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Audio-visual capabilities and applications supported by terrestrial IMT systems

M Series

Mobile, radiodetermination, amateur and related satellite services

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REPORT ITU-R M.2373-0

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(2015)

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1 Introduction

This Report examines the capabilities of IMT systems to deliver audio-visual services, especially, given the increasing desire by users to consume such content at any time, in any place with their preferred device. It examines those user requirements as well as some of the requirements from the audio-visual content providers. It examines the use cases where IMT offers advantages over other audio-visual delivery systems, and evaluates the capabilities of the system in meeting those requirements. It also contains a discussion of desirable future enhancements to facilitate provision of audio-visual services over IMT.

The Annexes contain a detailed description of the features of IMT enhanced Multimedia Broadcast Multicast Services (eMBMS) that enable transport of content to multiple users.

2 Background and motivation

IMT has become an indispensable part of the daily life of consumers in many countries all over the world, and has become a common access platform for different services and applications. There is a growing demand by consumers for new services and applications in particular, for audio-visual content. Future developments of IMT are expected to enable service providers to satisfy many of these growing demands by providing audio-visual services over IMT. Today, audio-visual services over IMT (for both linear and on-demand audio-visual content) represent a small percentage of total audio-visual content consumption; however, it is expected that audio-visual over IMT will increase in the future and that it will be the major traffic contributor in IMT networks.

Mobile broadband users are demanding spontaneous access to audio-visual content and a higher-quality experience than ever before. Subscribers like to be able to consume content on multiple screens anytime, anywhere. As a result, new business models are emerging in which the line between fixed and mobile is becoming indistinct. Service providers – especially over-the-top (OTT) players and content aggregators are making premium content available anytime, anywhere on a variety of devices. Mobile network operators (MNOs) are being challenged by the need to give consumers what they want, while preserving the economics of their networks and creating new opportunities for revenue growth.

Through deployment of eMBMS in IMT networks, MNOs can manage network assets better by allowing multicast for popular content demanded by multiple subscribers, such as live TV and events. MNOs can also utilize off-peak capacity to deliver new service offerings, such as rich media caching or managed software updates. Lastly, broadcast capabilities enable MNOs to improve the quality of service (QoS) while managing the costs of delivering audio-visual content. Audio-visual over IMT already contributes to national economies and social development by enabling a range of applications, such as social media, distance learning, health and entertainment. Other applications that benefit from unicast and multicast capabilities of IMT include e.g. early warning, disaster mitigation and relief operations, public safety alerts, amber alerts[1] and automatic upgrades of application software and operating system (for example, downloaded outside peak hours).

Audio-visual over IMT could further contribute to the reduction of the digital divide between urban areas and rural areas or certain underserved communities. Socio-economic demands are already driving requirements for access to audio-visual services and applications, for users to experience

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[1] Amber alert is a warning system that quickly alerts the public about abducted children, who are in imminent danger.[2] "The DigiWorld yearbook 2014 from IDATE indicates that linear TV still represents 90% of the world audio-visual services market, which has grown 4.2% from the previous year; while OTT (Over The Top) represents 4.4% of the market, growing 37% in 2013."

similar quality of experience (QoE), including coverage and data rates in rural areas and urban areas. Therefore, there is already a need to provide cost-efficient coverage and capacity in rural areas, especially in developing countries.

Audio-visual over IMT, in conjunction with availability of traditional broadcasting systems (cable, satellite or terrestrial delivery) or other broadband services (fixed internet access or Wi-Fi), is essential to satisfy consumer demand for audio-visual content. It is important to take advantage of the benefits of IMT (personalized service, portability, easy to use, ability to consume content anytime anywhere) in order to enhance the access to audio-visual services and applications.

3 Related documents

1 Recommendation ITU-R M.1079-2 − Performance and quality of service requirements for International Mobile Telecommunications-2000 (IMT-2000) access networks (2003).

2 Recommendation ITU-R M.1822 − Framework for services supported by IMT (2007).

3 CITEL Technical Notebook “Cooperation and convergence between broadcasting and mobile services using LTE networks” Available: https://www.citel.oas.org/en/SiteAssets/About-Citel/Publications/Technical_Notebook/P2!R-3339p1_i.pdf.

4 EBU Technical Report TR 027 “Delivery of broadcast content over LTE networks”, July 2014. Available: https://tech.ebu.ch/docs/techreports/tr027.pdf.

5 EBU Technical Report TR 026 “Assessment of Available Options for the Distribution of Broadcast Services”, June 2014. Available: https://tech.ebu.ch/docs/techreports/tr026.pdf.

6 ECC Report 224 “Long Term Vision for the UHF broadcasting band” November 2014. http://www.erodocdb.dk/doks/doccategoryECC.aspx?doccatid=4

4 Glossary of terms

In this Report following terms are used with the following meanings:

Audio-visual content

Audio-visual content is data which represents moving pictures (or a series of still pictures), normally accompanied by related sound. Sometimes, the content can be just audio.

Linear audio-visual service

A linear audio-visual service refers to the “traditional” way of offering radio or TV services. Listeners and viewers “tune in” to the content organized as a scheduled sequence that may consist of e.g. news, shows, drama or movies on TV or various types of audio content on radio. These sequences of programs are set up by content providers and cannot be changed by a listener or a viewer.

Linear services are not confined to a particular distribution technology. For example, a live stream on the Internet is to be considered as a linear service as well.

On-demand audio-visual service

A communication service providing any type of audio-visual content, which gives users the freedom to choose when to consume the content. The user can select individual pieces of content and can control the timing and sequence of the consumption.

Examples of popular on-demand services are TV catch up and time-shifting. Other forms of on-demand services include downloading content to local storage for future consumption or access to audio-visual content for immediate consumption.

Hybrid service

A hybrid service consists of both linear and on-demand elements. They complement each other in the sense of enriching the linear offering but also in order to inter-relate both types of services. This requires a certain level of integration when producing the content.

Examples include slideshows for digital radio or second screen television.

Audio-visual service use case, use case

A use case is a combination of an audio-visual service (linear, on-demand or hybrid), the user environment in which the service is used, and a user device (see section 6 for more details).

5 User requirements and trends for audio-visual services and applications

Traditionally, audio-visual content has been delivered by broadcast networks. By its nature, this delivery is linear. With the rise of broadband networks (both fixed and mobile), it has become possible for users to request content in an on-demand fashion as well as continuing to consume linear services. In the last few years, on-demand consumption of audio-visual content has grown rapidly[2], although the delivery via IMT networks is still in an early phase, noting that in many mobile networks in year 2014, 40 – 60 % of video traffic was from YouTube[3]. Linear audio-visual consumption remains relatively constant[4] and it appears that part of the growth of online on-demand consumption is arising from a reduction in other on-demand delivery (such as DVDs and CDs). Furthermore, the digitalisation of television broadcasting has substantially increased the number of linear audio-visual services, while releasing spectrum for IMT.

There are significant spikes in audio-visual consumption, due to major sporting events, breaking news, highly watched TV programs and celebrity events, for example, final soccer matches, the Oscars, concerts, royal weddings, and so on. It is expected that usage of audio-visual content over IMT networks will be similar. As IMT networks' coverage and capability increase, it is expected that the amount of audio-visual content delivered to IMT user devices will also increase. A study by Bell Labs estimates that by 2016 video streaming will account for almost two-thirds of all mobile traffic[5]. In the long term, the balance between linear and on-demand distribution is uncertain. There is evidence that younger generations are watching less linear and more on-demand audio-visual content, but also some evidence that as they grow older, these users return towards the more "traditional" linear behavior of older generations. Whether this will remain true for today's teenagers – the first generation to have truly grown up with on-demand content readily available – remains to be seen.

Audio-visual over IMT will also be an important means of getting information to citizens from local and national authorities in times of natural disasters and other emergencies. This function is particularly relevant to the multicasting capability of IMT networks together with the capability of focusing alerts to particular geographical areas.

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[2] "The DigiWorld yearbook 2014 from IDATE indicates that linear TV still represents 90% of the world audio-visual services market, which has grown 4.2% from the previous year; while OTT (Over The Top) represents 4.4% of the market, growing 37% in 2013."

[3] http://www.ericsson.com/mobility-report.

[4] DigiWorld yearbook by IDATE: key indicators of the digital economy, November 2014, http://www.idate.org/en/Forum/DigiWorld-Yearbook_40_.html.

[5] Report ITU-R M.2370-0 – IMT Traffic estimates for the years 2020 to 2030.

5.1 Emerging trends in user behavior

Consumption of audio-visual content on mobile devices such as smartphones and tablets is increasing. It is expected that this trend will continue. There has been an increase in the average amount of time spent by users watching audio-visual content on mobile devices (see Fig. 1).

