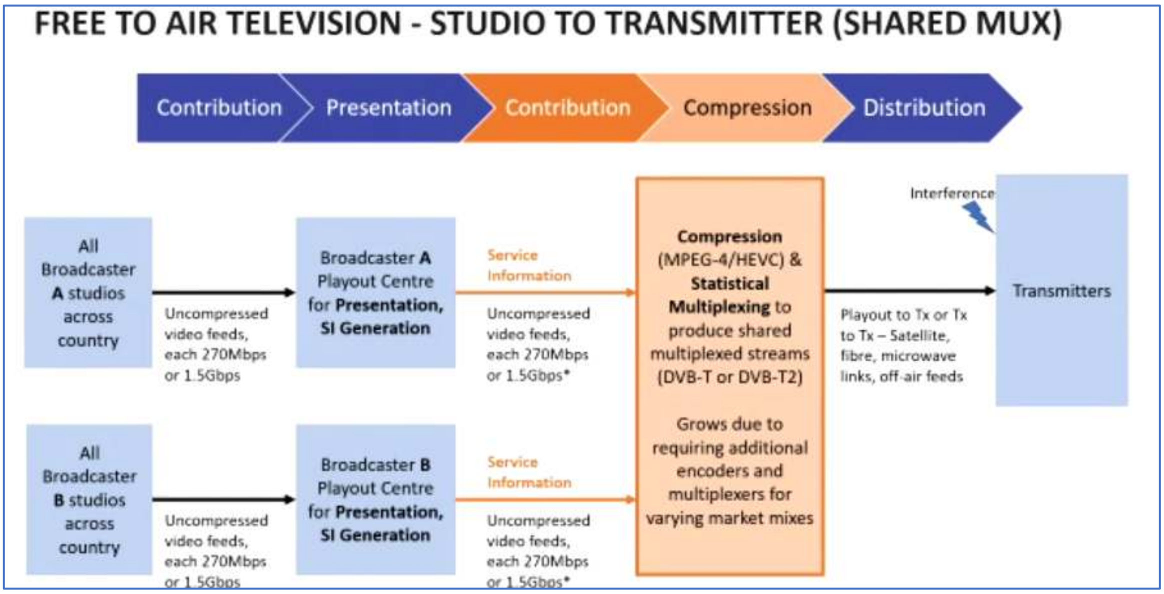

Figure 2: Free to Air TV – Studio to Transmitter; block diagram showing the flow of contribution from Broadcaster A and Broadcaster B to a combined Compression/Multiplexing and then output for distribution. Image by ABC. The orange shaded steps (contribution and compression) are additional steps for shared Multiplexing, beyond the current process.

3.8 Distribution

The distribution part of the digital TV system refers to the playout to transmission portion of the broadcasting chain. The MUX output is distributed to any transmitter on the network via one or a combination of the following distribution feed methods:

- Fibre, where signals are distributed via means of fibre in the ground to transmission points. Fibre is an effective distribution method as long as fibre is already available. New fibre routes would require trenching to lay fibre, which can be costly and complex depending on the route topography and length of route, and may not be practical for regional areas.
- Satellite, where signals are distributed via Satellite systems. One of the advantages of satellite distribution is the large footprints they provide and the ability to serve remote regions in Australia, but it is presently difficult to target localised content to individual areas using satellite distribution.
- Microwave linking – where signals are distributed via dedicated microwave links to the transmitters. These links require link equipment such as microwave dishes and radios, a clear radio path for the link and also frequencies for the links to operate on. In some cases multiple links may be required to cover the path distance and/or local terrain.
- Off-air feeds to retransmission sites. Retransmission sites are sites/transmitters that re-broadcast content from a parent transmitter to help supplement the parent transmitter's service, generally to small portions within its service area that are not adequately covered, or as an extension to its service area. These get their inputs off-air from the parent transmitter and can either re-broadcast on the same frequency (repeater) or on a separate frequency (translator). Changes to the parent transmitter can have a flow on effect to these retransmission sites.

4 Technical Issues in General

This Section provides commentary on the main technical issues regarding the proposed spectrum consolidation, the stakeholder views and our analysis of their views. This Section takes a more general approach to describing each issue and is not focused on a specific Scenario as such. Further analysis of the different consolidation Scenarios is given in Section 5.

Where relevant, key findings and suggested areas for further work are provided. Note that not all Sections will have these, with the aim being to capture issues that benefit from being highlighted as key findings in this report, and for some issues where more work is suggested as a next step.

Note, references to stakeholder views are based on commentary provided during this consultancy process (in particular views expressed during the bilateral meetings and the stakeholder workshop). The TV broadcasting industry stakeholders that took part in this process included individual broadcasters (both National and Commercial), Free TV, infrastructure providers (BAI and TX Australia), the consumer electronics suppliers (CESA) and the regulator, the ACMA, took part as on observer. The ACMA's views are not considered as part of any consensus view.

As it would be impractical to list every stakeholder view and identify individual stakeholders that share similar views – the stakeholders view section has attempted to capture the key points raised during the consultancy process by the numerous stakeholders that have some agreement, but noting that these points do not necessary form any consensus views across all stakeholders. In addition, in many of these cases only preliminary views were formed and provided by stakeholders. Further work is needed to form more definitive views or conclusions on the possible spectrum consolidation and all its complexities.

4.1 Single Frequency Networks

F4.1 Key Findings

- Greater use of Single Frequency Networks (SFNs), as one possible planning approach, may enhance the possibility of releasing 84 MHz for some of the scenarios.
- Wide area SFNs as part of the DVB-T2 standard, could increase the amount of spectrum released for some of the scenarios considered, although the use of such wide area SFNs brings its own set of complexities and challenges.
- One of the key disadvantages of the use of more SFNs is the impact to viewers who may need to repoint or upgrade their receive equipment and or installations. This impact could be exacerbated by the introduction of wide area SFNs.
- The use of more SFNs or wide area SFNs are not the only planning approaches available to achieve the consolidation of broadcasting spectrum. Other planning tools or methods will need to be considered as part of a wider evaluation process going forward.

W4.1 Possible Area for Further Work

- More work is needed to understand the practical use and implementation of wide area SFNs, should this be one of the planning approaches used for any potential consolidation of broadcasting spectrum.

There are an extensive number of DVB-T SFNs currently operational in Australia to optimise spectrum use. SFNs require more infrastructure than MFNs, such as GPS synchronisation, dedicated links to daisy-chain transmitters etc. SFNs also create a more complex reception environment that is best suited for reception equipment that have quality installations.

DVB-T2 allows for wide area SFNs which is useful for spectrum efficiency but will cause more complexity compared to SFNs currently used in DVB-T. Wide area SFNs would also introduce added infrastructure requirements and further complexity in planning (such as more complex SFN timing parameters), and potentially increase the portion of viewers that could be impacted.

Stakeholders view:

There are already SFNs deployed across Australia, with an extensive number of sites already part of SFNs.

The stakeholders note that the current status of SFN use should not change under Scenarios 1 and 4, whereas the other Scenarios would likely increase the number of SFNs required. The stakeholders note that the use of wide area SFNs (as part of the DVB-T2 standard) could help maximise the amount of spectrum released.

As noted in their Green Paper response; the initial modelling by BAI Communications on the increased use of wide area SFNs to release 84 MHz has been positive. In general the stakeholders note that more detailed analysis and testing is required to understand the viability of these SFNs for the Australian environment, and the capability of receivers to handle such transmissions.

SFNs are complex and more expensive to establish and may require a number of off-air retransmission sites to convert to microwave links, adding capital and ongoing costs and complexity to operate. However SFNs are viewed as necessary in areas where there are spectrum planning challenges and no clear channels available.

Analysis:

SFNs provide a means to optimise the spectrum plan and allow greater consolidation of the spectrum but they are more costly to plan, establish and operate. The use of SFNs is not a new concept, as SFNs are extensively used in Australia currently.

The impact to viewers due to the use of more SFNs than is currently used, which could be a planning approach for some of the scenarios to allow broadcasters to retain more capacity, needs considering. SFNs bring about a more complex TV reception environment and do not easily serve viewers with sub-optimal receive equipment or installations. Antenna repointing (which could involve a truck roll from an installer), or upgrading reception equipment to receive signals from SFNs could be a significant cost and effort to address should the number SFNs increase. This is one of the key disadvantages to introducing more SFNs as part of any spectrum consolidation scenario.

The use of wide area SFNs enabled by the DVB-T2 standard could help maximise the amount of spectrum released by providing more capacity to either maintain the same amount of content and quality, or enable a wider range of content and or higher picture quality, while releasing the full 84 MHz of spectrum (or close to as in Scenario 6 with up to 77 MHz released). The use of wide area SFNs compared to SFNs, could however further impact more viewers (as noted above e.g. antenna repointing, upgrading reception equipment etc.) who may not have been previously affected, but now find themselves captured by the larger coverage footprints of these wide area SFNs. Wide area SFNs are also likely to be more complex to plan than SFNs, for example factors such as SFN timing parameters have to consider the larger number and spread of transmitters in the wide area SFN, and the larger population base that could be potentially affected.

The industry has extensive experience with SFN deployments as part of the current DVB-T network in Australia, including wide area SFNs.

Although the practical performance of SFNs is well understood, more work is needed to understand the impact to viewers if the current use of SFNs in Australia was to be expanded using DVB-T or DVB-T2. This work could include more detailed planning and understanding the interference and threshold limitations supplemented by laboratory testing, detailed assessments on the effect to input feeds, testing or trials over live broadcast channels and receiver testing. Some of the challenges of testing include needing live transmitters and spectrum to test with and having a sufficient range of receivers to allow the tests to be representative of the overall receivers in the marketplace.

Wide area SFNs could give rise to more complex spectrum requirements for regional areas or overlapping markets, where the SFN size could cross boundaries with different content or coverage requirements, and more so than the existing SFNs in use today in Australia. It may be inefficient to carry all national, commercial and regional content over a one wide area SFN. Regional SFNs would be more suited to serve these separate markets (however the use of wide area SFNs could also free up some spectrum for use in these markets).

Note, the use of more SFNs or wide area SFNs for some of these Scenarios are not the only planning approaches available to help realise a potential reduction in spectrum use. There are other planning tools that could also be considered such as revised interference planning and revisiting protection ratios/thresholds, looking at other channel options, looking at the transmitter numbers and powers to help mitigate interference, looking at the enhanced suite of DVB-T2 parameters that could help increase robustness etc. However, all options raise trade-offs and it is a complex exercise to work through all the interactions and permutations of all these approaches. This report is not in the position to test or analyse the suitability of these approaches but they should be considered as part of the wider evaluation process.

