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Spectrum Allocation Options for Point-to-Multipoint Services in 5G

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Abstract. If the same content is to be delivered to a large number of users at the same time, point-to-multipoint transmissions (broadcast/multicast) could present a more efficient delivery mechanism when compared to point-to-point transmission schemes (unicast). Therefore point-to-multipoint is considered to be an essential feature for many 5G applications. Different 5G applications differ greatly in terms of coverage, bit rate and quality of service they require. This paper considers spectrum allocation options for different use cases in the following 5G vertical sectors: Media & Entertainment, Public Warning, Automotive and Internet of Things. This study analyses the spectrum allocation options for each use case in different spectrum bands and with different spectrum allocation methods, ranging from exclusive licensing to spectrum sharing and unlicensed spectrum. The different analyses map use cases to spectrum bands, spectrum bands to allocation options, use cases to allocation options, and all these are brought together in use case - spectrum band - allocation option - operator mapping.

Keywords: 5G · Point-to-multipoint · Spectrum · Allocation · Media and Entertainment · Public warning · Automotive · IoT

1 Introduction

In scenarios where a very large number of users consume the same data, such as popular media content, emergency messages and software updates, broadcast/multicast technologies can be used to deliver the same content to potentially unlimited number of users within the network coverage area with a defined and stable quality of service [1]. The broadcast/multicast services are a point-to-multipoint (PTM) scheme, while the traditional unicast services are a point-to-point (PTP) scheme. The use of PTM instead of PTP can be very cost-effective and high-quality delivery mechanism when data needs to be delivered to a large number of users, while the networks using PTP data delivery can potentially get congested in such scenarios as the data needs to be sent to each user individually.

5G-Xcast is a 5G-PPP Phase 2 project which develops an architecture for PTM capabilities in 5G. The project has identified and defined six different use cases which could benefit from PTM capabilities. This paper describes spectrum allocation options for these six different 5G PTM service use cases. Three of the use cases are in the field

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of media and entertainment, one in public warning, one in automotive and in Internet of Things.

The use cases differ greatly in terms of required coverage, bit rate and quality of service. This paper studies and analyses the spectrum allocation options for each use case in different spectrum bands and with different spectrum allocation methods, ranging from exclusive licensing to spectrum sharing and unlicensed spectrum. We also study the type of operator who would have most benefit in the selected combination of use case and spectrum assignment.

This paper analyses spectrum allocation and usage options under the following categories and allocation options: use cases (M&E1, M&E2, M&E3, PW1, Auto1, IoT1), spectrum bands (470–694 MHz, 700 MHz, 2.3 GHz, 3.5 GHz, 3.8–4.2 GHz, 6 GHz, 26 GHz and above), allocation/usage options (Nation-wide long-term licenses, Local and temporary licenses, CBRS, Licensed Shared Access, Concurrent Shared Access, Unlicensed spectrum.), and operator (MNO, broadcaster, other).

The uses cases are presented in Sect. 2, the spectrum bands, the allocation and usage options and the operators in Sect. 3. Section 4 presents the analysis and results of mapping different use cases, spectrum bands, and allocation options while Sect. 5 concludes the paper.

2 Use Cases

PTM transmissions present a more efficient delivery mechanism compared to PTP when the same content is to be delivered to multiple users at the same time. Therefore PTM is considered to be an essential feature for many 5G applications. Use cases evaluated in 5G-Xcast project cover the following vertical sectors: Media & Entertainment (M&E), Public Warning (PW), Automotive (Auto) and Internet of Things (IoT) [2]. The use cases are briefly described in the following sections. More detailed descriptions are available in [2].

2.1 Use Case M&E 1 – Hybrid Broadcast Service

Users have access to any combination of linear and non-linear audio-visual content in addition to social media. Content and services can be delivered over a combination of several networks and types of networks simultaneously. Continuity of the users' experience is preserved when switching between different access networks, possibly operated by different operators. The population of concurrent users may be very large (i.e. millions of viewers of a popular live event) and may substantially change over short periods of time.