FIGURE 1

Consumption of audio-visual content by device:
BASE: Base 9 Markets[6] (those who have and use respective device)
Source: Ericsson ConsumerLab TV & Media 2014 Study

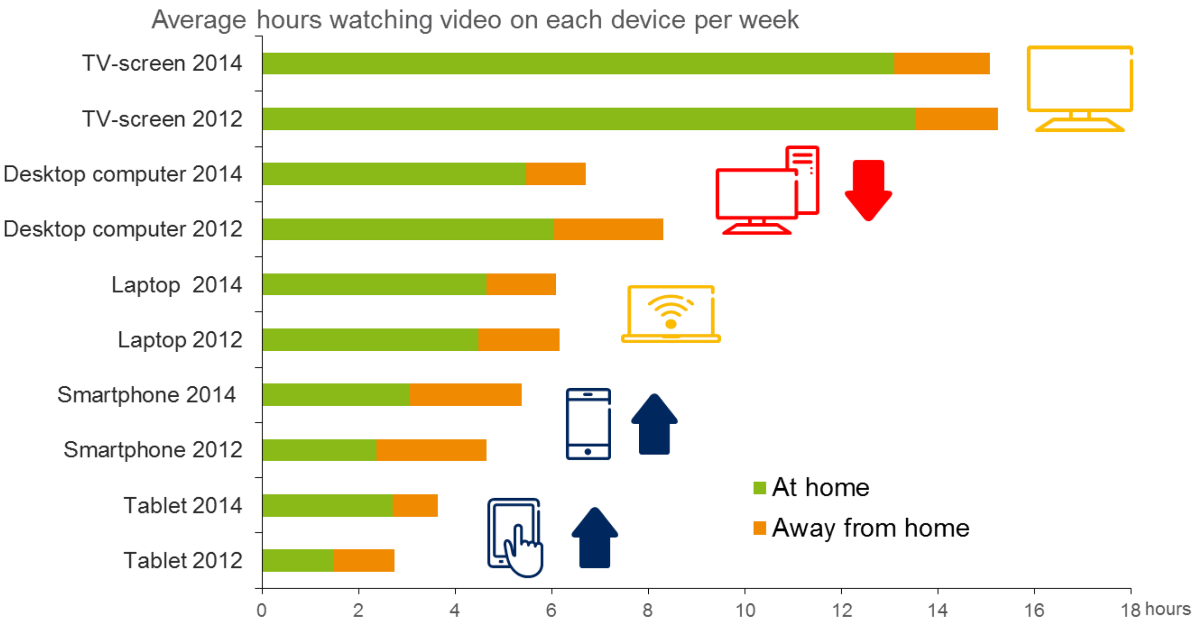

Figure 1 is based on habits and behavior reported by viewers, rather than, for example, on-device measurements. Hence, the data may differ from that found in some countries through traditional broadcast audience measurement (e.g., BARB or Nielsen).

Consumers wishing to consume audio-visual content on a mobile device face different barriers (see Fig. 2), outside the home, which tend to limit their mobile audio-visual usage. These barriers cause many consumers to prioritize other activities (e.g. gaming, browsing) instead of watching video or wait until they are home or have Wi-Fi coverage. The study reveals three categories of barriers, cost technology and user behavior. Once the limiting barriers have been removed or reduced, it is likely that mobile consumption will increase.

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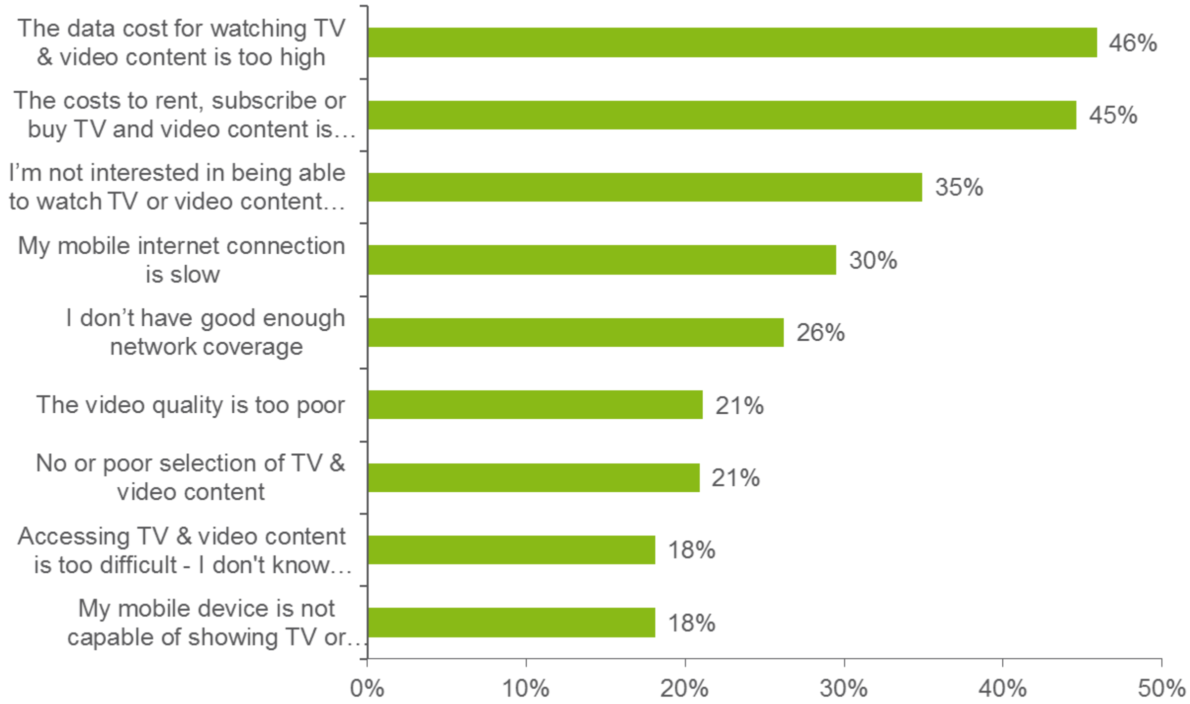
6 Brazil, China, Germany, South Korea, Spain, Sweden, Taiwan (China), UK, US.

FIGURE 2

Mobile barriers: When away from home, to what extent are the following factors limiting your consumption of TV and video content on a mobile device (Showing top 2 alternatives on a 7-graded scale).
BASE: Base 23 Markets[7], Source: Ericsson ConsumerLab TV & Media 2014 Study

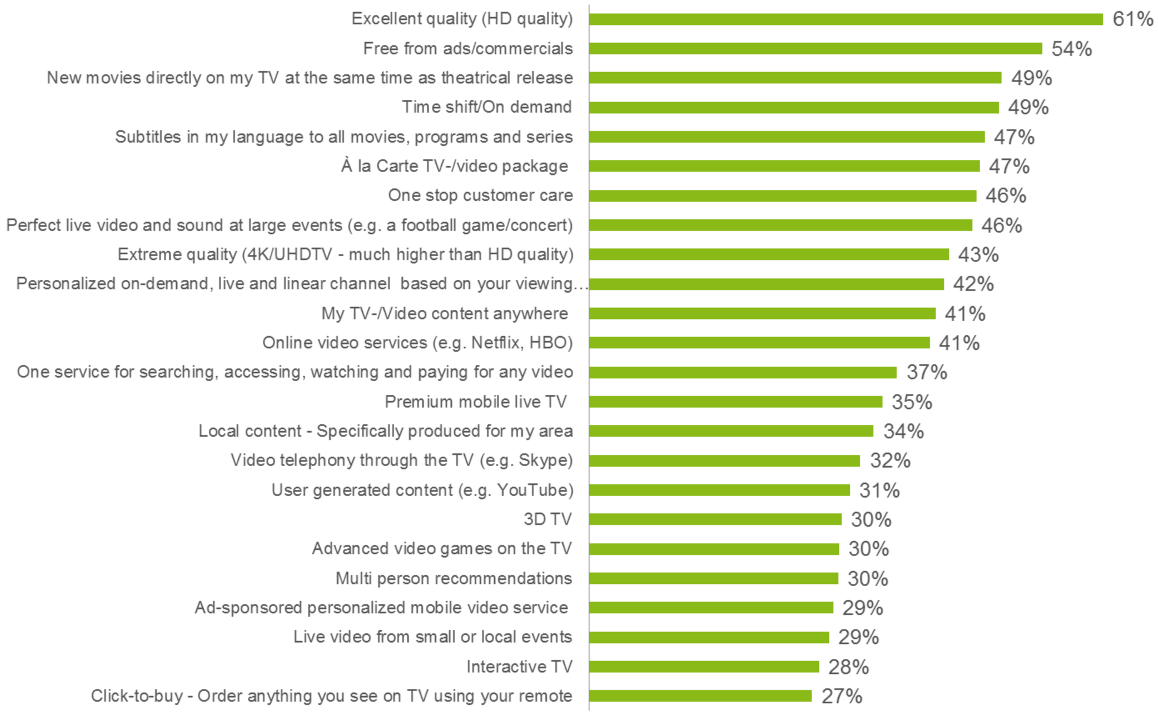


Another trend is that the user expectations of picture quality are constantly increasing (see Fig. 3). This is a natural part of the evolution of audio-visual and is likely to continue as enhancements, such as higher definition, become available.

[7] Brazil, Canada, Chile, China, France, Germany, Greece, Indonesia, Ireland, Italy, Malaysia, Mexico, Portugal, Russia, Singapore, Spain, South Korea, Sweden, Taiwan (China), Turkey, UAE, UK and US.

FIGURE 3

Important TV features: BASE: Base 23[3] Markets (Interest, top 2 answers on 7-graded scale). Source: Ericsson ConsumerLab TV & Media 2014 Study



Consumers are increasingly expecting to be able to access their services and content across all platforms and devices. This will not only extend to linear and on-demand services but include areas such as video communication, remote participation or control, cloud computing for games, safety etc. This will in turn put higher and new requirements on the delivery networks as well as the business models associated with them (roaming, data traffic, QoS).

5.2 Linear vs. on-demand content

Most audio-visual content consumed on mobile devices in 2014 was on-demand[8] content using unicast delivery. There are advantages in delivering linear content using multicast, if the content is simultaneously used by multiple users, because multicast uses the same radio resource for all interested users. On-demand services generally have to be delivered by unicast, unless devices make use of local caching, allowing on-demand use of content from local storage that was delivered by means of multicast. Under normal conditions, where the majority of audio-visual content consumption on IMT networks is on-demand, multicast functionalities, such as eMBMS, are of limited use. However, under certain conditions when sufficiently large groups of users are consuming the same content in a small geographical area, for example, in a sports arena, traffic jams or in a subway, multicast functionalities can be used.