4.2 Digital TV Transmission Standards

F4.2 Key Findings

- If a transition to a new standard is appropriate, then DVB-T2 is the logical choice to transition from DVB-T, as its transmitters and receivers are typically backwards compatible and is of the same family of DVB standards.
- The use of DVB-T2 allows greater capacity in a given amount of spectrum, compared to DVB-T, but the use of DVB-T2 in itself would not allow more spectrum to be released as this would be dependent on how much spectrum broadcasters choose to use.
- DVB-T2 is not the only standard available to transition to, although moving away from the DVB family of standards raises greater complexities than staying within it.

W4.2 Area for Further Work

- Should it be determined that a new transmission standard is appropriate it would be important to have the Australian DVB-T2 standard finalised, which the broadcasting industry is currently progressing.

The current Australian standard is DVB-T. Alternatives to DVB-T2 exists such as ATSC 3.0 and are being implemented elsewhere in the world. A new standard DVB-I is being worked on and not likely to be available for several years.

Stakeholders view:

Stakeholders view DVB-T2 as the logical choice of digital TV technology standard to migrate to if a transition to a new standard is appropriate as the Australian market is currently aligned with the DVB family of standards. Stakeholders agree that the technology roadmap for the Australian market should stay with this group of standards (i.e. DVB-T, DVB-T2, DVB-I etc.). DVB-T2 receivers have backward compatibility with DVB-T signals, which means a DVB-T2 capable TV set can be purchased and operate using DVB-T or DVB-T2 i.e. the receiver would be ready if DVB-T2 becomes available.

Stakeholders recognised other benefits of DVB-T2 including the ability for larger SFNs, HEVC encoding and IP encapsulated transport protocols. DVB-T2 not only allows for a capacity increase, it also provides a platform to offer 4K and 8K quality content in the future that is not possible with the current platform. Stakeholders also noted that DVB-T2 could allow a potential future integration of terrestrial and online delivery of TV content. These attributes are considered important as there are concerns that if a transition takes place, the move to DVB-T2 from DVB-T could be perceived by viewers as being of little benefit, compared to the previous re-stack. Stakeholders recognised previously there was both higher quality pictures and additional content offered.

The stakeholders note that work is already underway to finalise the Australian DVB-T2 standard, which is due to be completed by mid to late 2022.

Analysis:

If a transition to a new standard from DVB-T is considered to be appropriate, then the logical standard would be DVB-T2, which is part of the same family of standards. DVB-T2 transmitters and receivers are typically backwards compatible with DVB-T. This does not suggest that a transition to DVB-T2 or a transition away from the current DVB-T standard is inevitable as part of any potential consolidation of broadcasting spectrum.

If DVB-T2 is the new standard to transition to, then the use of the enhanced parameters such as wide area SFN capability, HEVC etc. must be considered to realise the full benefits of a possible transition to DVB-T2, such as providing more capacity to either maintain the same amount of content and quality, or enable a wider range of content and or higher picture quality. The use of DVB-T2 allows greater capacity in a given amount of spectrum, compared to DVB-T, but the use of DVB-T2 in itself does not allow more spectrum to be released as the result of spectrum consolidation. The amount of spectrum that would be released is dependent only on the number of RF channels that would be retained for TV broadcasting.

With a transition there is a need to demonstrate the benefits to the viewers and encourage them to upgrade their receiver equipment. It is important that the Australian standard for DVB-T2 be finalised so that stakeholders such as the equipment manufacturers can start producing receivers to meet the Australian DVB-T2 standard should a transition proceed.

4.3 Compression Standards

F4.3 Key Findings

- An efficient compression standards combination, such as transition to exclusive use of MPEG4, would allow additional capacity for the same amount of spectrum used. The adoption of DVB-T2 transmission and HEVC compression would significantly expand the capacity of multiplexes.
- A coordinated approach is key to ensure receivers can use these compression standards.

Currently, a combination of MPEG2 and MPEG4 compression is used in the terrestrial platform with the DVB-T transmission standard.

Stakeholders view:

The view of the Free TV stakeholder group is that HEVC compression technology along with the DVB-T2 standard should be part of the long term technology roadmap. However, as HEVC is not efficient for SD content MPEG4 would likely continue to be used. For example, there will be no worthwhile reduction of required picture bit-rate when using HEVC for SD and HD-interlaced content, which is currently carried by Australian DVB-T broadcasts.

Therefore, a combination of MPEG4 and HEVC is seen as a practical solution for Scenarios 4, 5 and 6. MPEG2 is likely to be phased out because receivers are expected to be mostly MPEG4 capable now (industry believe over 90%), and particularly more so by the time consolidation is implemented. Broadcasters would wish to provide an incentive for viewers, such as increased picture quality, to increase the pace of take up, which may further affect any decision to not retain MPEG2 content.

A significant benefit of moving to HEVC compression is achieved for progressive scanning formats where the standard is designed to code for. This has great quality improvement impact to the end viewers providing progressive frames compared to the current interlaced picture quality, for example smoother videos. However, moving from interlaced to progressive does require additional capacity to provide twice the frames required for progressively scanned pictures.

Analysis:

For any change in compression standard (such as moving from MPEG2 to MPEG4, or introducing HEVC) to be successful, a co-ordinated approach is needed so the receiver population is established and capable. The roadmap of migration to MPEG4 and HEVC as part of a DVB-T2 standard appears to be a practical one to maximise capacity.

4.4 Shared Multiplexing

F4.4 Key Findings
• Moving to MUX sharing will require changes to allow the contribution of program content to a centralised location. There would be both set up costs and ongoing operational costs to be considered.

The current MUX arrangement in use by Australian digital television broadcasters is one of exclusivity. That is, each broadcaster has the overall use of an individual MUX. The proposal for this potential spectrum consolidation will require MUX sharing where more than one broadcaster combines their program content together in an individual MUX. This arrangement will require additional distribution/combining of transport streams and a potential 3rd party management role that centralises all the streams into a common platform. There would be both set up costs and ongoing operational costs to be considered.

Stakeholders view:

The stakeholders have raised a number of concerns such as:

1. The ownership, management and control of the shared MUX and its parameters. Broadcasters currently have control of the quality of their services – for example premium services such as sports have high quality whereas lower quality can be assigned to pre-recorded drama etc. There are concerns on how this would be controlled in a shared statistical MUX arrangement.
2. How the capacity would be divided, equally for all stakeholders or do the Nationals share a MUX with the Commercials sharing the remainder.
3. MUX sharing could be complicated if National and Commercial services share a MUX (See Appendix 2 for more commentary on this issue).
4. The need for holistic consideration of the design and implementation of a shared MUX across all elements of the network including: network configuration, contribution feeds and the technologies utilised, the manner in which statistical multiplexing is applied, the generation and insertion of Service Information and MUX boundary management.

Available capacity could reduce for a shared MUX, compared to what is carried now. The overhead of EPGs increases as extra information is required to be carried by each stakeholder. At the workshop, a rough estimate of another 1.5Mb/s may be needed to carry the extra Service Information (SI), but this will depend on the scenario.

Analysis:

Additional MUX sharing complexities are discussed in Appendix 2. In summary these complexities include further discussions on the National vs Commercial broadcast licence areas, and contribution and distribution complexities to and from a Shared MUX.

4.5 Receiver Population and Capability

F4.5 Key Findings
• A well-designed consumer survey would provide Government and the broadcasting sector with evidence of the existing capability of household receivers.

W4.5 Area for Further Work
• Conduct a survey to gain an understanding of the technical capability of the receiver population and gauge the impact on consumers.

Currently there is limited knowledge of the technical capability of the receiver population especially for older receivers. Note that MPEG4 was included in AS 4933:2010 only as optional and in AS 4933:2015 as mandatory, so some receivers manufactured up to 2015 may still be MPEG2 only. There is little evidence about how many receivers would be capable of receiving HEVC or DVB-T2 signals or signals from a shared MUX.

Stakeholders view:

The existing receiver population that are MPEG2 only has restricted the broadcasters from transitioning more services to MPEG4, which are concerned about losing viewers that do not have MPEG-4 capable receivers. Broadcasters do not have strong evidence on how many households still rely on MPEG-2 broadcasts, but have stated they believe with confidence that this represents significantly below 10% of the total receiver population and that most of these sets have been relegated to secondary and tertiary viewing areas. In addition, broadcasters have suggested that submissions in response to the Green Paper indicate that most or all receivers sold today are likely to be T2-ready (subject to the Australian DVB-T2 standard being finalised) and that this has been the case for some time.

Broadcasters have also noted that the Oztam report 2017, Q4, shows that 97% of households were able to receive HD services transmitted in MPEG-4 at year end 2017, and noted that in Australia, circa 2 million TVs are sold annually, and this continuous upgrade of TV stock means the number of households not able to receive MPEG-4 transmissions at all could be less than 1%.

Receivers currently in the market may state they support HEVC compression, however this may only be for the IP data streaming services such as Amazon Prime and Netflix, and not HEVC on the terrestrial input. Manufacturers are cautious to avoid product returns on their specification technology claims. This may complicate any consumer survey efforts to understand the scope of the receiver capabilities currently in use.

There is concern when a MUX is shared that the increased and combined SI may mean some receivers will not function correctly and more testing of this is needed to understand the likely quantity of receivers affected. It would be difficult to test old sets on their compatibility to such as shared SI arrangement.

In terms of a possible transition to DVB-T2, the stakeholders note that the Australian DVB-T2 standard is scheduled to be finalised by mid to late 2022, and the full technical development of receivers specific the Australian market will take place after the standard is finalised.

Stakeholders also noted that viewers may not necessarily be inclined to upgrade sets to DVB-T2, when they already have a large widescreen TV set. This drive was there in the first spectrum consolidation, more than now. There is also the added competition for streaming services that was also not present during the first spectrum consolidation. Households that do not have DVB-T2 capable receivers would not need to purchase a new television if broadcasters transitioned to this transmission standard, as they could simply install a new STB.

Analysis:

A survey of the numbers and capability of the existing receiver population and testing a sample before implementing any changes in transmission would be sensible to gauge how consumers would be affected.

Of key importance is the need for an Australian DVB-T2 standard to be finalised before any changes to the transmission, thus allowing the equipment manufacturers to develop products for the Australian market that can be sold and marketed based on the technology claims that are aligned to the Australian standard.