2.2 Use Case M&E 2 – Virtual/Augmented Reality Broadcast

Virtual Reality (VR) is a technology that creates a perception of a user's physical presence in a rendered environment, real or imagined, leading to an immersive experience and may allow for user interaction. Virtual realities artificially create sensory experience, which in principle can include sight, touch, hearing, and smell. Augmented

Reality (AR) is a technology that composites multimedia or other types of content in the user's view of the real world. In this use case, large amount of users should be able to receive high-quality VR/AR content over the air simultaneously.

2.3 Use Case M&E 3 – Remote Live Production

In order to support the workflows in a typical production environment, it is often required that different people have access to the same video feed at the same time (e.g. directors, editors, commentators, those that create metadata). Given the potentially very high bit-rates in use, it is not practicable to carry multiple unicast copies of content. Instead, a feed from the production equipment such as cameras and microphones is carried over a unicast uplink connection (e.g. multilink) to the infrastructure access point and distributed via multicast to enable concurrent viewing by multiple users. The most important capability is to receive the video feed continuously, without breaks, freezes, artefacts or other issues. M&E use cases are illustrated in Fig. 1.

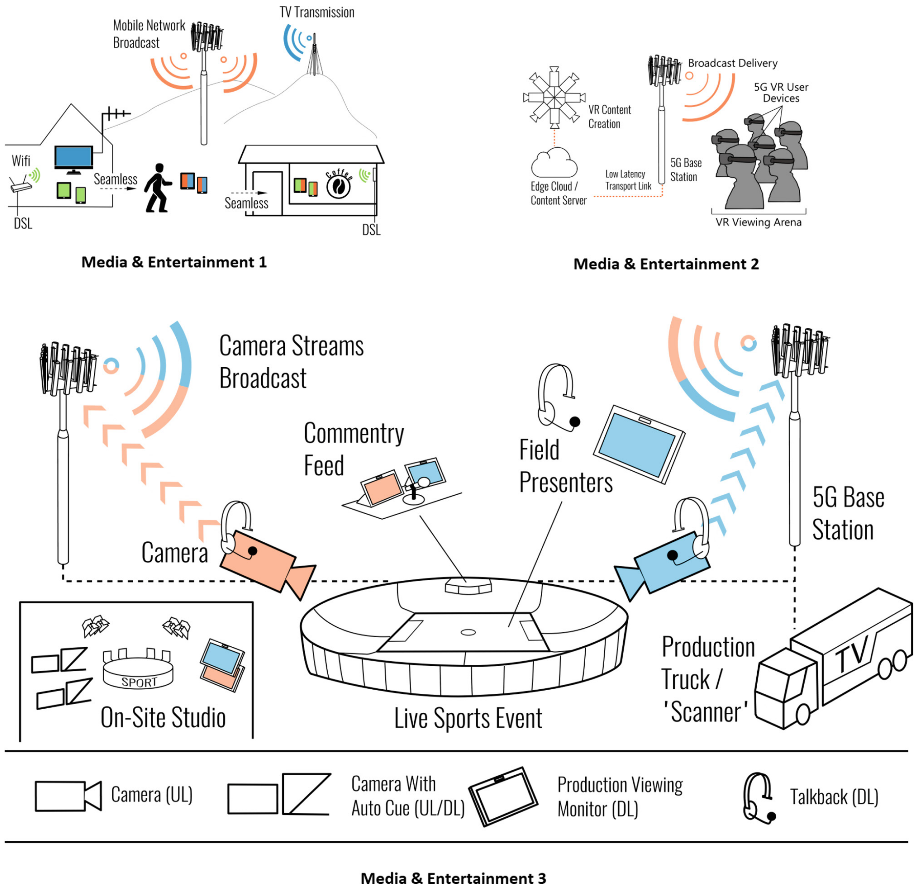

Fig. 1. Media & Entertainment use cases 1–3 [2].