8 http://www.ericsson.com/mobility-report.

5.3 Summary of user requirements

Audio-visual over IMT should be able to support the following services and applications:

- Rapid, flexible and straightforward on-demand delivery of relevant content.
- Downloading of content for later access and use.
- Easy access to services essential for use in remote-areas e.g., tele-medicine, emergency services, disaster recovery, etc.
- Easy access to services for remote learning, also using one-to-many coaching and teaching and group presentation scenarios.
- Delivery of on-demand content; e.g. premium, free-of-charge or metadata to enhance user experience of live events such as sports events, music concerts, theatre events, carnivals etc.
- Audio-visual services configured to ensure a high-quality viewing experience.
- Support for high definition (HD) audio-visual content as well as for higher resolution content in the future.
- Sponsored data and promotional messages.
- Allowing for bundling with other audio-visual and information sources.

6 Identification of relevant use cases for audio-visual distribution over IMT

Given the many ways in which audio-visual content can be consumed, some way of categorizing them can be helpful when assessing each of them. It is likely that many of the possible ways will not occur in real life and can be neglected. Others may be highly relevant and will require more detailed assessment.

In this section, different consumption patterns ("Use cases") are identified as combinations of three independent factors:

- audio-visual service type;
- user environment; and
- user device.

The first of these is defined in Section 4. User environment and user device are explained below.

A use case is a unique combination of all three factors, for example on-demand service / Static user environment / Tablet user device. Many of these combinations are not likely to be relevant; others are of relevance for further study. Table 2 shows those use cases considered most relevant, along with a brief analysis of each.

User environments

Two different user environments are considered:

- *Static* – In this user environment, the user is within (or moving within) a private location that they use very regularly, for example the home, an indoor work environment (office, workshop, etc.), or is an audio-visual display in a public location, and the user/owner has a high degree of control over the means of access to audio-visual services.
- *Dynamic* – In this user environment, the user is either nomadic or mobile in a location that they use occasionally, for example an airport, a train station or a shopping mall, or is travelling (in cars, trains, etc.), where they have limited control over the means of access to audio-visual services.

User devices

The following user devices are considered to be currently representative with regard to access to audio-visual services. It is assumed that all these devices could be connected via IMT networks, possibly in addition to other connections (e.g. fixed/wired connections). Other device types might emerge in future, and would need to be considered in future assessments.

TABLE 1

User device
Stationary TV set/video screen
Portable TV set
TV receiver/screen in a vehicle
Home audio system ('Hi-Fi')
Portable ('kitchen') radio
Radio receiver in a vehicle
Small ('pocket') radio
Desktop computer
Portable ('laptop') computer
Smartphone
Tablet

After elimination of non-relevant use cases, 19 use cases remain, as shown in Table 2.

TABLE 2

Relevant use cases

AV service type	User environment	User device	Remark
Linear	Static	Stationary TV set/video screen	This use case includes other situations where linear TV is delivered to stationary TV sets, such as public indoor spaces, outdoor public viewing, etc.
	Static	Portable TV set	Portable TV sets are often used as second sets in domestic settings (e.g. in kitchens and bedrooms).
	Static	Desktop computer	Many early online video distribution systems targeted desktop computers as the main device in the home with an IP connection.
	Static	Portable ('laptop') computer	Less convenient than smartphones and tablets, though often with larger screens In the home, laptops are often not the first choice devices for linear TV

AV service type	User environment	User device	Remark
	Static	Smartphone	Increasingly important device in the future due to its easy usability, ready availability and that the majority of users carry them all the time High relevance because e.g. in the home smartphones can be connected to a large screen.
	Static	Tablet	This is an increasingly important device due to its capabilities, easy usability and size of screen
	Dynamic	TV receiver/screen in a vehicle	Increasingly common means of video consumption
	Dynamic	Smartphone	Primarily for short programs such as news
	Dynamic	Tablet	This is an increasingly important device due to its capabilities, easy usability and size of screen
On-demand	Static	Stationary TV set/video screen	This use case could be highly relevant This use case includes other situations where on-demand TV is delivered to stationary TV sets via apps and widgets, and for uses such as public indoor information and advertising screens In the home smartphones can be connected to a large screen system
	Static	Portable TV set	This could become highly relevant as portable TV sets gain IP connectivity
	Static	Desktop computer	High relevance because of a growing market for on-demand TV services via personal computers.
	Static	Portable ('laptop') computer	High relevance because of a growing market for on-demand TV services via personal computers.
	Static	Smartphone	Increasingly important device in the future due to its easy usability, ready availability and majority of users carry them all the time
	Static	Tablet	This is an increasingly important device due to its capabilities, easy usability and size of screen
	Dynamic	TV receiver/screen in a vehicle	Likely to become increasingly relevant as on-demand services become more easily accessible
	Dynamic	Portable ('laptop') computer	Nomadic access to on-demand content is increasingly prevalent.
	Dynamic	Smartphone	Widely used for short video clips (e.g. news or YouTube)
	Dynamic	Tablet	Likely to become increasingly relevant as on-demand services become more easily accessible. Already commonly used for “pre-downloaded” content

When evaluating various use cases involving IMT, the following observations regarding general trends in audio-visual services and the associated user behavior should be borne in mind:

– Linear viewing is currently the preferred way of watching audio-visual content and it is expected that this will not change in the near future. On-demand viewing will continue to grow.

– The majority of audio-visual consumption, both linear and on-demand, currently occurs in the home. It is expected that this will not significantly change despite the increased usage of portable and mobile devices, nor with the growing adoption of innovative media services. Nevertheless, usage in dynamic user environments will increase.

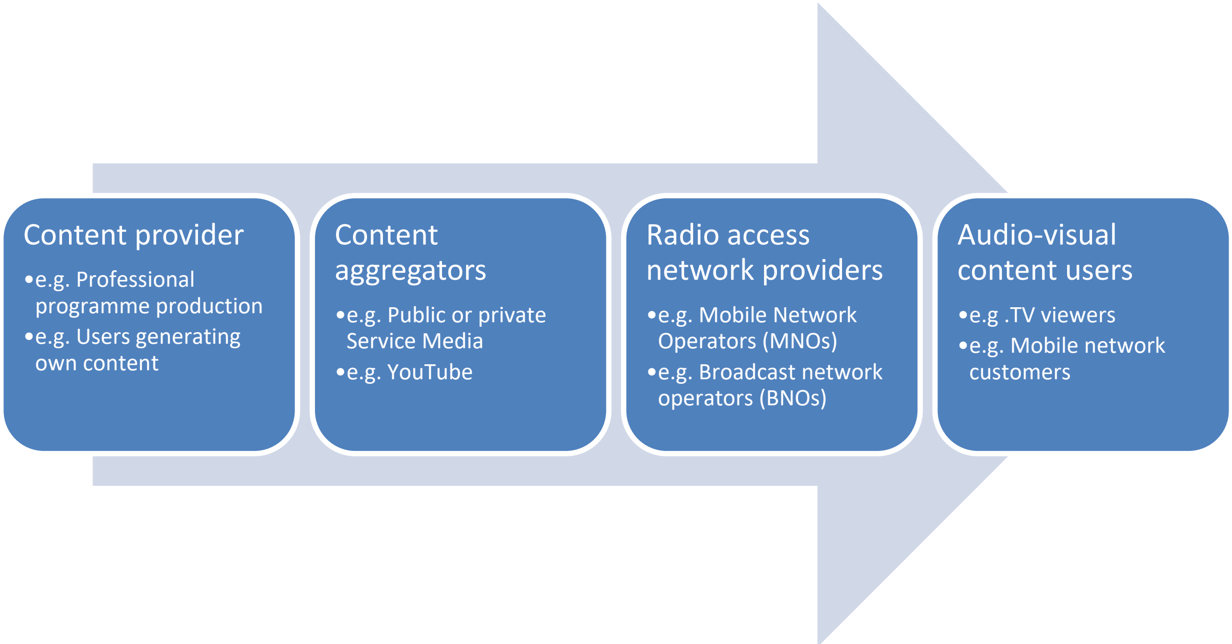
– Hybrid broadcast-broadband services (e.g. tweeting while watching TV) are becoming commonplace based on broadcast platforms and fixed broadband infrastructures. In the future, hybrid services may also make use of wireless broadband.

7 Requirements for Audio-visual content provision

The provision of audio-visual content to users can be characterised by a chain of providers: firstly, content producers, then content aggregators, followed by the IMT service providers, and finally the users of audiovisual content.

FIGURE 4

Audio-visual Content Value Chain



In section 7.1, some consideration is given to the operations of the radio access network providers, and this highlights some of the likely requirements of the interface between content aggregators and access providers.

In this Report, the needs of the content providers and aggregators are considered together, in section 7.2.

7.1 Audio-visual radio access network providers' requirements

For IMT service providers, audio-visual content delivery solutions need to be arranged in such a way that they enable radio access network providers to deliver multi-format and multi-screen services to users in a range of different circumstances, e.g. from stationary large screens to smartphones in high speed vehicles, as well as using agreed automated or pre-set content management procedures, allowing for efficient operations. Audio-visual content service solutions need to support standardized content formats as well as standardized interfaces between the content provider/aggregator and the radio access network provider.

Payload (involving e.g. coding, quality, resolution, frame rate, etc.) and content management procedures between content provider/ aggregator and the radio access network provider need to be efficient (including energy efficiency) and support technical evolutions.

7.2 Assessment of current IMT systems' ability to meet PSM general distribution requirements

Public service media (PSM) have certain general requirements which are considered relevant when specifying distribution options. These are shown in Table 3. For each of the general requirements listed in Table 3, an assessment is provided of how it can or may be met by IMT-based systems on the basis of its technical characteristics as of today.