4.6 Spectrum and Logistics Planning

F4.6 Key Findings

- Spectrum planning should consider planning for the RF broadcast channels as well as the inputs, but prioritise the RF channels as these are the only means to provide the broadcast services to viewers.
- Should the Government decide to offer broadcasters the choice to move to a consolidation of TV spectrum (as per the green paper proposal), ACMA has noted that it would work to identify the planning approach, in consultation with the industry, based on the high-level objectives set by the Government, once confirmed. This planning approach would then be used by ACMA in preparing the channel plans.
- It is too early for detailed logistics planning to take place.

W4.6 Area for Further Work

- Should the Government decide to offer broadcasters the choice to move to a consolidation of TV spectrum, comprehensive spectrum planning would need to be undertaken once associated policy decisions had been made.

Any spectrum consolidation scenario or transition to a new standard would require comprehensive spectrum and logistics planning. The issue with this spectrum consolidation is not just about the RF spectrum that will be used for broadcast.

Stakeholder view:

The stakeholders note that planning to date has been focused primarily on the spectrum side for the RF channels to be broadcast, and the input side may have not been fully factored in. Planning the shared MUX and the distribution needs to be considered. Stakeholders note that the ACMA does not protect the off-air inputs, but planning needs to be based around it as it will be used for SFNs.

The stakeholders note that spectrum planning should shift from a coverage-based methodology to an interference-limited methodology.

In terms of logistics planning, the stakeholders note that no substantial planning of such nature has been undertaken so far. See Section 5.7 for more details on how this planning could apply to the different Scenarios.

Analysis:

Planning for this potential spectrum consolidation should consider the spectrum for the RF channels, as well as the off-air input feeds to the transmitters. However priority should be given to the RF channels as spectrum to serve the viewers is limited and there is only one way to provide this broadcast service to viewers via these RF channels, whereas there are multiple ways to provide the input feeds to the transmitters. Planning for interference protection to all off-air input feeds would likely compromise the use of the RF channels for coverage.

No new planning parameters have been developed but a direction on which consolidation scenario is to be pursued, and the finalising of the Australian DVB-T2 standard should come first, before comprehensive planning can take place as these would drive the planning requirements. Note that not all the scenarios require a transition to DVB-T2, and hence not all of the scenarios would require the Australian DVB-T2 standard to be finalised.

The ACMA worked closely with industry for the last consolidation process and this approach should be considered for this proposed spectrum consolidation. The ACMA has noted that it will work to identify the planning approach, in consultation with the industry, based on the high-level objectives set by the Government. The planning approach sets the methodology for moving existing channel blocks to clear the spectrum (depending on the objectives). This would then be used by the ACMA in preparing the channel plans.

Comprehensive logistics planning of the migration to the new consolidated spectrum and technology standard will also need to be carried out once the amount of spectrum to be released and technology have been decided, but based on the consultations it could be too early to conduct this planning at this stage.

5 Analysis of Scenarios

This section provides analysis of the specific Scenarios in more detail and follows on from the technical issues described more broadly in Section 4.

Where relevant, key findings and suggested areas for further work are provided. Note that not all Sections will have these, with the aim being to capture issues that benefit from being highlighted as key findings in this report, and for some issues where more work is suggested as a next step.

5.1 Number of Channels - Overview

The Scenarios analysed include the current situation (Scenario 0) plus three based on DVB-T and three on DVB-T2.

Although there are other possible Scenarios, these have been selected to cover the range and the more feasible Scenarios. Two of these, Scenarios 2 and 4, were added at the workshop to give a more complete picture as alternatives to Scenario 1, three metro and three regional channels.

Scenario	Transmission Std	Video Compression	Metro Channels	Regional Channels
0	DVB-T	MPEG2 and MPEG4	5	5
1	DVB-T	MPEG4	3	3
2	DVB-T	MPEG4	4	3
3	DVB-T	MPEG4	5	3
4	DVB-T2	MPEG4 and HEVC	3	3
5	DVB-T2	MPEG4 and HEVC	4	4
6	DVB-T2	MPEG4 and HEVC	5	4

Table 1: Scenarios and number of channels

The DVB-T2 standard allows for wide area SFNs, which would likely allow for greater spectrum re-use and therefore require less spectrum overall. The better SFN capability provided by DVB-T2 could assist in mitigating potential consumer disruption.

In the Metro areas, although the channels are in the VHF band, there are numerous UHF translators to cover poor reception areas and in the Metro/Regional overlap markets adjoining the Metro areas (e.g. Central Coast, Gold Coast etc).

5.2 Spectrum Consolidation

F5.2 Key Findings

- All Scenarios would allow free to air television services to be delivered using less radiofrequency spectrum than is presently used. Some Scenarios achieve a reduction of as much as 84 MHz; others achieve a lower reduction.
- Scenario 1 is the most practicable in terms of spectrum planning. Scenario 4 would be similarly practicable from a spectrum planning perspective.

W5.2 Area for Further Work

- Detailed spectrum planning would need to be completed to understand the potential amount of spectrum released for each Scenario.

Scenario	Metro/ Regional Channels	Spectrum Released (MHz)	Spectrum planning degree of difficulty
0	5/5	0	Current situation.
1	3/3	84	Straightforward.
2	4/3	84 or 77	Very Challenging to get 84 MHz due to the metro and overlap markets.
3	5/3	77 or 70	Very Challenging to get 77 MHz due to the metro and overlap markets.
4	3/3	84	Relatively Straightforward.
5	4/4	84	Very challenging - wide area SFNs needed to achieve the required channels in the metros and overlap markets at least.
6	5/4	77 or 70	Very challenging - wide area SFNs needed to achieve the required channels in the metros and overlap markets at least.

Table 2: Scenarios, channels, possible amount of spectrum released and spectrum planning difficulty.

The spectrum released in table 2 is still subject to spectrum planning work and in three cases, an extra channel may be required (indicated in the table above by the "or"). The need for the extra channel, or potential two 7 MHz channels, will not be known until the spectrum planning work is undertaken. These channels, which reduce the amount of spectrum released are needed to fit the scenario into the spectrum with minimal interference. From the workshop and consultations, some stakeholders have completed a high level spectrum plan for some of the Scenarios but detailed planning has not been carried out to the point where the amount of spectrum released is confidently known for Scenarios 2, 3, 5 and 6. All parties acknowledge that for these Scenarios, the spectrum planning would be very challenging to release the amount of spectrum shown. Key aspects that make it very challenging are:

1. The overlap markets where the five Metros and three Regional networks are broadcast. Additional channels need to be accommodated in these markets, whereas the non-overlap areas need spectrum for five channels.
2. The translators or in-fill UHF services in the metros. While the main VHF services are relatively straightforward to plan for in the Scenarios, the need for four or five UHF channels inside the metro areas while fitting in with the overlap markets, and also the metro translators in some Scenarios, would need planning work before the result can be known with confidence.

3. Minimising co-channel interference. Some areas suffer from co-channel interference with the existing plan. Any revision should look to address this.

Analysis:

Scenario 1 is the most straightforward to plan the spectrum channelling as it uses the current standard with well-established technical planning guidelines and only calls for three RF channels. The current co-channelling arrangements are well known and would likely to be preserved.

Scenario 4 is made slightly more difficult since it uses DVB-T2 and would require technical planning guidelines to be established first. The other Scenarios become very challenging to plan the spectrum as they call for more RF channels to co-exist. It is anticipated that the hardest areas to plan will be for the overlap markets and for the Metro translators. Again, the current co-channelling arrangements are well known and would likely to be preserved.

Scenarios 2, 3, 5 and 6 are all very challenging to plan the spectrum and the transition. Migration from the existing channel arrangement to the final arrangement of channels is likely to occur in a staged manner and therefore a number of intermediate channel plans is likely to be needed. There is potential for these plans to be very complex.

5.3 Channel Data Capacity

F5.3 Key Findings

- Under any consolidation scenario there would be different options available to the broadcasters regarding how they might share MUXes.
- The Scenarios have different implications for the data capacity available to broadcasters. For example, one option under Scenario 1 could involve three commercial broadcasters sharing two MUXes and the national broadcasters sharing one MUX with DVB-T. Under this option, the commercial broadcasters would need to share a total capacity of 45 Mb/s and the national broadcasters would need to share a total capacity of 22.5 Mb/s. An alternative option could involve five broadcasters sharing three MUXes. Under this option, broadcasters would need to share a total capacity of 67.5 Mb/s.
- Three RF channels using DVB-T2 would allow the current number of programs and in the current quality.

Stakeholders view:

The table below has been prepared based on industry inputs:

Scenario	Transmission standard	Metro/ Regional Channels	Data Rate per channel typical after overheads (Mb/s)	Total Capacity (Mb/s) (Metro/Regional)
0	DVB-T	5/5	22.5	112.5
1	DVB-T	3/3	22.5	67.5
2	DVB-T	4/3	22.5	90/67.5
3	DVB-T	5/3	22.5	112.5/ 67.5
4	DVB-T2	3/3	31.5	94.5
5	DVB-T2	4/4	31.5	126
6	DVB-T2	5/4	31.5	157.5/126

Table 3: Scenarios and data capacity.

The table shows that the current total capacity is 112.5Mb/s (5x 22.5Mb/s). Note this does not include the largely-vacant 6th channel.

			Mux Sharing Scenarios														
Program Stream Combo's per Network	Transmission	Transmission	2 into 1			3 into 2			4 into 3			5 into 3			5 into 4		
		Program Stream Types	HD	SD	DC	HD	SD	DC	HD	SD	DC	HD	SD	DC	HD	SD	DC
		Total Channels for all Networks	4	4	4	6	6	6	8	8	8	10	10	10	10	10	10
2 x HD 2 x SD 2 x Datacast (DC) (Today's Config)	DVB-T	Remaining Capacity with Achievable Program Streams	2%			3%			6%			2%			12%		
		No. of Program Streams Achievable	4	2	0	6	6	3	8	8	8	10	10	0	10	10	10
	DVB-T2	Remaining Capacity with Achievable Program Streams	1%			24%			33%			16%			37%		
		No. of Program Streams Achievable	4	4	4	6	6	6	8	8	8	10	10	10	10	10	10

Table 4: Table above sourced from Seven Network

Table 4 above shows how many of the baseline services fit when combining multiple Networks and demonstrates the capacity advantage of DVB-T2.