2.4 Use Case PW 1 – Multimedia Public Warning Alert

In the Multimedia public warning alert, users are notified with alerts carrying multimedia and manifold information, which improves the effectiveness and reactivity of the users' responses. The alert is send to a targeted location. Within that targeted location, all users need to be notified promptly.

2.5 Use Case Auto 1 – V2X Broadcast Service

Various V2X applications like road safety, signage, mapping and autonomous driving require information delivered from the Intelligent Transport System (ITS) infrastructure (such as ITS roadside units and sensors) to the vehicle. The delivery of information that would benefit multiple recipients concurrently could utilize a point-to-multipoint service.

2.6 Use Case IoT 1 – Massive Software and Firmware Updates

IoT devices such as smart water-metering are installed deep indoors and wake up once or twice a day to send the consumption reports to the water metering network that is regularly extended. Based on the growing amount of data, the system configuration is adjusted, requiring the delivery of small configuration updates to all metering devices. Moreover, the water metering manufacturer regularly provides non-critical software updates. Figure 2 illustrates the public warning, automotive and IoT use cases.

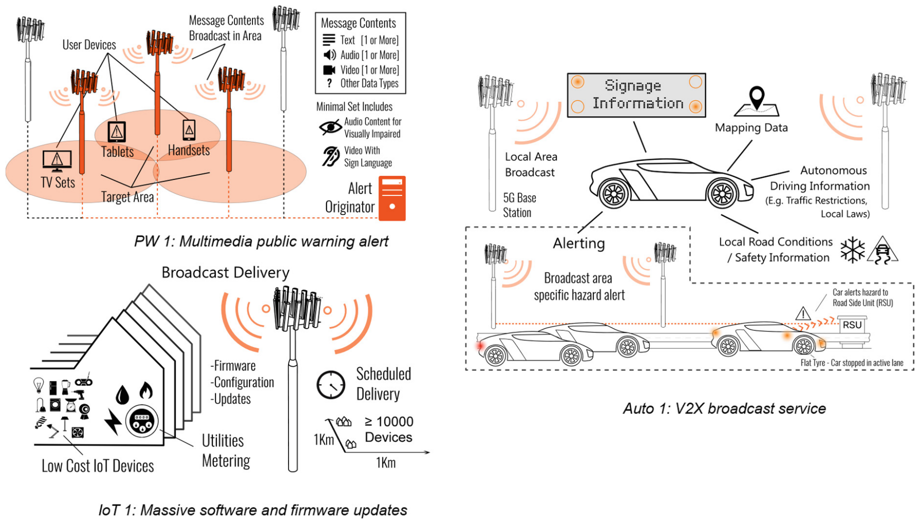

Fig. 2. Public warning, automotive and IoT use cases [2]

3 Spectrum Bands, Allocation Options and Operators

This section discusses the different spectrum bands, spectrum allocation methods and types of operators for the considered use cases. The spectrum bands are divided into three groups: coverage bands below 1 GHz, mid-capacity bands between 1 to 6 GHz and high capacity bands above 6 GHz. Sections 3.1, 3.2 and 3.3 discuss these bands, Sect. 3.4 the options for spectrum allocation and Sect. 3.5 the operator types.

3.1 Sub-1 GHz Bands: 470–694 MHz & 700 MHz

The frequency bands of mobile networks are traditionally divided to coverage bands and capacity bands. The coverage bands are below 1 GHz. They propagate well over long distances and it is economical for a mobile operator to build a nation-wide coverage using the coverage bands. The bandwidth in the coverage bands is narrow, and due that it is difficult to provide broadband connectivity or have many data-hungry applications in the same cell simultaneously. All capacity bands have been utilized tens of years and in order to get coverage bands for 5G, the bands have to be cleared from the existing use. The coverage bands are difficult to share with other types of spectrum users and the primary spectrum assignment method for coverage bands is exclusive licensing. In practise, the coverage bands have been used by the terrestrial television. The pioneer 5G coverage band globally is 700 MHz band, and it may be extended to cover lower digital TV UHF bands 470–694 MHz in the future.