TABLE 3

Assessment of IMT ability to meet general distribution requirements

	General requirements	Assessment
1	Possibility for free-to-air or equivalent, with no additional costs for the viewers and listeners	Unencrypted content delivered via eMBMS can be received without a SIM card whereas in case it is delivered via LTE unicast a SIM card is required. The SIM card may be specifically configured by the provider to enable access only to the TV service and can also be provided for free. The associated regulatory, operational and business aspects need to be addressed.
2	Ability to deliver services of PSM to the public without blocking or filtering the service offer, i.e. no gate keeping.	Feasible subject to commercial agreements.
3	Content and service integrity - no modification of content or service by third parties, e.g. TV content must be displayed on screen unaltered and without unauthorised overlays.	Technically feasible
4	Quality of service requirements to be defined by the content provider, such as: – QoS when the network is up and running – Availability of network: robustness, up-time, reliability	Feasible, subject to commercial agreement
5	Quality of service for each user shall be independent of the size of the audience	For unicast, subject to network capacity, as concurrent users share the available network capacity. Feasible for eMBMS.
6	Geographical extent of the service area (e.g. national, regional, local) is to be defined by the content provider.	Feasible, although the current specification of eMBMS constrains the area of the individual eMBMS single frequency network (SFN)
7	Distribution option, audio-visual over IMT needs to be viable on the market and capable of supporting at least a minimum service offer (e.g. a minimum number of programs) defined by the content provider.	Feasible
8	Ease of use - straightforward accessibility of content offer	User device dependent
9	Low barrier for access to broadcasters' content and services for people with disabilities	User device dependent
10	Ability to reach audience in emergency situations	Technically feasible Mobile networks can suffer congestion at peak times, for example, in an emergency situation. At such times, reserving a minimum capacity for certain audio-visual content may be desired.

Any distribution option needs to comply with these principles in order to be suitable for PSM. Given the current capabilities of IMT, these requirements can be technically met by mobile networks. In practice, some of these requirements are not met in current network deployments and devices. Nevertheless, mobile networks are already used to deliver PSM content in a manner complementary to broadcast networks. Once mobile networks and devices have evolved to meet these PSM requirements, they could become an important pillar in the distribution strategy of PSMs.

7.3 Specific requirements

Some performance and quality of service requirements are given in Recommendations ITU-R M.1079-2 (2003) for IMT-2000 and ITU-R M.1822-0 (2007) for IMT. In addition to these general requirements, there are some specific requirements for audio-visual over IMT depending on the use case, which need to be considered, including data rate, bit error ratio, end-to-end delay (latency) and concurrent audience size. The ability to fulfill these specific requirements does not only depend on different delivery mechanism being used, but also on the specific network deployments under consideration.

When considering the network requirements to deliver the relevant use cases, the following need to be considered:

– Neither a broadcast network (terrestrial, satellite or cable) nor a mobile broadband network on their own will be able to offer hybrid TV to large audiences, but a combination of a broadcast network and a mobile broadband network will be able to offer such services. Adding eMBMS to IMT networks implementations would allow both functionalities.

– The delivery of on-demand audio-visual services to TV sets requires an internet or cable-TV connection. Currently available TV sets are equipped with tuners for terrestrial, satellite and cable reception or are attached to a set top box. Newer ("smart") TV sets are capable of connecting to the internet or are attached to a separate device for this, e.g. a game console.
    – TV sets in vehicles are often equipped with a tuner for terrestrial reception and may also be connected via mobile broadband.
    – Radio-only receivers in a vehicle are generally equipped only with a terrestrial tuner. It is rare for them to be also connected to mobile broadband.

8 Key characteristics of terrestrial IMT that enable audio-visual services and applications

The rapid adoption of smartphones and tablet devices with built-in support for high quality audio-visual capability has enabled mobile access to multimedia services including high quality mobile audio-visual recording and uploading.

8.1 Unicast

Audio-visual over IMT is provided by packet-switched streaming (PSS) resources typically dedicated to individual consumers, applying the unicast access scheme.

Capacity issues of IMT can be solved by smaller cells in bands up to few GHz complemented by Wi-Fi capacity in license-exempted bands (best effort basis). Consumption of audio-visual content results primarily in traffic on the downlink (DL), i.e. towards the end user. Hence, an asymmetry of up to 1:10 can be observed in data demand between uplink (UL) and DL[9] . Symmetric frequency division duplex (FDD) assignments typically yield UL:DL ratios of 1:2 due to higher transmit power and more

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[9] Draft ITU-R IMT.BEYOND2020.TRAFFIC.

transmit antennas in DL direction. This can be increased by supplemental downlink (SDL) that provides additional RF bandwidth exclusively in DL direction to better match the asymmetric traffic demand. SDL is already implemented in IMT.

8.2 Multicast

In the case of audio-visual content, like linear TV, delivered by IMT, there will be situations when many users want to watch the same content at the same time. Examples are live events of high interest like breaking news, sport events, live shows, etc.

For these cases, multicast, known from the fixed internet, is clearly an appropriate access scheme to be applied. eMBMS is a point-to-multipoint interface specification for LTE networks, which provides delivery of broadcast and multicast services, both within a cell as well as within the core network. For broadcast transmission across multiple cells, it defines transmission via single frequency network configurations. A detailed technical description of the LTE eMBMS features that are relevant for the distribution of multicast services is provided in Annex 2.

eMBMS sessions can be set up dynamically, sharing the resources with unicast sessions in existing IMT spectrum. Different types of audio-visual services could be provided through the implementation of eMBMS, such as: OTT, broadcasting and pay TV. When providing each type of audio-visual service, further consideration should be given to their specific requirements.

8.2.1 Benefits of eMBMS

Some of the benefits of eMBMS can be summarized as:

– eMBMS chipsets are already available. No hardware changes are required to the subscriber device hardware that implements an eMBMS-compatible chipset.

– A common eMBMS service layer middleware can be utilized across all devices to simplify broadcast application development, provide consistent user experiences, and minimize interoperability testing with LTE infrastructure.

– No hardware changes required to the LTE RAN – while eMBMS does require an additional server in the evolved packet core (EPC) and a new software load on the eNB, no hardware changes are required to the LTE eNBs. This minimizes deployment costs.

– Since new subscriber devices and specific content formats are not required, eMBMS could be deployed and be available to the entire LTE subscriber base.

8.3 What SDL can do for audio-visual services

SDL capacity can be used for different purposes. Besides MBB use for individual content (unicast), it can also be used to configure broadcast channels with eMBMS. As discussed in [9], the rise of audio-visual content distributed by IMT will make traffic even more dominated by the downlink. SDL allows this asymmetry to be directly addressed and there would be no need to devote paired spectrum to the uplink.

9 Desirable future enhancements to facilitate provision of audio-visual services over IMT

Some enhancements of eMBMS could facilitate audio-visual over IMT in the case that eMBMS is considered to replace or complement current DTTB:

– To support larger inter-site distances supporting larger multimedia broadcast and multicast single frequency network (MBSFN) areas, e.g. by specifying longer cyclic prefix. In order to maintain the same capacity with an unchanged carrier bandwidth, the number of subcarriers could be increased. This would enable higher spectral efficiency, in particular for roof-top targeted reception and for HPHT transmitters.

– Dedicated carriers that can be allocated 100% to eMBMS transmissions - today max 60% of capacity can be used for eMBMS.
– Standalone carriers, which can be defined as a dedicated carrier that provides all necessary signaling, so no cross-carrier signaling is required: A dedicated multicast carrier may not transmit the signaling that is required by a device, e.g. for carrier detection and synchronization, therefore a device may have to rely on signaling from another carrier to be able to use the dedicated carrier. In contrast, a standalone carrier may be a dedicated multicast carrier providing all necessary signaling.
– Providing linear, on-demand or hybrid services without identification of the end user. E.g. Ability to provide "free to air" services without subscription (SIM-card). Service description (e.g. a service guide) delivery may also be addressed.
– Possible enhancements to synchronisation issues with regard to multi-operator scenarios. The goal would be to support broadcast carriers that are accessible by devices while they can simultaneously use mobile broadband services from the subscribed IMT network (or a roaming partner thereof). The broadcast carriers may be provided by a separate network.
– For specific use cases, further optimizations may be possible, e.g. to cope with the differences in transmissions for fixed or for mobile reception. IMT is currently designed for mobile reception up to 350 km/h at frequencies of up to 3 GHz, resulting in very high Doppler frequency. This implies a relatively high overhead for tracking the rapidly varying channel (channel estimation). For (quasi-) stationary reception and in UHF spectrum, Doppler is smaller than 1% of the IMT design target, enabling a reduction of the channel tracking reference symbols density. Such reduction in overhead leads to higher payload capacity.
– Improve the spectrum efficiency e.g. with MIMO, which improves throughput of the network.
– Advanced interference suppression techniques: Interference from certain directions may be suppressed by appropriate weighted combining of signals received by the multiple antennas in an IMT device. Furthermore, intersymbol and intercarrier interference due to signals arriving with relative propagation delays exceeding the cyclic prefix can be suppressed to some extent by signal processing in the device.
– Improve the ability to reach audiences in emergency situations: Today this type of functionality is covered in 3GPP 36.300 section 23.3, which supports public warning system operating using eMBMS and/or cell broadcasting

10 Conclusions

IMT systems have the potential to provide high-quality audio-visual services to users. With the rise of broadband networks (both fixed and mobile) and the availability of more audio-visual content (e.g. from PSM providers), on-demand consumption has grown rapidly in past few years. Especially, younger generations are watching less linear and more on-demand audio-visual content. As IMT networks' coverage and capability increase, it is expected that the amount of audio-visual content delivered to IMT users will also increase.