A channel configuration of 2x HD, 2x SD and 2x DC (lower quality SD) services per Network is representative of the current configurations[5].

Baseline used: HD=4.3Mb/s, SD=1.95Mb/s, DC =1.3Mb/s and all in MPEG4.

The percentage figure shows how tight the fit is and a measure of any possible growth over and above the baseline of 2 x HD, 2 x SD & 2 x DC. With the higher percentage MUX sharing Scenarios, more services or higher quality services, for example 4k, are possible.

To retain the current TV and radio programming content with less spectrum, additional capacity per channel would be needed. Additional capacity can be obtained by utilising enhanced video compression methods (e.g. MPEG4 only), reducing quality of existing services (e.g. HD to SD), statistical multiplexing, upgrading the transmission standard (e.g. DVB-T2) and/or removing simulcast offerings.

DVB-T2 implementation results in Broadcasters maintaining their current program stream and quality (2 into 1) or provides additional capacity.

Analysis:

Under any consolidation scenario there would be choices to be made, and different options available to broadcasters regarding how they might share multiplexes.

For example, one option under Scenario 1 could involve three commercial broadcasters sharing two MUXes and the national broadcasters sharing one MUX with DVB-T. Under this option, the commercial broadcasters would need to share a total capacity of 45 Mb/s and the national broadcasters would need to share a total capacity of 22.5 Mb/s. An alternative option could involve five broadcasters sharing three MUXes. Under this option, broadcasters would need to share a total capacity of 67.5 Mb/s.

5.4 Contribution and Distribution

All scenarios that require MUX sharing will affect the contribution and distribution arrangements for each broadcaster that share the MUX. There are no specific differences between the various scenarios in regards to the complexity, effort and or costs to the contribution and distribution arrangements. Section 4.4 and Appendix 2 provides more discussions on the complexities of the contribution and distribution issues due to MUX sharing.

- [5] Not every broadcaster offers this base case. Service offerings vary by broadcaster and licence area, but the base case represents a typical commercial broadcaster's service offering. The base case presented is in line with Free TV's illustrative example on page 69 of its green paper submission (noting two of the SD services are MPEG-2 simulcasts). This is more likely to represent a commercial service offering. Free TV has noted that these are not necessarily representative of video bitrates on air today, and do not include the extra overheads required in a shared multiplex scenario for SI data.

5.5 Impact on Consumer Reception Equipment

F5.5 Key Findings

- Minimising the change and effort that consumers need to make to receive a suitable service is viewed by broadcasters as paramount in order to maintain their audience numbers.
- From a technical perspective, consumers could be affected by changes in band, rescanning, repointing antennas and or upgrading equipment to receive SFN signals, moving away from MPEG2 etc.

Stakeholders view:

A key message from the stakeholders and workshop is that any change that a consumer is required to make to get an adequate service should be as seamless as possible. If it is difficult or convoluted, then consumers/viewers could potentially be lost from the audience as these consumers may seek to stream or cast on-line services. This impacts the Regional broadcasters, who have no streaming services due to their affiliate contracts, more than the Metro broadcasters however both are affected when viewers move to streaming services.

Across the Scenarios, the need for a consumer to change their rooftop antenna is likely to be rare. Consumers however would have to bear the costs if a situation arises that would necessitate the replacement of these antennas with band appropriate equipment. If this cost was to be borne by the consumer, stakeholders have expressed concerns that this could encourage some households to permanently migrate away from terrestrial TV. Also a subset of antennas and or receive equipment may need repointing or upgrading due to the greater use of SFNs or wide area SFN as part of the proposed Scenarios. These situations would be identified in the spectrum planning work.

Rescanning the channels, moving away from MPEG2, sharing multiplex program information and/or the introduction of DVB-T2 involved in all or some of the Scenarios is likely to affect the consumer either in a minor or significant way.

Another theme across all stakeholders is the lack of information on the current receiver population and the capability of both older sets and relatively recent sets.

Regardless of the Scenario pursued (bar Scenario 0), an understanding of the following will help gauge the consumer impact:

1. MPEG4 vs MPEG2 only sets - to allow a migration to MPEG4 only.
2. How many DVB-T2 capable sets already exist and are they compliant with the (yet-to-be-finalised) DVB-T2 standard.
3. How sets will respond to the Service Information (SI) on shared MUX Scenarios.
4. HEVC capability and if the codec receives the terrestrial input, not just the streaming input.

Analysis:

This report considers the technical impact on consumers of various Scenarios with respect to the impact on their reception equipment (e.g. antennas and TVs), but broader issues, such as consumer preferences for amount or quality of programming, were outside of the scope of this report.

Scenario 1 would be the least disruptive for consumers as most receivers are already MPEG4 capable. How well existing receivers handle the shared MUX Service Information still needs to be determined.

Scenarios 3, 4 and 5 (DVB-T2) will be more disruptive for consumers. Even if they replace their main receiver with a DVB-T2 receiver, their older non-DVB-T2 capable receiver would require an STB to function if it was still in use in the household.

A consumer survey (as suggested in Section 4.5) would help gain an understanding of the receiver population and gauge the impact on consumers in any of the Scenarios (other than Scenario 0 – the current situation).

5.6 Implementation Logistics

F5.6 Key Findings

- All Scenarios (other than Scenario 0 – the current situation) will have some impact on the consumer, and both the Government and the broadcasters attach a high priority to minimising this impact.
- Further work would be required to better understand specific implementation logistics to transition to a new Scenario. However, a five to 10 year transition timeframe to free up the spectrum was deemed reasonable by all participants in the workshop.

Stakeholders view:

All Scenarios (other than Scenario 0 – the current situation) will have some impact on the consumer and the objective for the broadcasters would be to minimise this impact so viewers are not lost. Stakeholders have stressed at length the importance of minimising the impact on viewers.

From the stakeholder meetings, workshop and Green Paper submissions, it appears to be too early to develop a detailed migration plan for any of the Scenarios. However, stakeholders did note that the 6th channel could be used for a simulcast period, or there could be a hard switch over. The migration plan would affect the timing and cost to transition.

Implementing Scenario 1 using the current DVB-T sets would appear the most straightforward. From a consumer perspective there is some uncertainty about the number of sets capable of MPEG4 and also how the existing sets would handle the shared MUX Service Information for multiple networks. It is envisaged that all sets would need a rescan/retune and most would need a manual rescan/retune (rather than an autoscan). Past experience has shown that these are disruptive and difficult to viewers. Help lines and public awareness/education campaigns would help minimise the transition pain.

Stakeholders generally agreed that the timeframe to transition in the DVB-T Scenarios would mean that it would be at least five years before the spectrum would be available for other uses.

Implementing Scenarios 4, 5 and 6 (where a new DVB-T2 set is required) could be made more straightforward if TV sets being purchased now were all capable of DVB-T2 so that when the transition were to be implemented there would be a large base of compliant sets. Work is currently underway to finalise the receiver standard for Australia regarding DVB-T2 sets arriving in Australia.

Using the 6th channel (currently largely vacant with the exception of community broadcasters in Melbourne and Adelaide) as a "lollipop" channel with attractive features and programming is a potential option to help bring forward the uptake of DVB-T2 sets. After DVB-T2 is migrated onto channels 1-5, the 6th channel could provide a legacy service with DVB-T but there is no consensus or advanced planning about how this might work.

Opinion from the stakeholders on the migration timeframe for these Scenarios ranges from five to 10 years before the released spectrum would be available.

Analysis:

For all the scenarios, the Broadcaster would need to implement changes to transmission equipment, new arrangements for contribution, distribution and the MUX.

Scenario 1 is likely to be the fastest to implement and the five year timeframe before the spectrum is fully available is reasonable.

Scenarios 4, 5 and 6 that use DVB-T2 rely on the consumer uptake of receivers capable of receiving DVB-T2, so while the transmission aspects (including contribution and distribution) could be transitioned in a five year period, the uptake or penetration of DVB-T2 and the migration plan success would likely be key in determining the timing of the spectrum becoming available. A 10 year timeframe for consumers to replace existing receivers with DVB-T2 capable receivers has been suggested based on the number of imported new receivers.

5.7 Costs

F5.7 Key Findings

- Costings for the Scenarios are not well developed because the variables are still to be determined, including the transition methodology (simulcast, hard switch etc.). However, some stakeholders have offered some figures. While no in-depth costings have been completed, the costs to implement Scenario 1 are likely to be the lowest. The highest costs would likely be for the Scenarios with more RF channels and use of DVB-T2.

W5.7 Area for Further Work

- Suggest further work be undertaken to better understand the overall end-to-end costs to consolidate the spectrum.

Stakeholders view:

Costings for the Scenarios are not well developed due to the variables still to be determined like the transition methodology (simulcast, hard switch etc) however some stakeholders have offered some figures outlined below.

High level estimates of transmission restack costs range from $150 million to $350 million for the various Scenarios. A DVB-T2 transition would be more costly and if the 6th channel were used as part of the transition, then more costs would occur to establish (and then disestablish) the transmission.

Costs associated with aligning National and Commercial coverage footprints (likely required for MUX sharing) have not been envisaged in any of the stakeholder costings.

Distribution and Contribution costings are difficult to predict until the spectrum plan and MUX sharing arrangements are firmer.

Some broadcasters have long term transmission contracts and there will be costs associated with ending these contracts early to transition to a shared mux model.

Analysis:

Costs to consolidate the spectrum would arise across the broadcasting ‘chain’, from the studio to contribution and distribution, to the transmission sites and in some cases to viewers themselves. No in-depth costings have been done however costs to implement Scenario 1 will be the lowest. Highest costs would likely be for the Scenarios with more RF channels and use of DVB-T2.

Costs would be significantly affected by the transition plan (i.e. hard switch, simulcast period etc).

All Scenarios would require changes to contribution, distribution and input feed arrangements and there would be both set up costs and ongoing operational costs to be considered.

6 Conclusion

Seven Scenarios have been analysed and compared: the current situation, another three with DVB-T and three more with DVB-T2. They cover a range of total channels and differing numbers of channels in the metro areas to the regional areas.

The views, commentary and discussions in this report represents early and preliminary views only. Additional work would be required to provide more definitive conclusions or plans for any spectrum consolidation going forward.

If a transition to a new standard is appropriate, then DVB-T2 is the logical choice to transition from DVB-T, as its transmitters and receivers are typically backwards compatible and is of the same family of DVB standards.

Some Scenarios achieve a reduction of as much as 84 MHz; others achieve a lower reduction.