3.2 1 to 6 GHz Range: 2.3 GHz, 3.5 GHz, 3.8–4.2 GHz, and 6 GHz

The capacity bands begin from 1 GHz and extend to higher frequencies. In some cases, the frequency bands between 1 and 2 GHz may be used as coverage bands by the mobile operators. The coverage bands offer wider bandwidths than coverage bands making them possible for mobile broadband services. The cell sizes of the capacity bands are smaller than those of coverage bands making it easy to build high capacity network areas, but uneconomic to build nation-wide coverage. As the capacity bands are not expected to be deployed with full coverage, spectrum sharing with other spectrum users becomes feasible.

The mid-band of the capacity bands is limited to 6 GHz in the high end. The first pioneer capacity mid-band is 3.5 GHz. It will be extended to cover 3.4–4.2 GHz. Also the LSA band 2.3 GHz will be used for 5G and 6 GHz is being harmonized for unlicensed use. The countries which are able to clear the band before assigning them to 5G can assign nation-wide licenses or in some cases a part of the spectrum is dedicated to private LTE/5G networks. Most countries will not be able to clear all mid-capacity bands and different spectrum sharing methods will be used depending on the characteristics of the incumbent spectrum user. For static incumbents, static sharing using license terms is the prevailing method and for the dynamic incumbents, dynamic spectrum sharing is required.

3.3 Above 6 GHz: 26 GHz and Above

The high-frequency capacity bands are above 6 GHz. Although, the band naming begins on 6 GHz, the pioneer band is 26 GHz, and it will be followed by even higher frequencies. They are often called millimeter waves. The bandwidths are very wide compared to any other communication system allowing gigabit/second-level wireless bitrates. The connectivity between the base station and user equipment requires a line of sight, the cell sizes are very small and the beams can be very directive. The millimeter wave bands are very suitable for spectrum sharing. Italy is the first European country, which included club use-type of spectrum sharing as a part of the 26 GHz auction rules.

3.4 Spectrum Allocation Options

The considered allocation options are exclusively licensed spectrum, nation-wide long-term licenses, local and temporary licenses, and shared spectrum. Following the 5G Spectrum Position Paper [3] of GSMA, the primary spectrum management approach for 5G remains exclusively licensed spectrum. Practically, all mobile network bands are currently on exclusively licensed bands. Spectrum sharing and unlicensed bands complement that. An option for assigning spectrum for industrial users are local licenses for private LTE/5G networks.

Furthermore, GSMA Public Policy Position [4] about Spectrum Sharing from November 2018 states that the commonly discussed spectrum sharing frameworks include Citizens Broadband Radio Service (CBRS), Licensed Shared Access (LSA), and Concurrent Shared Access (club licensing). CBRS has been developed for the band 3550–3700 MHz in the US. It is based on the Federal Communications Commission (FCC) regulation Part 96 [5]. LSA has been specified by ETSI [6] and CEPT [7], and it has been decided to be used in the 2300–2400 MHz band by the European Commission [8]. Concurrent access is defined in the GSMA Public Position Paper as club-use, meaning that the band is divided to the license holders. The license holders have the national priority for their own part of the band, but if they do not deploy the network in a part of the country, the other license holders have a right to use it on secondary basis.

Unlicensed spectrum is the most difficult one for sharing with incumbents. A part of 5 GHz unlicensed band is shared with radars and all devices using the shared part of the spectrum have to support Dynamic Frequency Selection (DFS). The spectrum users have felt the DFS use cumbersome and the channels requiring DFS are very little used. The next significant unlicensed band allocation will be 6 GHz and it will require fixed link and satellite ground station incumbent protection in a few countries as well. FCC has proposed a central interference protection system called Automated Frequency Coordination (AFC) for that band.