Provision of linear services will be enhanced by continued development of eMBMS as described in section 9 of this Report. In general, eMBMS is suitable for the provision of linear services but this report describes some areas that need to be improved in IMT networks in the case that eMBMS is considered to replace or complement the DTTB networks.

On-demand services are typically unicast with the exception of some specific cases like sport events or traffic jams, which may benefit from the use of eMBMS. For unicast, the capacity available to IMT users in an area depends on the total radio resource available in that area. On-demand usage can also be satisfied by the use of other radio access technologies (such as Wi-Fi) or fixed broadband connections.

Annexes:

Annex 1: List of acronyms

Annex 2: Detailed description of LTE features

Annex 3: Demonstration trials of audio-visual over IMT

Annex 1

List of acronyms

AAC	Automatic congestion control
AL-FEC	Application layer froward error correction
AMR	Adaptive multi-rate
BLER	Block error ratio
BM-SC	Broadcast-multicast service center
CP	Cyclic prefix
CRC	Cyclic redundancy check
DASH	Dynamic adaptive streaming over http
DL	Downlink
DL-SCH	Downlink synchronization channel
DRM	Digital rights management
DTT	Digital terrestrial tv
DTTB	Digital terrestrial television broadcasting
DVB-T	Digital video broadcasting - terrestrial
eMBMS	Enhanced multimedia broadcast and multicast service
eNB	E-UTRAN Node B, evolved Node B, ‘LTE base station’
EPC	Evolved packet core
EPG	Electronic program guide
E-UTRA	Evolved universal terrestrial radio access network
FDD	Frequency division duplex
FEC	Forward error correction
FFT	Fast Fourier transformation
FLUTE	Protocol for the unidirectional delivery of files over the internet, which is particularly suited to multicast networks
FRAND	Fair, reasonable and non-discriminatory
GBR	Guaranteed bit rate bearer
GPS	Global positioning system
HD	High definition
HSPA	High speed packet access
HTTP	Hyper text transfer protocol
IP	Internet Protocol
IP-OTT	IP over the Top content

LTE	Long term Evolution
LTE PDCP/RLC/MAC	LTE packet data convergence protocol/radio link control/medium access control
M1	Logical interface between MBMS GW and eNBs
M2	Logical control interface between MCE and eNBs
M3	Interface between MME and MCE
MBB	Mobile broadband
MBMS	Multimedia broadcast and multicast service
MBMS CP	Multimedia broadcast and multicast service cyclic prefix
MBMS GW	MBMS gateway
MBMS SAI	MBMS service area identity
MBSFN	Multimedia broadcast and multicast service single frequency network
MCE	Multi-cell/multicast coordination entity
MCH	Multicast channel
MCS	Modulation and coding scheme
MDT	Minimization of drive tests
MIKEY	Multimedia Internet KEYing
MIMO	Multiple input multiple output
MME	Mobility management entity
MNO	Mobile network operator
MSK	MBMS service key
MSP	MCH scheduling period
MTK	MBMS traffic key
NCT	New carrier type
O&M	Operations and maintenance
OFDM	Orthogonal frequency division multiplex
PDN	Public data network
PSM	Public service media
PSS	Packet-switched streaming
P-TM	Point-to-multipoint
P-P	Point-to-point
QCI	Qos class identifier
QoE	Quality of experience: The overall acceptability of an application or service, as perceived subjectively by the end-user. It includes the complete end-to-end system effects (client, terminal, network, services, etc.) And it may be influenced by user expectations and context.
QoS	Quality of service

RRC	Radio resource control
RTCP	Rtp control protocol
RTP	Real time protocol
SCTP/IP	S common transport protocol
SDL	Supplemental downlink
SFN	Single frequency network
SGmb	Reference point for the control plane between BM-SC and MBMS GW
SGi-mb	Reference point for the user plane between BM-SC and MBMS GW
SIM	GSM subscription identity module
SINR	Signal to interference + noise ratio
Sm	Reference point for the control plane between MME and MBMS GW
SRTP	Secure real-time transport protocol
SYNC	MBMS synchronisation protocol
TCP	Transmission control protocol
TDD	Time division duplex
T_{CP}	Cyclic prefix length
T_u	Useful symbol time
UDP	User datagram protocol
UE	User equipment
UHD	Ultra high Definition
UL	Uplink
UP	User plane
USD	User service description

Annex 2

Detailed description of LTE eMBMS features[10]

A MBMS mode has been standardized by 3GPP. For LTE MBMS has been standardized in 3GPP Release 9 and is often called eMBMS. The LTE standard consists of a number of specification documents each covering a functional category or protocol layer. While TS 26.346[11] defines a set of media codecs, formats and transport/application protocols to enable the deployment of MBMS user services and TS 23.246[12] provides a high-level MBMS architecture and functional description, there is no single dedicated specification document for eMBMS, the related additions are included in the appropriate documents of the LTE specifications. Section 15[13] of TS 30.300 provides an overall technical description of the radio-level functionality.

A2.0 General description

A HSPA MBMS application was standardized by 3GPP, and since Release 9 it is termed ‘evolved MBMS’ or eMBMS for short, now adapted for LTE. Notably, eMBMS is time multiplexed with unicast services, which can be used to enable interactivity for multicast services, including for future hybrid digital-TV. Currently, with regard to the LTE transmission protocol, in the time multiplexed configuration, up to 6 out of the 10 sub-frames of a radio frame can be dedicated to eMBMS in the FDD mode, or up to 5 sub-frames in the TDD mode. eMBMS can employ a single-frequency network (SFN) configuration establishing a so-called MBSFN. Cells in an MBSFN have to be adequately time synchronized. Again, eMBMS is currently built on the LTE downlink OFDM physical layer with a cyclic prefix (CP) of 16.7 μs. This CP is extended in comparison with that typical used for the LTE unicast service[14]. This implies that, for two base station sites, when the distance difference between the UE and base stations is up to 5 km, no interference would occur between them, although in practice, interference from base stations more than10 km away would have to be taken into account in the network design.

A base station cell can be associated with up to 8 different MBSFN areas, allowing for overlapping national, regional, and local MBSFN service areas. Each MBSFN area supports 15 multicast channels (MCH), each of which can be configured with a different modulation and code rate to support tailored robustness under various reception conditions. Up to 29 multicast content program channels can be configured per MCH. Further details can be found in Annex 3 section A3.5.

On the transport layer, eMBMS employs internet protocol (IP) packets. eMBMS provides a streaming and a file download service type to the consumer device. As fast retransmissions are not supported in eMBMS for error correction purposes, increased transmission robustness can be achieved by

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[10] Some material by permission from Jörg Huschke and Mai-Anh Phan, "An Overview of the Cellular Broadcasting Technology eMBMS in LTE," in David Gómez-Barquero (ed.), Next Generation Mobile Broadcasting, Boca Raton, Florida: Taylor & Francis Group, LLC, 2013.

[11] 3GPP TS 26.346, “Multimedia Broadcast/Multicast Service (MBMS); Protocols and Codes”.

[12] 3GPP TS 23.246, Multimedia Broadcast/Multicast Service (MBMS) – Architecture and Functional Description.

[13] 3GPP TS 36300 v11.1.0, “Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2”, March 2012.

[14] In an optional configuration, the CP could be increased to 33.3 μs. Currently, signalling to identify which sub-frames use the CP of 33.3 μs is missing from the standard, therefore user equipments (UEs) cannot be assumed to understand this mode yet.

additional forward error correction on the application layer (AL-FEC). This also achieves increased diversity in the time domain for further robustness as large AL-FEC blocks are also supported in the eMBMS mode of operation.

A very basic requirement for the terminal is the capability to find the wanted content, i.e. the TV programs. Information about how to access the multicast content is contained in the so-called user service description (USD) which can be retrieved either by a request through an LTE uplink or Wi-Fi connection, or can be provided separately, either by using a preconfigured device or a USB stick. Access to electronic program uides (EPG) can be enabled in a similar manner.

A2.1 Service framework

The MBMS user service addresses service layer protocols and procedures above the IP layer and includes streaming and download delivery methods. Both the download and the streaming methods deliver media data encoded in various formats, e.g. video in H.264 and audio in AMR or AAC format.

The MBMS download delivery method was originally intended to increase the efficiency of file distributions, e.g. for media files that are cached in the user equipment (UE) after reception so that user have offline access to the content at any time (within any rights management constraints defined by the service provider). The download delivery method can also be used for DASH based streaming, as explained in subsequent sections. The streaming delivery method was intended for RTP-based continuous reception and play-out used e.g. in mobile TV applications.

FIGURE A2-1

Protocol stacks used for MBMS delivery methods 26.346[6]

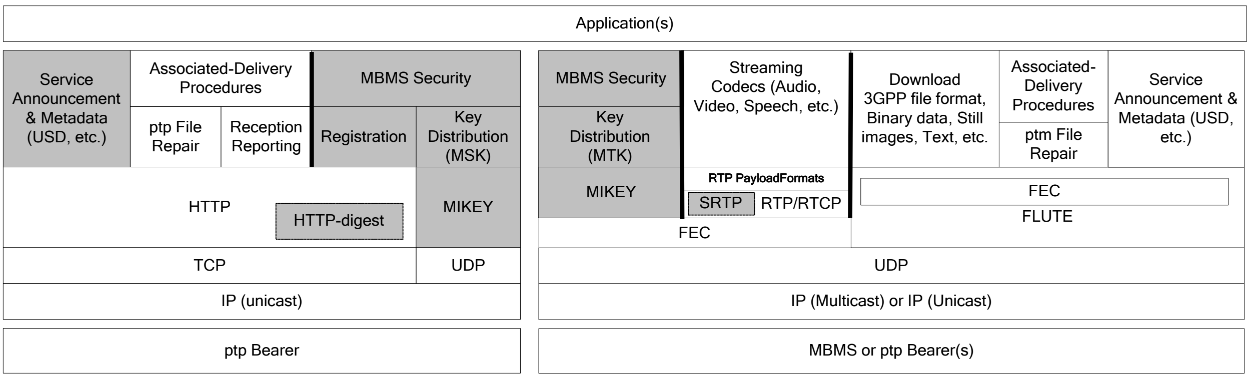

Figure A2-1 shows the protocol stacks which are used for MBMS as specified in TS 25.346[6] (gray boxes are defined therein by reference). The left side depicts the part of the protocol stack which requires an IP unicast bearer. The right side shows the part of the protocol stack which was designed for MBMS bearers carrying UDP.