There are trade-offs involved, whichever Scenario is chosen. For example, Scenario 1 could be achieved relatively quickly and most consumers would not need to purchase new equipment; however it offers less capacity than some other Scenarios.

Transmitters may require the addition of microwave links, fibre or similar and an alignment of regional markets and would raise cost considerations.

Sharing of MUXes between broadcasters will mean a change in the contribution arrangement and MUX management.

Distribution arrangements become complex when MUXes are shared, with an increase in cost.

All Scenarios (other than Scenario 0 – the current situation) will cause some disruption for the viewer. Stakeholders are concerned about the risk of losing viewers, especially with the competition of the streaming services. To gauge the impact on consumers of any of the Scenarios, an understanding of the receiver population is needed.

Stakeholders generally agreed that the timeframe to transition in the DVB-T Scenarios would mean that it would be at least five years before the spectrum would be available for other uses. For the DVB-T2 Scenarios, some stakeholders suggest it could take five to 10 years depending on the future receiver population and migration methodologies.

Costings for the Scenarios are not well developed due to the variables still to be determined like the transition methodology (simulcast, hard switch etc.). Costs associated with aligning National and Commercial coverage footprints (likely required for multiplex sharing) have not been accounted for to date. Distribution and contribution costings are difficult to predict until the spectrum plan and MUX sharing arrangements are firmer.

7 References

Specific references referred to in this document:

- Standards Australia:
- AS 4599.1:2015 – Digital television – Terrestrial broadcasting, Part 1: Characteristics of digital television transmissions.
- AS 4933:2015 – Digital television — Requirements for receivers for VHF/UHF DVB-T television broadcasts including ancillary services.

General standards relevant to digital TV that this document has derived information from:

- European Broadcasting Union (EBU):
- EBU Tech 3348 – Frequency and Network Planning Aspects of DVB-T2.
- TR 016 – Benefits and Limitations of Single Frequency Networks (SFN) for DTT.
- TR 036 – TV Programme Accommodation In A DVB-T2 Multiplex for U(HDTV) With HEVC Video Coding.
- European Telecommunications Standards Institute (ETSI): ETSI EN 300 744 – Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television.
- International Telecommunication Union (ITU): BT.2254-4 – Frequency and network planning aspects of DVB-T2.

Green Paper:

This document includes commentary relevant to the Media Reform Green Paper – November 2020, as well as considerations of the Green Paper submissions provided by the Stakeholders.

8 Glossary

Term	Description
256-QAM	256-state Quadrature Amplitude Modulation, available in DVB-T2.
ACMA	Australian Communications and Media Authority.
ATSC	Advanced TV Systems Committee; responsible for digital TV standards primarily in use in America and Korea i.e. ATSC 3.0.
Bit rate	Refers to the number of bits that can be transmitted in a given unit of time, commonly measured in Mb/s or Megabits per second.
CAPEX	Capital Expenditure.
Channel Block	Used for planning purposes by grouping RF channels into a block (sometimes referred to as Channel Planning Block). Currently in Australia there are 5 DTV Channel Blocks with 6 RF channels per block; these channel blocks are referred to Blocks A to E.
Commercial Broadcaster	Commercial TV broadcaster in the Australian Market. Regulated by ACMA and represented collectively by Free TV Australia.
Community Broadcaster	Community based broadcasters; non-commercial broadcasters operated by a community group.
Compression	Video compression and multiplexing - the process that effectively 'compresses' and combines a number of TV channels/services.
Daisy chained site	Sites linked from one to another in a line or chain topography. For example, a primary DTV transmitter links via microwave to a secondary DTV site, the secondary DTV site links via an off air feed to a DTV relay site.
DC	Data Cast; lower quality video resolution with respect to SD (Standard Definition).
DTH	Direct To Home; in reference to Satellite reception.
DTV	Digital TV.
DVB-I /DVB-IP	Digital Video Broadcast - IP; next generation standard incorporating IP (Internet Protocol) capabilities.
DVB-S2	Digital Video Broadcast - Satellite transmission standard.
DVB-T	Digital Video Broadcast - Terrestrial transmission standard.
DVB-T2	Digital Video Broadcast - Terrestrial 2nd generation.
EPG	Electronic Program Guide; viewer menu system displaying the scheduled program content.
ETSI	European Telecommunications Standards Institute; responsible for developing the DVB standard.
GPS	Global Positioning System; used for SFN synchronisation.
Guard Interval	An overhead used to prevent interference between different transmissions; used for SFNs to allow reception of multiple incoming synchronised signals using the same frequency at a receiver without creating interference.
HbbTV	Hybrid Broadcast Broadband TV; an interactive standard that supports applications on Smart TVs.

HD	High Definition; next generation video resolution standard up from SD.
HEVC	High Efficiency Video Coding; next generation compression standard H.265.
HPON	High Power Open Narrowcasting; Digital TV licence category.
In-fill	A DTV transmitter site designed to service a specific geographical area that may not receive an adequate service from a primary/secondary transmitter due to interference, coverage footprint restrictions, terrain etc.
LIPD	Low Interference Potential Devices; low power devices operated within a LIPD class licence ie. wireless microphones utilising UHF spectrum.
Licence Area (TV)	A geographical area that is in a television licence area plan (TLAP). A commercial TV broadcaster operates and their service is protected within this geographical boundary.
Metropolitan Broadcaster	A broadcaster providing service across the Australian metropolitan centres; Sydney, Melbourne, Brisbane, Adelaide and Perth.
MFN	Multi Frequency Network; traditional DTV network where adjacent transmitters use multiple frequencies to cover a geographical area.
Microwave feed	Input DTV signal is received via a microwave link.
MPEG	Moving Pictures Expert Group; set standards for video encoding such as MPEG-2/H.262 and MPEG-4/H.264 compression standards.
MUX	Multiplex; technology used to combine multiple digital transmissions together for broadcast.
National Broadcaster	Australian Government funded broadcasters; ABC and SBS.
OFDM	Orthogonal Frequency-Division Multiplexing; encoding method of digital signals onto a carrier signal for broadcasting.
Off-air feed	Input DTV signal is received over the air path from another transmitting service.
OPEX	Operating Expenditure.
Regional Broadcaster	A broadcaster providing service across regional areas outside of the main metropolitan centres.
Restack	The process of clearing spectrum and reallocating existing TV services.
Retransmission	DTV licence category where a service is retransmitted to cover a new coverage area.
RF Channel	A 7 MHz wide digital television channel. Currently in Australia RF Channels 6 to 12 in the VHF band (minus the digital radio allocation on RF channels 9 and 9A) and RF Channels 28 to 51 in the UHF band are allocated to digital television.
Satellite feed	Input DTV signal is received via a satellite input signal.
SD	Standard Definition; video resolution standard.
SFN	Single Frequency Network; several DTV transmitters broadcasting the same signal over a single frequency channel.
SI	Service Information; metadata providing the readable program information/descriptions for the EPG.

Simulcast	A transmission of the same DTV program content at the same time on multiple channels. This simulcast content may be compressed via different formats i.e. MPEG2 and MPEG4 compression.
Simulcast Period	Refers to a period of time when multiple services are broadcast simultaneously; potentially as part of a transition migration path during a restack.
STB	Set Top Box; TV decoding device.
Static Delay	A method by which transmitters can apply a delay (static delay) to their synchronized transmission to have their signals arrive at a certain time in relation to other signals arriving at the same location. This will not in itself mitigate self-interference due to transmitters spaced farther than permissible, but this interference can be 'steered' to fall on areas with no or sparse population, thus having less of an impact as long as the resulting self-interference is acceptable.
Transport Stream	Multiple digital streams, ie. digital video, audio or data streams are multiplexed together to form a single transport stream. This transport stream is modulated over a single RF channel.
UHD	Ultra High Definition; 4K video resolution and above.
UHF	Ultra High Frequency; radio spectrum between 300-3,000 MHz.
VAST	Viewer Access Satellite TV; satellite digital TV service in use mainly in remote areas of Australia.
VHF	Very High Frequency; radio spectrum between 30-300 MHz.
Wide area SFN	Wide area Single Frequency Network; allows greater distances between SFN transmitters covering a larger geographical area (possible with the DVB-T2 standard).

Appendix 1 – Explanatory Material

A1.1 Multi-Frequency and Single Frequency Networks

MFN Topology

An MFN is a network topology where transmitters use different frequencies in a coordinated manner to provide broadcast coverage to service area. Each frequency is planned to co-exist with the other frequencies to mitigate interference issues. Content does not need to be identical and no frequency or time synchronisation are required as long as careful spectrum planning has considered all the interference issues such as co-channel and adjacent channel relationships between the transmitters.

SFN Topology

An SFN is a network topology where transmitters within the SFN broadcast identical content, synchronised in time, and on exactly the same frequency. The multi-path immunity of OFDM used by the DVB-T and DVB-T2 standards allow for the use of SFNs. There will be no interference from using the same frequency as long as these signals are synchronised and arrive at the receivers within a specific time, called the guard interval. The receivers can then decode and use the data. GPS is used to provide the time synchronisation for the various transmitters within an SFN. The guard interval determines the maximum permissible distance between transmitters in the SFN. This could limit an SFN's ability to cover whole licence areas that are larger than the maximum SFN size, in particular for DVB-T. Wide area SFNs as part of the DVB-T2 standard could help mitigate this issue.

MFN vs. SFN: Benefits and Disadvantages

The benefits of using SFNs when compared to MFNs include:

- More efficient use of spectrum, which is the *key benefit* of SFNs. A number of transmitters can share the same frequency to provide coverage to a service area without introducing unwanted interference. This is valuable in areas where spectrum is scarce. This also helps free up valuable spectrum for reallocation to other services, or for other uses such as providing regional content or managing frequency allocations for overlapping markets.
- SFNs could allow more flexible implementation of new transmitters to gap fill or extend coverage to a particular service area, *in terms of allocating new frequencies* to these transmitters.
- The use of SFNs could also give planners flexibility in coordinating and re-using frequencies across markets or regions. A smaller subset of frequencies across say two adjacent networks, could give more planning flexibility compared to two neighbouring MFNs in situations where spectrum is scarce.
- The use of SFN timing can potentially allow more transmitters to share the same frequencies, but that are spaced further apart that the maximum permissible SFN size. SFN timing planning is a method by which transmitters can apply a delay (static delay) to their synchronized transmission to have their signals arrive at a certain time in relation to other signals arriving at the same location. This will not in itself mitigate self-interference due to transmitters spaced farther than permissible, but this interference can be 'steered' to fall on areas with no or sparse population, thus having less of an impact as long as the resulting self-interference is acceptable.
- The overlapping coverage from various transmitters within an SFN decreases the variability of the signal strength if it were to come from a single source. This helps provide more uniform coverage over the planned service area and potentially mitigate areas of poor coverage that could be affected for example by localised shading (e.g. hills, foliage, buildings etc.).
- A lesser benefit to fixed installs is the gain associated with combining signals of similar power level that arrive within the guard interval – this can result in a minor improvement in the received signal level however may lead to Modulation Error Ratio degradation. This can potentially help improve coverage to areas that have some deficiencies or extend the fringe coverage radius of the network, but as noted the benefits are not significant for fixed receive installs and not one of the deciding factors in the use of SFNs. The decrease in variability and potential minor increase in received signal power is known as the network gain of an SFN.