3.5 Operator Types

Mobile network operators (MNOs) are the entities operating mobile networks that are used to transmit audio and mobile broadband services. They traditionally use exclusive spectrum licenses. The typical mobile network transmissions are low tower low power (LTLP), as the transmitter heights are typically below 50 m.

Broadcasters are the entities which operate broadcast networks that are used to deliver audiovisual TV content over digital terrestrial television (DTT) networks, traditionally using exclusive spectrum licenses. The existing infrastructure used to broadcast DTT transmissions is characterized by very tall towers and high transmission powers. Transmissions of this type are known as high tower high power (HTHP). The height of HTHPs is typically around 300 m and the transmitter coverage around 100 km.

Other types of operators could include for example virtual network operators and local private network operators. The number of private LTE/5G networks is growing significantly at the moment as the regulators begin to assign radio licenses also to local networks on LTE and 5G bands.

4 Analysis and Results

This section analysis the mapping of different use cases with the selected spectrum assignment options. The different mappings are: use case to spectrum band, spectrum band to allocation option, use case to allocation option, and all these are brought together in mapping use case – spectrum band – allocation option – operator.

4.1 Mapping Use Cases to Spectrum Bands

The linear TV services have been offered on UHF terrestrial TV band on 470–862 MHz for tens of years and it not surprise that the same frequency band is recommended also in this study. M&E1 shares the same basic characteristics as linear TV and due to that the mapping of linear TV and M&E1 are generally the same. Virtual and augmented reality require very high bitrate and due to that they fit best to the highest capacity bands. Remote live production benefits from high uplink capacity. On the other hand, live production in a remote location needs coverage. The coverage is best achieved on the coverage bands and utilization of the current primary PMSE camera link band, 2.3 GHz for shorter communication distances, could be a practical combination. Public warning should reach as many people as possible, so coverage bands are preferred. The media services require more capacity than the coverage bands can offer, so the mid capacity bands could be used for providing them. The use case spectrum band mapping can be found in Table 1.

Table 1. Use case to spectrum band mapping

MHz	Linear TV	M&E1	M&E2	M&E3	PW1	Auto1
470–694	X	X				
700	X	X		X	X	
2300				X		
3400–3800			X			X
3800–4200			X			
6000			X			X
26000			X			

4.2 Mapping Spectrum Bands to Allocation Options

The combinations of allocation options and spectrum bands are not directly related to the requirements of the use cases, but in practice spectrum bands and the allocation options are tied together. Nation-wide licenses require clearing the band and should be possible on coverage bands and at least in a few countries in the 3.5 and 3.7 GHz bands. Local licenses for private LTE/5G networks have been allocated in the mid-capacity bands and they will most like be allocated on millimeter waves, as well. At the moment we do not expect CBRS to be deployed in Europe in near or medium term. The dynamic spectrum access option for Europe is LSA and dynamic incumbents can be found in the mid-capacity bands. The concurrent shared access as club licensing has been proposed for 26 GHz. The next unlicensed band for broadband communication is expected to be 6 GHz, see Table 2.

Table 2. Allocation option to spectrum band mapping

MHz	Nation- wide	Local, temporary	CBRS	LSA	Concurrent	Unlicensed
470–694	X					
700	X					
2300		X		X		
3400–3800	X	X		X		
3800–4200		X		X		
6000						X
26000		X			X	

4.3 Mapping Use Cases to Allocation Options

All use cases can be used with nation-wide exclusive licenses, which are the primary spectrum allocation option for 5G and other mobile networks. The main question here is which services could also be operated using the other allocation options. Linear TV, hybrid broadcasting and public warning need nation-wide coverage and do not tolerate any service breaks; the nation-wide exclusive licenses are the only recommended option for them. Virtual reality services will be offered largely also in Wi-Fi networks, which only provide opportunistic access. The M&E2 services could be provided with any allocation option which can offer high bitrates. The remote video production requires more guarantees for service coverage and capacity than unlicensed bands can offer. Local, temporary licenses, and LSA could complement well the exclusive licensing. Video services for automotives could also use any capacity available. Concurrent use was left out, because it is expected to be used mainly on 26 GHz, which has too small cells to provide media services to moving vehicles. The results of use case to allocation option analysis are collected in Table 3.