Since UDP packets can also be sent over unicast bearers, the right side of the protocol stack can also be implemented on top of a unicast bearer.

It can be seen that service announcements and other metadata can be delivered both over unicast and multicast connections. This means that a client can for instance download service announcement related information from a web page, or it receives the information via a multicast bearer. Unicast and multicast delivery of service announcement information can also be combined.

For the associated delivery procedures, certain procedures such as point-to-point file repair and reception reporting require a unicast connection whereas other procedures such as point-to-multipoint file repair (e.g. of missing packets) can be executed over a MBMS bearer.

The download delivery method can be used for file distribution services, which store the received data locally in the UE. Some recent video services on the internet appear to the end user as streaming services, but actually, they use file based transmission where the entire media file is divided into fragment files that are transmitted sequentially, using e.g. the DASH protocol[15].

In contrast, the original MBMS streaming delivery method is based on the Real Time Protocol (RTP[16]). Meanwhile the newest trend is to implement video delivery using DASH rather than RTP. Therefore we will not discuss the RTP based MBMS streaming delivery method here. With DASH, a video stream is segmented into segment files, each one containing the data for a short playout interval, typically 1s.

During the MBMS data transfer phase, certain terminals may experience packet losses due to fading conditions or handovers. Naturally, full reliability cannot be offered in a pure unidirectional distribution scheme because the packet-loss rate can be excessive for some users. Therefore, three packet error recovery schemes are foreseen for the download delivery method. The most important one is the use of application layer forward error correction (AL-FEC) code, which allows recovery of lost packets during the MBMS data transfer phase without any server interaction. The other two recovery schemes use file repair procedures, where the first scheme is a point-to-point (P-P) repair mechanism using interactive bearers and the other one is a point-to-multipoint (P-MP) repair mechanism using MBMS bearers.

The Raptor AL-FEC code[17] was chosen as a basis for FEC protection of the files[18] and has also been adopted by DVB. The Raptor AL-FEC code generates a number of redundant FEC symbols for each source block. The FEC symbols are assembled into IP packets. A multicast signal of newly created FEC packets during the MBMS data transfer (phase 1) is of benefit for all receivers, which have not successfully reconstructed the original source block. When Raptor is used with DASH, then typically each video segment file forms a source block. Using segments covering of e.g. 1s playout time and ensuring that the transmission on the radio interface is distributed as uniformly as possible over each interval of 1s, this scheme achieves time diversity of 1s, because the Raptor code can recover any IP packet that a received failed to receive during that interval. In order to tolerate longer burst losses the video segment length can be increased, however, this implies an increase in end-to-end delay as well as the time it takes for a receive to switch between separately encoded video segment streams.

During a file repair procedure, further Raptor AL-FEC packets are transmitted to the receivers. If an interactive bearer is used, the repair data is independently sent to different receivers and can even be tailored to the actual losses of that receiver. On the contrary, if the MBMS bearer is used, the same

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[15] ISO/IEC DIS 23009-1.2, "Dynamic Adaptive Streaming over http (DASH)", Nov. 2011.

[16] H. Schulzrinne *et al.*, "RTP: A Transport Protocol for Real-Time Applications", IETF RFC 3550, July 2003.

[17] A. Shokrollahi, "Raptos Codes", IEEE Trans. On Information Theory, vol. 52, No. 6, pp. 2551-2567, June 2006.

[18] M. Luby, T. Gasiba, T. Stockhammer, and M. Watson, "Reliable Multimedia Download Delivery in Cellular Broadcast Networks", IEEE Trans. On Broadcasting, vol. 53, no. 1, pp. 235-246, March 2007.

repair data is sent only once to multiple receivers and the repair data should be useful for all receivers with losses. Therefore, the rateless property of the Raptor code is very beneficial for the P-TM repair mechanism.

If a file repair procedure is used (phase 2), the MBMS client waits until the end of the transmission of files or sessions and then identifies the missing data from the MBMS download. Afterwards, it calculates a random back-off time and selects a file repair server randomly out of a list. Then, a repair request message is sent to the selected file repair server at the calculated time. The file repair server responds with a repair response message either containing the requested data (interactive bearer), redirecting the client to an MBMS download session (MBMS bearer), redirecting the client to another server, or alternatively, describing an error case. The repair data may also be sent on a MBMS bearer (possibly the same MBMS bearer as the original download) as a function of the repair process[19][20].

A2.2 Service discovery

The availability of a scheduled transmission is usually shown to the user by an application (app) that implements e.g. an Electronic Program Guide. Each transmission session is defined by a user service description (USD) which contains all information necessary for the UE to find the content data in the overall LTE signal.

Content can be protected on the application layer using standardized DRM methods such as MBMS service keys (MSK) and MBMS traffic keys (MTK). eMBMS does not make use of the LTE specific ciphering. Therefore, it is in principle possible to receive eMBMS services without a SIM card of an operator. Two preconditions are that the UE supports this operation mode and the USDs of the scheduled services are made available to the UE by other means (as mobile broadband access is not available without a SIM card), e.g. through a home Wi-Fi. In the case that the content is encrypted by application layer DRM, the decryption keys also have to be made available to the UE in this way.

Note: A more detailed description of service discovery is provided in Annex 9 of the EBU TR027 (reference 4 in section 3).

[19] T. Lohmar and M. Elisova, "Evaluation of the File Repair Operations for Multicast/Broadcast Download Deliveries", Proc. European Wireless, Nicorsia Cyprus, 2005.

[20] T. Lohmar and J. Huschke, "Radio Resource Optimization for MBMS File Transmissions", Proc. IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB), Bilbao, Spain, 2009.

A2.3 LTE downlink physical layer

In the following, we provide a brief introduction to the E-UTRA downlink physical layer[21] [22]. Like other multicasting standards, the E-UTRA downlink uses OFDM, because it efficiently supports flexible carrier bandwidth, allows frequency domain scheduling, is resilient to propagation delays, which is particularly beneficial for SFN configurations, and is well suited for multiple-input multiple-output (MIMO) processing.

The possibility of operating in vastly different spectrum allocations is essential. Different bandwidths are realized by varying the number of subcarriers used for transmission, while the subcarrier spacing remains unchanged. In this way operation in spectrum allocations of 1.4, 3, 5, 10, 15, and 20 MHz can be supported. Due to the fine frequency granularity offered by OFDM, a smooth migration of, for example, 2G spectrum is possible. Frequency-division duplex (FDD), time-division duplex (TDD), and combined FDD/TDD, are supported to allow for operation in paired as well as unpaired spectrum.

To minimize delays, the transmit time interval (TTI) is only 1 ms, corresponding to one sub-frame. A subframe can carry several transport blocks, each of which has a checksum attached (CRC) for error detection. Each sub-frame consists of two slots of length of 0.5 ms. Each slot consists of several OFDM symbols. A subcarrier spacing Δf = 15 kHz corresponds to a useful symbol time $T_u = 1/\Delta f \approx$ 66.7 μs. The overall OFDM symbol time is then the sum of the useful symbol time and the cyclic prefix length T_{CP}. Signals from eNBs arriving within the cyclic prefix (CP) duration of the UE synchronization point contribute useful signal energy and thereby improve the coverage.

Signals arriving outside the CP produce interference. Since the CP does not contain user data, its length is a trade-off between the time fraction available for user data and the SINR value achievable with the desired error probability. In order to cope with different propagation delays caused by different cell sizes, LTE defines two CP lengths for a typical subcarrier spacing of Δf = 15 kHz, the normal CP and an extended CP, corresponding to seven and six OFDM symbols per slot, respectively.

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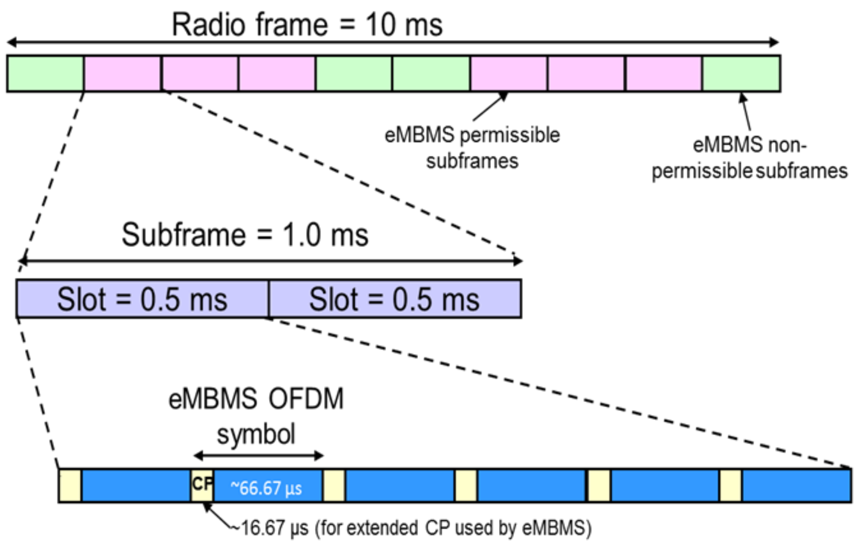
[21] E. Dahlman, S. Parkvall, J. Sköld and P. Beming, “3G Evolution: HSPA and LTE for Mobile Broadband”, Academic Press, 2008.