The disadvantages of SFNs compared to MFNs include:

- Difficulty in managing local content or overlapping markets due to the need for all sites within the SFN to share the same content. This is likely to place an overall limit on the practical scale of the SFN to keep within the market. The adjacent markets will require a new channel for operation.
- Increased infrastructure requirements, where additional equipment are needed to maintain synchronisation and precise control of all transmitters within the SFN.
- Increased complexity in the use of daisy-chain transmitters such as off-air fed transmitters. These may require dedicated microwave links or a second frequency.
- Impact to viewers who may need to repoint existing antennas, or upgrade their reception equipment to receive signals from SFNs.
- For SFNs to work, part of the signal's payload is given to the guard interval, which is an overhead on available throughputs. The size of the guard interval is directly proportional to the achievable size/scale of the SFN. The bigger the guard interval, and hence the larger the SFN the more overheads on the total payload.
- A failure of a single transmitter's synchronisation within an SFN can also cause part of SFN service area to fail. This may occur if the timing of one transmitter is not maintained resulting in co-channel interference over a wide area, referred to as self-interference. For example the other members of the SFN signals will still be timed perfectly for reliable reception, while the out-of-time member will overlay co-channel inference in the wider targeted coverage area. Loss of synchronisation could be due to a GPS fault, which could cause frequency or time to drift at the faulty site, or incorrectly set or corrupted parameters required for synchronisation and timing. Network operators will have an understanding of how big an issue this is but equipment do fail periodically and network parameters can get corrupted or set incorrectly. Good engineering practices, which should be a part of any network deployment, can help mitigate these issues. Some specific strategies to mitigate issues with SFNs include:
- Correct application of SFN parameters across all transmitters in the SFN.
- Deployment of equipment that meets the specifications for tight time and frequency synchronisation requirements.
- A documented control change process to ensure any changes to the site or network configuration continues to meet the SFN specifications.
- A maintenance programme where the network equipment and infrastructure, in particular the equipment needed to maintain the tight synchronisation, are checked on a regular basis to ensure continued operation.
- Network monitoring of all the key SFN elements and alarm/alerting via 24/7 network management system to enable the operators to respond quickly to any faults.
- A periodic field survey to measure SFN performance in known areas where self-interference could occur should there be a failure or drift in synchronisation.

Wide Area SFN

The DVB-T2 standard allows for permissible transmitter distances within the SFN to be larger when compared to DVB-T, which provides the capability for deployment of wide area SFNs. This allows more distant transmitters to share the same frequencies and increase the SFN size without causing self-interference within the SFN. Sharing the same frequencies across a larger area can give rise to more efficient spectrum use, which is the key benefit of using SFNs.

Wide area SFNs can be more complex to plan than SFNs used in DVB-T, due to the large number of parameters involved in the planning process that have to account for more distant transmitters and larger coverage areas. Guard intervals, timings, the maximum data rates, network size, frequency reuse distance, equivalent radiated power, effective heights of transmitters, variability of receiver performance etc. are all inter-related.

For example, some of the complexities to consider:

- As the guard interval takes up a percentage of the available data capacity, a larger SFN size requiring a larger guard interval would reduce the available capacity of the network.
- Choosing to provide a more robust signal, that is the minimum signal over noise that a receiver can use, will have reduced data capacity as more robust signals use lower modulations.
- Wide area SFNs could give rise to more complex spectrum requirements for regional areas or overlapping markets, where the SFN size could cross boundaries with different content or coverage requirements. It may be inefficient to carry all national, commercial and regional content over a one SFN. Regional SFNs would be

more suited to serve these separate markets. However the use of wide area SFNs could also free up some spectrum for use in these markets.

- SFN timing planning will likely be more complex with wide area SFNs compared to SFNs used in DVB-T. More distant transmitters would need to be considered along with their relationships with all other transmitters in the wide area SFNs. The population affected across the wider coverage footprint could also pose issues as to where a ‘steered’ self-interference zone would be acceptable.
- Wide area SFNs could also mean more equipment and changes to existing transmitters that are not currently part of an SFN due to their distance but are now included due to the increase in SFN size.
- Daisy chain retransmission sites that currently receive their feeds off-air from the parent sites would also need to consider the use of microwave linking, thus adding to the costs.
- Having more transmitters in an SFN over a wider area would affect more viewers who need to repoint antennas or upgrade their receiver equipment to have reliable reception.

These complexities however can be managed by considered planning and by development of an Australian specific DVB-T2 standard that chooses the most appropriate parameters to fit the mode of operation for the Australian digital broadcast environment. In general - the selection of the most appropriate parameters would be a balance of SFN size, required capacity, robustness of coverage, availability of spectrum and management of regional and overlapping markets content.

A1.2 Digital TV Transmission Standards

DVB-T

DVB-T is a standard for the broadcast of digital terrestrial TV. DVB-T transmits compressed digital video, digital audio and other digital data in an MPEG transport stream. The transmission uses a modulation scheme called Orthogonal Frequency Division Multiplexing (OFDM), which is a method of encoding digital signals onto a carrier signal for broadcasting. The DVB standard was developed by the European Telecommunications Standards Institute (ETSI).

Viewers receive this transmission using TV sets or STBs equipped with a DVB-T capable receiver.

DVB-T is currently the digital TV broadcast standard used in Australia. DVB-T coverage is provided by a large number of transmitter sites broadcasting in both VHF and UHF Bands, using a 7 MHz channel raster. The Australian digital TV broadcast standard is provided in the Australian Standards AS 4599.1:2015 and AS 4933.1:2015, noting that these standards are industry standards and are not automatically mandated by the ACMA under Section 158 of the *Radiocommunications Act 1992*.

DVB-T2

DVB-T2 is the second generation terrestrial standard for digital terrestrial TV developed and standardised by ETSI. This extension of the DVB-T standard was developed to provide advanced modulation scheme for digital terrestrial broadcasting. DVB-T2 has the same baseline principles as the DVB-T standard, but can be seen as a more efficient version of the original DVB-T standard, with new forward error correction, higher modulation constellations, reduction in overheads etc. The higher bit rate of DVB-T2 in comparison to DVB-T makes it suited for HD and Ultra HD (UHD) TV signals, although the Australian broadcasters have been providing HD services with the existing DVB-T, along with SD services.

Comparisons Between DVB-T and DVB-T2

Compared to DVB-T, DVB-T2 parameters have been extended to provide more options and improvements in efficiency such as:

- New Forward Error Correction (FEC), and higher modulation constellations (for example 256-QAM, allowing for higher data rates). This results in a practical capacity increase of approximately 30% over DVB-T. This extra spectral capacity is likely to be utilised by higher content demands of broadcasters such as increased video resolutions.

- Orthogonal Frequency Division Multiplexing (OFDM) carrier increase from 8k, to 16K and 32k options. 32k mode allows better performance for receivers with fixed installs that could suffer multipath effects (for example signals from the same source arriving at the receiver via different paths due to reflections, causing interference called slow fading over a period of time). This mode, with a longer symbol period, is less susceptible to time variations of the channel.
- New guard interval fractions, combined with subcarrier increases to 32k, giving greater choice of planning options and SFN sizes.
- Reduction in overheads, which increases useable payload for the same bandwidth compared to DVB-T.
- Wide area SFN areas are possible due to utilising modulation with significantly more subcarriers. This allows for a longer symbol period, as well as offering longer guard interval factors than DVB-T, and hence allowing transmitters spaced farther apart to share the same frequency. This can reduce the need for overlapping transmissions and reduce spectrum requirements in certain markets.
- Improved versatility and robustness by applying techniques such as rotated constellations, improved efficiency of the transmitters, Alamouti encoding (a method where data is encoded to broadcast over a number of antennas and received at an antenna where the various paths from the source antennas provide diversity to overcome effects such as fading or noise – this improves the reliability of the signal).

Taken together – the extended DVB-T2 parameters theoretically allows nearly a 50% increase in capacity over DVB-T. DVB-T2 is between 30-50% more spectrally efficient, for the same carrier to noise level than DVB-T.

The following table compares the key difference between the DVB-T (current implementation) and DVB-T2 (potential future) digital TV standards[6].

As well as theoretical differences, the existing and expected future modes of DVB-T2 are contrasted. This demonstrates the potential improvement to capacity, and SFN transmitter spacing for the same and shorter guard intervals.

[6] Trials have been conducted by Free TV and Broadcast Australia (BAI) testing the DVB-T2 transmissions in Queensland, Australia. The trials tested both VHF and UHF transmissions as well as SFN operation, H265 1920 x 540p video, 192 kbps AAC audio, and the trial DVB-T2 parameters used 7 MHz channel, 1/32 GI, 16k and SISO – noting that information about these parameters used in the trials have been obtained from publicly available information, and have not be validated.