Table 3. Use case to allocation option mapping

MHz	Linear TV	M&E1	M&E2	M&E3	PW1	Auto1
Nation-wide	X	X	X	X	X	X
Local, temp			X	X		X
CBRS						
LSA			X	X		X
Concurrent			X			
Unlicensed			X			X

4.4 Mapping Use Cases, Spectrum Bands, Allocation Options and Operators

Table 4 combines the results of the mappings in the previous tables. Linear TV and hybrid broadcasting fit best to the similar spectrum use as the TV services have been using for decades. The coverage bands below 1 GHz, nation-wide exclusive licenses having either broadcaster or MNO as the operator would work best considering also that societies have been using them for TV broadcasting. The virtual and augmented reality services require very high bitrates, which can only be provided on the highest capacity bands beginning from around 3 GHz. All spectrum allocation options are feasible. The operator for the services is most likely MNO, but other local operators can provide them in private LTE/5G networks, as well. Remote video production has two sides: one is remoteness and the other is bandwidth requirements of video. Remote can easily be translated to coverage band, i.e. 700 MHz and video production to 2.3 GHz which is used for that purpose by broadcasters and production companies. Any allocation method providing even a little bit higher availability than unlicensed should be considered. The spectrum license holder can be MNO, broadcaster or a private LTE/5G license holder. Public warning system requires highest coverage and availability limiting the choices to nation-wide exclusive licenses on 700 MHz and provided by MNO or broadcaster. Media services to vehicles could be provided in the 3.5 GHz or 6 GHz bands using any other allocation method but concurrent, which is expected here to be available only on 26 GHz. The media services to cars could be provided by broadcaster, MNO and other companies dedicated to roadside communications.

Table 4. Use case – spectrum band – allocation option – operator

	Linear TV	M&E1	M&E2	M&E3	PW1	Auto1
Band	<1 GHz	<1 GHz	>3 GHz	700, 2300 MHz	700 MHz	3.5, 6 GHz
Allocation	Nationwide	Nationwide	All	Nationwide, local, LSA	Nationwide	All, but concurrent
Operator	Broadcaster, MNO	MNO	MNO, other	MNO, Broadcaster, other	Broadcaster, MNO	Broadcaster, MNO, Other
Notes						

5 Conclusion

PTM transmissions (broadcast/multicast) could present a more efficient delivery mechanism in many scenarios when compared to PTP transmission schemes (unicast). 5G-Xcast project develops an architecture for PTM in 5G and has identified different use cases, or use case families, which cover the scenarios where the highest benefits of 5G PTM could potentially be achieved. The use cases belong to the following 5G vertical sectors: Media & Entertainment, Public Warning, Automotive and Internet of Things. Different 5G use cases and applications differ greatly in terms of coverage, bit rate and quality of service they require. Thus, the combination of spectrum bands and spectrum quality they need is different in each use case.

This paper has analysed spectrum allocation options in different frequency bands for the six different PTM use cases. The use cases have been analysed against the spectrum bands they could use, then the spectrum bands have been analysed against the different allocation options (ranging from exclusive licensing to spectrum sharing and unlicensed spectrum), and the use cases were analysed against the allocation options. Finally, all of these were brought together in use case - spectrum band - allocation option - operator mapping.

The analyses of this paper provide valuable information on what needs to be considered when choosing a combination of frequency band and allocation option for a service or use case. Though this paper considers only PTM use cases, the same methodologies can also be applied to PTP use cases.

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