[22] 3GPP TR 25.814 v.7.1.0, “Physical Layer Aspects for Evolved UTRA” Oct, 2010.

FIGURE A2-2

LTE symbol/slot/frame structure[23]



By extending the CP from 4.7 µs (normal CP for 15 kHz subcarrier spacing) to 16.7 µs (extended CP for 15kHz subcarrier spacing), it is possible to handle very high delay spreads that can occur in a large cell with a very large radius or when several cells transmit the same signal synchronously as in the MBSFN mode described in the next section. For larger distances, the extended CP can even be increased by a factor of two resulting in 33.3 µs. In order to limit the relative overhead imposed by this extended long CP, the OFDM useful symbol time is also doubled for the configuration with the long extended CP of 33.3 µs. In order to maintain the same capacity with an unchanged carrier bandwidth, the subcarrier spacing is also reduced by a factor of two, resulting in 7.5 kHz subcarrier spacing. Currently, signaling to identify which sub-frames use the CP of 33.3µs is missing from the standard, therefore UEs cannot be assumed to understand this mode yet. These parameters differ from e.g. DVB-T as LTE networks use small cells and therefore propagation delay differences are smaller, which in turn allows for smaller CP and accordingly smaller OFDM symbol sizes. This in turn allows for larger subcarrier spacing, which allows for the larger Doppler spread that result when using some of the high frequency bands defined for LTE.

A2.4 Segmentation/Concatenation across protocol layers

Figure A2-3 shows the processing of DASH media data segments in terms of segmentation/concatenation across protocol layers including in this order the AL-FEC layer, working internally with so called symbols, the IP layer (FLUTE, UDP, IP) and finally the physical layer transport blocks (omitting for brevity the LTE PDCP/RLC/MAC layers, which are also largely irrelevant in the eMBMS context)). Transport block error rate (BLER) is often used as a physical layer performance criterion. There are several factor impacting the relation between DASH segment error rate and transport block BLER, in particular the relative size of all the involved data block units on each layer, and the amount of application layer FEC repair data.

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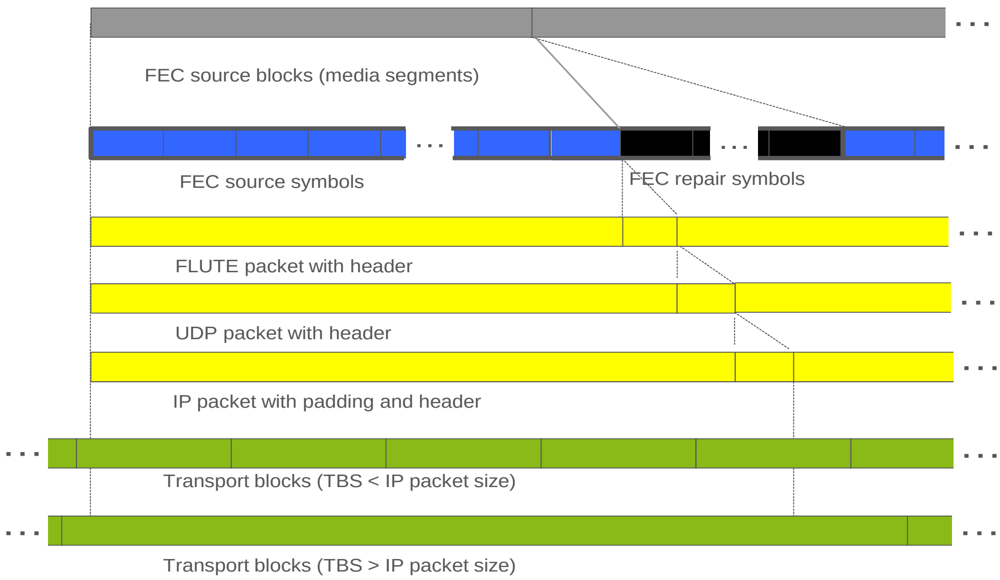
[23] A. Urie, A. Rudrapatna, C. Raman, J-M Hanriot, "Evolved Multimedia Broadcast Multicast Service in LTE: An Assessment of System Performance Under Realistic Radio Network Engineering Conditions", Bell Labs Technical Journal, Volume 18, Issue 2, pp 57-76, September 2013.

FIGURE A2-3

Segmentation/concatenation across protocol layers



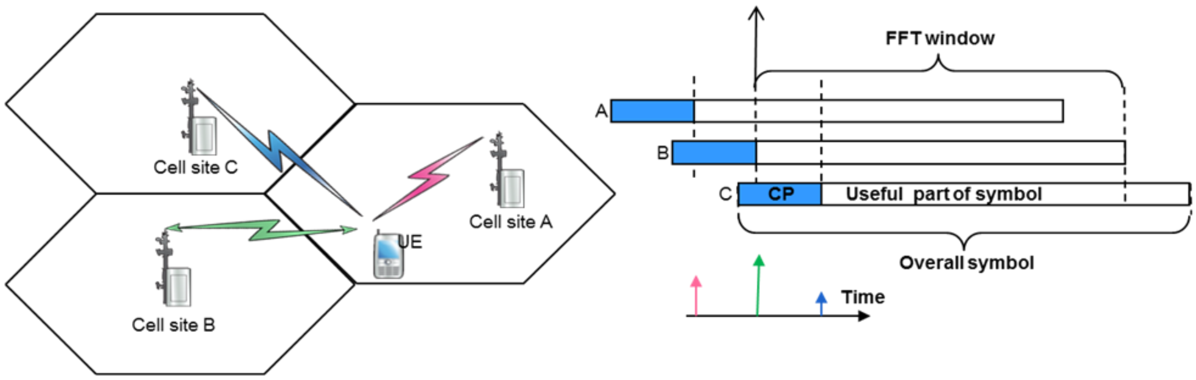
A2.5 MBSFN

If a larger number of users of a particular MBMS service are present in a cell, broadcast signal radio transmission in the cell is more suitable, which can be used either in single cell or multi-cell transmission mode. For P-TM transmission in both single-cell and multi-cell mode, a new transport channel, the multicast channel (MCH) was defined. The MCH can be time multiplexed on a sub-frame granularity of 1 ms with other transport channels such as the DL-SCH.

A multi-cell transmission essentially means that the cells transmitting the MBMS service are configured to form an MBSFN. If an MBSFN with multiple cells is established using a particular MCH, then the same MCH information is transmitted time aligned from these cells using identical transport formats, identical resource allocations and identical scrambling. From a UE point-of-view, such multi-cell MCH transmission will appear as a single MCH transmission. However, it is a channel aggregated from all cells involved in the MBSFN transmission and will typically have a large delay spread due to the differences in the propagation delay as well as residual transmit-timing differences as indicated in Fig. A2-4. In order to be able to properly demodulate the multi-cell MCH transmission, the UE needs an estimate of the aggregated channel. For this to be possible, MCH specific reference signals are needed that are identical for all cells involved in the MBSFN, i.e. identical time/frequency locations and identical reference signal sequences are used. In the current standard MCH transmission can only use a CP of 16.7 μs. In case sites with higher power and/or a higher tower are available, or with deployments in low frequency bands, good coverage can be achieved with even higher distance between sites, and in this case the extended CP of 33.3 μs should be used. For this CP, there is currently a missing piece in the standard: there is no signaling which sub-frames use this CP and the UE is not required to blindly detect it. An appropriate mechanism has to be defined to make the UE known where this CP is used.

FIGURE A2-4

Illustration of OFDM reception of SFN transmission from 3 cell sites[18]