Parameters	DVB-T	DVB-T2
Capacity, net bit rate (Mbit/s)	23 current 29 max	32 expected 40 max
C/N Ratio maintaining 20 dB (current and expected modes)	64QAM, FEC: 2/3, 8k, GI:1/8	256QAM, FEC: 2/3, 32k, GI:1/8
Power efficiency	Med	High
SFN usage	Good, long guard intervals	Well suited with longer guard intervals than DVB-T due to longer symbol period
SFN transmitter spacing, maximum possible	256 μs (74 km)	608 μs (182 km)
Practical SFN modes, comparing current 1/8 GI, with 1/16 and retaining 1/8. Increasing subcarriers from 8k to 32k	128 μs (34 km) [8k, 1/8 GI] 23 Mb/s	256 μs (76 km) [32k, 1/16 GI] 32 Mb/s 512 μs (136 km) [32k, 1/8 GI] 31 Mb/s
STB ballpark pricing	~$50 for basic STB and ~$400+ for more features such as recording, WiFi, streaming etc.*	~$50 for basic STB and ~$400+ for more features such as recording, WiFi, streaming etc.*
Resilience to impulsive noise source	High	Excellent
Transport Protocol	MPEG-Transport Stream	MPEG-Transport Stream or IP Encapsulated
Subcarriers	2, 8k	1, 2, 4, 8, 16, 32k
Modulation modes	QPSK, 16, 64QAM	-> plus 256QAM

*Table 5: Comparison of DVB-T and DVB-T2. *STB ballpark pricing based on information from dealers such as JB HiFi, Harvey Norman and Amazon. Actual pricing will vary, plus there are numerous models with different capabilities at different price ranges.*

Current Australian DVB-T mode sourced from ACMA General Planning Guidelines: (https://www.acma.gov.au/sites/default/files/2020-01/General%20Information.pdf)

Expected DVB-T2 modes from EBU Tech 3348 Planning Aspects of DVB-T2:

(https://tech.ebu.ch/docs/news/2012_01/wrcdocs/Planning%20aspects%20of%20DVB-T2%20-%20EBU%20TECH3348%20-%20May%202011.pdf)

Other Digital TV Standards

Other digital TVs standards include ATSC 3.0, DVB-I and DVB-S2. Based on feedback from the stakeholders during this consultation process – ATSC 3.0 is not a logical transition path for DVB-T as it is from different group of standards, and it does not have backwards compatibility with DVB-T, meaning any transition will require a wholesale change from the network to the viewer equipment.

DVB-I (where I stands for Internet) has been discussed as an option for the future. DVB-I is for delivery of IP services via the internet to devices with broadband connectivity. Services can range from broadcast like TV services to services such as Video on Demand and support services of different quality from SD to Ultra HD, plus various audio codecs.

DVB-S2 is the satellite transmission standard. The VAST Satellite network uses this standard and provides Direct to Home (DTH) services via an STB and is part of the distribution chain to some sites, providing DTV input to then be retransmitted terrestrially.

A1.3 Compression Standards

Moving Pictures Experts Group (MPEG) is an alliance of working groups that set standards for media coding. In the case of digital TV broadcasting in Australia, MPEG2 and MPEG4 are the compression standards for video encoding. MPEG4 was created as a standard capable of providing good video quality at substantially lower bit rates compared to MPEG2 and all receivers since 2015 are MPEG4 compatible.

Australia currently broadcasts digital terrestrial TV services in MPEG2 and MPEG4 format, in Standard Definition (SD) at 576i[7] and High Definition (HD) at 1080i format.

High Efficiency Video Coding (HEVC) was created to provide high efficiency coding rates for resolutions above HD (4K, 8K) and is more efficient for progressive[8] scanning rates.

Australian Standards AS 4933:2015[9] Clause 3.8.2 and Clause 3.8.3 sets out the receiver standards required for decoding MPEG2, MPEG4 and HEVC. In particular:

- Decoding all valid MPEG2 25 frames/s progressive and 50 fields/s interlace video formats.
- Decoding all valid MPEG2 HD 25/50 Hz formats (1080 active line formats and progressive formats at 50 frames/s).
- Decoding capability for MPEG4 video in SD and HD 25/50 Hz up to level 4 and decoding accompanying audio formats.
- Support for HEVC decoding including video, SD*, HD, 4K and Ultra HD is under consideration.

Progressive scanning (see footnote 8) has come to be more expected as this is the format used by personal computers and mobile devices commonly used to view streaming content. Progressive scanning can provide a smoother video than interlaced (e.g. 720p provides smoother video than 1080i) and can be beneficial for programmes such as sports. A modification to AS4933:2015 to remove interlaced transmissions as a compliant standard could cause a shift to progressive scanning for digital TV broadcasts. HEVC was designed to cater for these mobile devices to reduce the capacity requirements and data usage.

The HEVC compression standard offers 50% better data compression at similar video quality to MPEG4, or significantly improved video quality at the same bit rate as MPEG4. HEVC does not provide efficiency gains for HD 1080i, since it was designed for progressive scanned content, and was not designed to support SD content (noting that AS 4933:2015 states support for SD is under consideration). There is no clear data available showing current receiver compatibility for the HEVC standard over terrestrial transmission; receivers that do state HEVC compatibility may only be for streaming services.

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[7] Interlaced scanning is denoted with a lower-case *i* after the number of lines (for example 1080i) meaning for each picture frame, only alternate lines of pixels are refreshed with each scan. In this mode the frame is refreshed 50 times per second, while each pixel is refreshed every 25 times per second. This is the traditional method used for analogue TV. This reduces the capacity required to provide content.

[8] Progressive scanning is denoted with a lower-case *p* after the number of lines (for example 1080p) and differs by refreshing each pixel 50 times per second, which is twice as often as the interlaced mode. This mode requires more capacity than interlaced and delivers a higher perceived quality, although tests have shown that there is only minor increase in capacity for compressed progressive scanning mode compared to compressed interlaced scanning mode, for the similar perception of quality.

[9] Full details of standards are provided in AS 4933:2015

The MPEG2 and MPEG4 standards allows a maximum resolution up to HD (1080p), while HEVC is able to provide a significant advancement in quality for the viewer by allowed ultra-HD resolutions of 4K and 8K. Adopting HEVC will provide a future path of utilising the capability of modern television sets which today provide 4K and some now 8K capability. This will also help keep up with the resolutions offered by on-demand streaming services, which already offer ultra-HD resolutions.

The compression standards used for digital TV broadcast do not affect the spectrum allocation but can affect the number of program streams and/or the quality of those program streams.

The following table highlights the key differences the MPEG and HEVC standards provide in relation to digital TV broadcasting.

Parameter	MPEG2 / H.262	MPEG4 / H.264	HEVC / H.265
Bit rate	High (2 ~ 30 Mbps e.g. Typical HD ~ 12 Mbps)	Medium (same picture as MPEG2 for half the bitrate e.g. Typical HD ~ 6 Mbps)	Medium for HD Low for HD+ resolutions (3 ~ 6 Mbps, to be defined*)
Bandwidth requirement	Broader than MPEG-4	Narrower than MPEG-2	Narrower than MPEG-4 for HD+ resolutions. Same as MPEG4 for SD.
Quality	SD used in Australia supports up to HD	Supports up to HD	Most efficient for UHD, 4K, 8K in progressive scan format. Not efficient for SD
Receiver compatibility	Yes, current in Australia	All receivers since 2015 are compatible (Industry believes a significant number of households (~90%) currently have MPEG4 receivers, but suggests a survey to fully quantify this figure)	Early stages of adoption
Coding compression currently in use for terrestrial Australian Digital TV?	Yes for SD	Yes for HD (and some SD services)	Not currently
Worldwide adoption	Now an older standard phased out by MPEG4	High	Low, early stages of adoption in Europe and North America.

*Table 6: Comparison of compression standards, MPEG2, MPEG4 and HEVC. *Actual bit rates depend on several operating parameters (e.g. encoders used, statistical multiplexing requirements, single or multiple programmes carried etc.). Also currently broadcasters have control of their own statistical multiplexing arrangements, allowing them to allocate for example HD to premium services such as sports, and SD to other services such as pre-recorded dramas.*

Appendix 2 – Other Multiplex Sharing Factors

A2.1 National vs Commercial Broadcast Licence Areas

AF2.1 Key Findings

- Nationals and Commercials sharing a MUX could be complicated for areas where the coverage footprints differ significantly between the services, typically for high powered sites (Nationals do not have licence areas, Commercials do), noting that under any consolidation scenario there would be choices to be made, and different options available to broadcasters regarding how they might share multiplexes.

AW2.1 Area for Further Work

- Assess the scale and impact of sharing National and Commercials on the same MUX.

Currently the Commercial broadcasters transmit their signal into a licensed area and in many cases need to use transmit antennas with a shaped pattern, a directional antenna, to prevent signal overspilling outside their licensed area. The National broadcasters have no licence area restrictions and can broadcast from an omnidirectional antenna on the same tower in some cases.

Stakeholder view:

If the National and Commercial broadcasters were to share the same MUX and hence the same transmitter and antenna, an issue is created for some areas as the National and Commercial broadcasters where the coverage footprints between the two could be significant.

Analysis:

This becomes an issue on how to consolidate Nationals and Commercial broadcasters to a shared MUX, antenna and infrastructure when some of the areas have different coverage areas, though it should be noted that though Nationals do not have a licence area, whereas the Commercials do, this does not typically give rise significant variations in coverage areas. Typically it is the higher powered sites, for example above 7 kW that differ the most in coverage footprints between the Nationals and Commercial broadcasters. There is less impact to sites with lower power.

To test the potential scale of this issue, a quick analysis was carried out using the ACMA digital TV planning data dated 19 June 2017. The database was queried to help understand the portion of current areas served where the National digital TV broadcast services have a difference in coverage footprint to the Commercial digital TV services.

Of the 532 areas served the majority, 93%, had National and Commercial services that are near-sited and have the same Rad pat max ERP indicating that they may be suitable to transfer to a shared MUX and 36 Areas Served would be deemed unsuitable for MUX sharing given the current parameters. Note, although this shows they are potentially technically suitable for MUX sharing it does not address the issue of different fed input sources for the different market areas which currently differ between the Nationals and Commercials.

Note this analysis should not be considered comprehensive nor highly accurate as there were limitations in how the analysis was done, namely:

- Only one national and one commercial in the data were compared for each Area served, however in some cases the power, location or antenna differs between those in the same category (typically the nationals operate at similar parameters and likewise the commercials operate with similar parameters).
- Where the area served name differs between the national and commercial services, they will not have been captured.
- Differences in antenna height have not been considered but are likely to have a lesser impact on coverage.
- Any discrepancies in the digital TV planning data will impact the result.

The aim of this analysis is to gain a high-level preliminary view on the potential scale of the issue. Further detailed work should be carried out to better assess the impact of this issue.

Where there are significant differences in coverage - this could have implications on whether the National broadcasters can share a MUX with the Commercial broadcasters for these subset of high powered sites, should the licence areas have to be maintained for the Commercial broadcasters. This is of course not likely an issue for any MUX sharing arrangement where the Nationals share their own MUX independent of the Commercial broadcasters.

A2.2 Contribution to a Shared MUX

AF2.2 Key Findings

- All broadcasters' uncompressed signals need to come to a central location, encoded/compressed and statistically MUXed.
- Centralising a shared MUX would give rise to business decisions for stakeholders opting into a shared MUX arrangement, and there would be costs involved to get streams to a central location. There are differing views as to whether operating costs would increase or decrease. More work is required on the cost issues.

AW2.2 Area for Further Work

- Undertake further analysis to understand the contribution complexities involved, and the added costs, plus any potential offsets in costs that arise from a centralised shared MUX arrangement.

Contribution (from the studio/Playout centre to MUX) arrangements will change if MUXes are shared by different broadcasters. To share a MUX, the broadcasters would need to create links to a common physical MUX location. If housed by one broadcaster or an independent 3rd party provider, then the other broadcasters would still need to link to this central location.

Stakeholder view:

Stakeholders are of the view that to maintain highest efficiency in the contribution chain – all signals must come to a central place and be encoded/compressed at one point and then statistically multiplexed.

However, stakeholders are concerned about the significant added complexity and costs (such as carriage costs, which are not a current cost) to link the uncompressed content data and manage the shared multiplexed streams. Concern was also voiced over the additional overhead of multiple EPGs which will increase the service information (SI) requirement per MUX and decrease capacity.

Broadcasters are of the view that there would be no reduction in MUX operational expenses to offset the increased costs and that these operational expenses may in fact increase.

Analysis:

Costs associated with sharing a MUX include the CAPEX initially required to set up the links for transporting the uncompressed feeds to a common central location and the ongoing carriage costs associated with these links for example cost per bit rate over a fibre link. There would also likely be a shared management cost (shared between MUX users) to cover a 3rd party MUX manager. Some of these additional costs may be offset by potentially reduced MUX operational expenses such as lower power consumption, possible reduced playout equipment costs and lower maintenance expenses however these are unlikely to fully mitigate the increased costs associated with MUX sharing.

There are also potential costs associated with MUX sharing which could result from individual broadcasters losing statistical MUX control and/or having to rely on fixed MUX allocations (this could result in reduced revenue streams for individual broadcasters if there is a loss in the number of services provided dependant on the scenario implemented).

Contribution costs are difficult to quantify until the spectrum plan and MUX sharing arrangements are better understood. These issues are more related to business decisions for stakeholders opting into a shared MUX arrangement rather than technical impediments that make the contribution side of MUX sharing unfeasible.

A2.3 Distribution from a shared MUX

AF2.3 Key Findings

- The current distribution chains are the most efficient solution, technically and economically.
- The distribution arrangements need to be carefully considered for a shared MUX. These issues are more related to business decisions for stakeholders opting into a shared MUX arrangement rather than technical impediments that make the distribution side of MUX sharing unfeasible.
- A number of off-air inputs may no longer work and would require direct microwave links or fibre, increasing CAPEX and ongoing costs to upgrade.
- A rebuild of some of these distribution chains could be complex and expensive.
- Satellite distribution could be considered as an option for remote transmitters.

AW2.3 Area for Further Work

- Undertake further work to understand the distribution complexities involved and the added costs, that takes into consideration the outcome of the spectrum plan and MUX sharing arrangements.

One of the key points is that the entire system (contribution, distribution etc.) needs to be carefully considered for a shared MUX, and not just focus on the spectrum issues

For distribution (getting the signal from the MUX to the transmission site), the Regional and National broadcasters have many more transmitter sites than their metro counterparts, so they are affected to a much higher degree in all of the Scenarios. While the National Broadcasters predominantly use Satellite for distribution, the Regional Commercial broadcasters rely on off-air reception from a parent transmitter as the input to their transmitters.

Note that the VAST satellite service provides the distribution to 124 sites, with 75 owned by the broadcasters and the remainder being community or council owned.

Stakeholder view:

If a spectrum consolidation is pursued, some of these inputs would need to be replaced with an alternative such as microwave links or fibre. They raise this as there could be a significant cost to establish and to operate for their remote sites.

Satellite could be considered as an option to reduce some of these distribution costs to the remote areas, as satellite is more cost effective in covering sparsely populated areas compared to terrestrial broadcast, allowing some smaller transmitters to be decommissioned. Approximately one million people are already on VAST, which is heavily government subsidised. However without subsidies, the costs to install DTH reception equipment could be prohibitive. VAST is also due for an upgrade to newer platforms.

The stakeholders note that the existing complex distribution chain for a typical Regional Commercial broadcaster is required to serve many of the smaller markets, this is particularly important for their business viability. They consider the current distribution chains to be the most efficient technical and economic solutions.

Having to have a common transport/feed for shared MUX for all broadcasters is a big issue, and complex. It could mean a rebuild of the networks for distribution to the shared platform. There are currently multiple transport streams across multiple areas. Complexity is huge from a distribution planning perspective to move to a shared MUX distribution system, and the entire system needs to be considered and not just from the spectrum end.

Analysis:

If a spectrum consolidation is pursued, it can be expected that a number of off-air links, in particular to daisy chain transmitters, may not be possible and would need to be replaced by direct microwave links or a fibre solution. Adding infrastructure to this distribution network would add significant complexity, capital and ongoing costs, and could impact the feasibility of small sites serving low populations.

The consolidation process may generate a need to increase distribution via the VAST Satellite service to transmitter sites for retransmission terrestrially, potentially as a result of off-air feeds no longer being viable, congested microwave spectrum and/or broken links higher up the distribution chain. This could lead to less targeted geographic specific content in particular to regional markets than the current terrestrial feed network system. Newer satellite platforms that may offer better regional capabilities could be considered as part of a future roadmap.

National broadcasters have fewer state markets to serve and their existing distribution chains have been set up accordingly. Any MUX sharing between National and Commercial broadcasters would add further complexity to distribute the correct content to the appropriate market/s. A shared distribution model could mean a rebuild to large parts of the distribution networks for some of these stakeholders, who have multiple transport streams Serving their networks.

One of the key points is that the entire system (contribution, distribution etc.) needs to be carefully considered for a shared MUX, and not just focus on the spectrum issues.

Distribution costs are difficult to quantify until the spectrum plan and MUX sharing arrangements are better understood. These issues are more related to business decisions for stakeholders opting into a shared MUX arrangement rather than technical impediments that make the distribution side of MUX sharing unfeasible.

Appendix 3 – Other Issues

A3.1 Considerations in Regard to Adjacent Users

AF3.1 Key Findings

- There is potential for coexistence issues from mobile phone transmissions that are adjacent to the TV spectrum for this proposed consolidation, but this is not an assumed outcome.
- Band replanning activities would be expected to look at supporting the coexistence of spectrum users and could help mitigate the issue, should it be significant.
- Coexistence will need to be managed and coordinated between broadcasters, mobile phone operators and the Government.

AW3.1 Area for Further Work

- Examine the impact of mobile phone carriers on adjacent channels to understand the interference potential and scale of problem (adjacent spectrum and intermodulation) once there is direction on the preferred approach to spectrum consolidation.

It is anticipated that mobile phone carriers would transmit on the spectrum immediately adjacent to the TV spectrum (reverse duplex) and even with a guard band there may be some potential for interference though this is not an assumed outcome. Any actual interference issue would need to be managed.

Stakeholder view:

There is concern from the stakeholders about interference to TV reception from users of the spectrum after it has been repurposed. Stakeholders consider there is a significant risk of potential interference from adjacent users of the spectrum, and suggest that this risk might be more widespread and harder to mitigate than occurred during the previous consolidation of broadcasting spectrum. Interference is most likely to occur in low signal strength reception areas where a mast head amplifier is used, or to Master Antenna (MATV) systems. Filters can be used to alleviate the issue at the consumer's antenna but there is a cost to consumers.

Additionally, some off-air links may be compromised if the mobile base-station is located near the transmitter site. Filters can be used to solve this issue but at a significant cost as the use of 10 pole filters could be required to establish a steep roll-off to mitigate the unwanted noise. There is also potential for intermodulation interference (where frequencies combine to create a new noise product on a different frequency).

Stakeholders suggested a fund could be established to finance solutions for interference to TV reception caused by the mobile phone carriers, similar to that set up in the UK by OFCOM.

Analysis:

Interference could potentially occur due to the use of the adjacent spectrum, but the likelihood and the magnitude of the problem is hard to determine at this preliminary stage. This issue could affect the viewers directly, or affect transmitters that are in close proximity to mobile base-stations. Trials could be run to see how bad the issue could be should it need to be quantified. Where the issue is present - there could be additional costs to viewers that have to install filters, or to broadcasters who may have to install expensive filters at their transmitter sites to cope with the interference from nearby mobile base-stations.

Coordination with the mobile phone carriers should be part of the consideration for any mitigation. If the issue becomes widespread and is unmanaged – it could cause viewers to turn to alternative means such as streaming.

Planning for coexistence of all spectrum users is part of any band planning or replanning activity and this would help mitigate this risk.

Looking at other markets (for example the United Kingdom) that have gone through similar learnings could be part of an examination to further assess this potential issue. As the preferred Scenario for this spectrum consolidation has not yet been determined it would be premature to conduct a detailed examination to fully assess the impact at this stage.

A3.2 Wireless Microphone/Audio Device Spectrum Availability

AF3.2 Key Findings
• There would be impacts on the spectrum available for wireless microphones and other wireless audio devices as part of a spectrum consolidation.

AW3.2 Area for Further Work
• Undertake further work to understand the impact to wireless microphones/audio devices once there is direction on the preferred approach to spectrum consolidation.

Currently wireless microphones and other wireless audio devices use the gaps in the UHF TV spectrum however with any consolidation, these gaps will reduce and may create an interference problem.

Stakeholder view:

There is concern about sufficient spectrum for wireless microphones post any spectrum consolidation. Broadcasters are extensive users of wireless microphones themselves, and these devices are also used by other groups such as schools, places of worship, community centres, theatres and events etc.

Analysis:

Any change in the spectrum available for wireless microphones should be assessed as part of this potential spectrum consolidation. There may be less spectrum available for use however this should be tested further, by for example looking at the differences between the previous restack and this potential spectrum consolidation, and or looking at other markets (for example the United Kingdom) that have gone through similar learnings. As the preferred Scenario for this spectrum consolidation has not yet been determined it would be premature to conduct a detailed study to fully assess the impact to wireless microphones/audio devices. Further work should be conducted at a later date to assess the impact further.