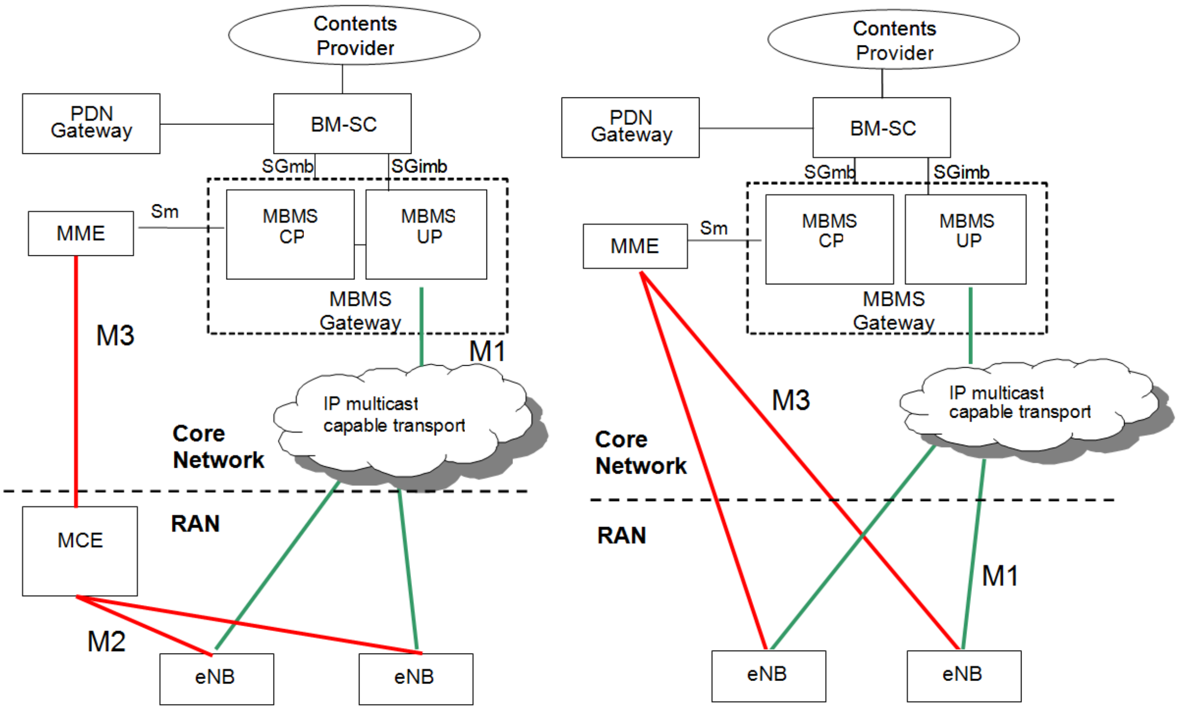


A2.6 eMBMS architecture

MBMS in LTE uses an evolved architecture in order to support MBSFNs with high flexibility, which was an important design goal of LTE from the start. Furthermore, for LTE it is desired to support MBSFN transmission and user individual services on the same carrier. The architecture needs to support the coordinated allocation of radio resources within the carrier for MBSFN transmission across all cells participating in the particular MBSFN. Figure A2-5 shows the eMBMS architecture, which is based on enhancements to the LTE Release 8 architecture. The default architecture is shown to the left. The alternative to the right is discussed along with the MCE below. The architecture defines a functional split – several functions can be co-located or even integrated in the same hardware box.

FIGURE A2-5

MBMS architecture in SAE / LTE



Left: Separate MCE Right: MCE functionality integrated into eNB

The following logical entities are defined:

– **BM-SC**. The broadcast-multicast service centre (BM-SC) controls MBMS sessions and corresponding MBMS bearers.

– **MBMS GW**. The MBMS gateway (GW) is an entity that is located between the content provider and the evolved base stations (eNode Bs, or eNBs). The control plane of the MBMS GW is involved in the MBMS session start/setup towards the LTE radio access network (RAN) via the mobility management entity (MME). The user plane (UP) is responsible for delivering the user data over the IP multicast capable transport network to the eNBs and participates in the content synchronization for MBMS services using MBSFN. The MBMS GW is part of the evolved packet core (EPC).

– **MME**. In the context of MBMS, the mobility management entity (MME) is responsible for session control signaling.

– **MCE**. The Multi-cell/multicast coordination entity (MCE) is responsible for coordinating the usage of MBSFN transmission within the same MBSFN area in the LTE RAN. Therefore, in the architecture alternative shown on the right of Fig. A2-5, where the MCE is integrated to each eNB, the necessary parameters must be consistently configured by O&M for all cells of an MBSFN area, since there is no interface for coordination between MCEs. Otherwise, an MBSFN area can only cover the cells served by the respective eNB.

– **eNB**. The eNB is the evolved base station in LTE responsible for multiplexing, framing, channel coding, modulation and transmission.

The following logical interfaces are defined:

– **M1**. Is a logical interface between the MBMS GW and the eNBs. The transport on this interface will be based on IP multi-cast. The MBMS content is transported in a frame or tunnel protocol, in order to support content synchronization and other functionalities. IP multicast signaling is supported in the transport network layer in order to allow the eNBs to join an IP multicast group.

– **M2**. Is a logical control interface between the MCE and the eNBs. This interface is used to coordinate the setting up of an MBMS service in the eNBs for MBSFN operation. SCTP/IP is used as signaling transport i.e. point-to-point signaling is applied

– **M3**. Interface between MME and MCE. Supports MBMS session control signaling, including the QoS attributes of each service (does not convey radio configuration data). The procedures comprise e.g. MBMS session start and stop. SCTP/IP is used as signaling transport i.e. point-to-point signaling is applied.

– It is not precluded that M3 interface can be terminated in eNBs. In this case MCE is considered as being part of eNB. Therefore M2 does not exist in this scenario. This is depicted in Fig. A2-5, which depicts two envisaged deployment alternatives. In the scenario depicted on the left, MCE is deployed in a separate node. In the scenario on the right MCE is part of the eNBs.

– **Sm**. The reference point for the control plane between MME and MBMS GW.

– **SGmb**. The reference point for the control plane between BM-SC and MBMS GW.

– **SGi-mb**. The reference point for the user plane between the BM-SC and MBMS GW.

A2.7 Synchronisation

Within a so called MBSFN area, all eNBs need to be synchronized within 1 μs, which would facilitate 5 km propagation difference for 16.7 μs CP. Each μs translates to approximate 300 m. If the synchronization drifts by 1 μs, then the distance between transmitters should not be more than 4.7 km in order to allow UE to receive the signals within the length of CP (16.7 μs). Also, the radio frames need to be aligned. The method of achieving the required tight synchronization is not defined in the LTE specifications; this is left to the implementation of the eNBs. Typical implementations are likely to use satellite-based solutions, e.g. GPS, or possibly synchronized backhaul protocols, e.g. IEEE1588. Tight synchronisation may not only be required for MBSFN operation but also for other LTE features, e.g. TDD operation, time-domain inter-cell interference coordination or coordinated multipoint transmission (a form of very small SFN for unicast).

The MCE is responsible for configuring identical MBSFN sub-frame allocations and MCH scheduling periods (MSP) in all cells of an MBSFN area, as well as the MCH modulation and coding scheme, satisfying the guaranteed bit rate of the MBMS bearer. The MCE also defines the common order in which services are scheduled in all eNBs of an MBSFN area.

Finally, content synchronization needs to ensure that the IP packet multiplexing and mapping to transport blocks in MBSFN sub-frames is identical in all these cells, taking into account that IP packets have varying size and packet losses can occur between the BM-SC and the eNB. This is achieved by the SYNC protocol[24] where the packet flow is grouped into synchronization sequences. A separate instance of the SYNC protocol is associated with each MBMS bearer.

For each synchronization sequence, the BM-SC tries to ensure that it does not send more packets to the eNB than allowed by the guaranteed bit rate of the MBMS bearer, discarding packets if necessary.

[24] 3GPP TS 25.446 v.10.2.0, “MBMS Synchronisation Protocol (SYNC)”, Dec. 2011.

The BM-SC labels all packets of a synchronization sequence with an identical time stamp telling the eNB when to start the transmission of the first packet of that synchronization sequence.

The time stamp has to cover transfer delays between the BM-SC and all eNBs in the MBSFN area to ensure that all of them have received and buffered the packets of an MSP before any of the eNBs is allowed to transmit the first packet. The MSP is configured by the MCE, but must be an integer multiple of the synchronization sequence duration to make this concept work.

The transmission delay differences from the BM-SC to the eNBs are typically smaller than 100 ms, even with a single BM-SC and an MBMS service area involving all eNBs of a country. The SYNC protocol can handle this delay, i.e. the data will be delayed by up to 100 ms in the first eNB receiving the data first from the BM-SC, to transmit them synchronously with the last eNB when it has received the data.

A2.8 eMBMS area concepts

For the MBMS service provisioning, the MBSFN area and MBMS service area need to be distinguished. The MBMS service area defines a geographic area where a service shall be multicasted. Within the network, the operator identifies each MBMS service area by one or more MBMS service area identities (MBMS SAIs), and each MBMS SAI defines a group of cells. A cell can belong to and is therefore addressable by one or more MBMS SAIs.

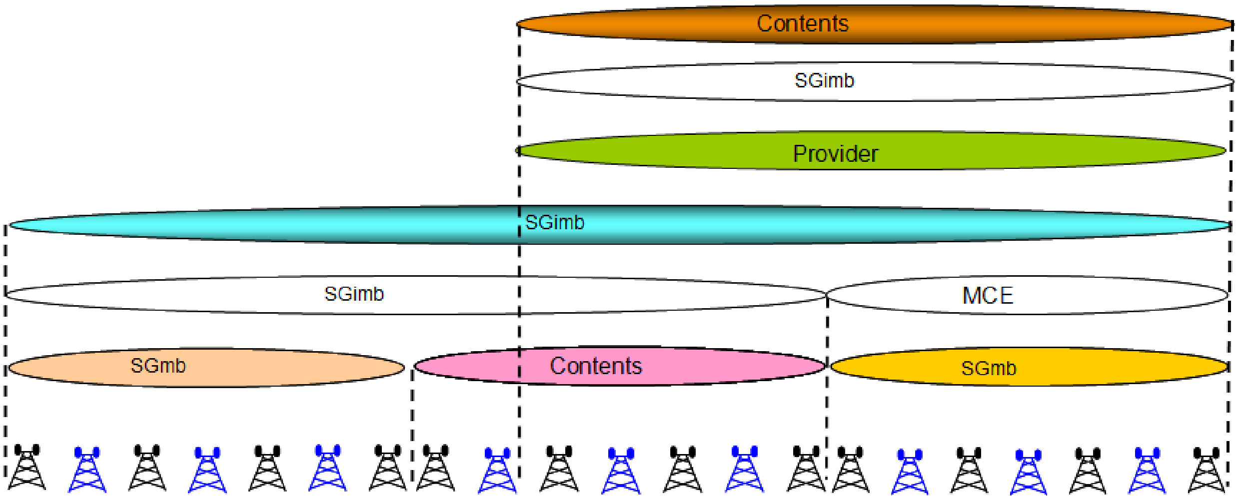
An MBSFN area defines the set of cells participating in the transmission of signals for one or more services in MBSFN mode. An MBMS service area (identity) may comprise one or more complete MBSFN areas. Overlap between MBSFN areas, as well as between MBMS service areas, is supported. This also enables a smaller MBSFN area to overlap a large MBSFN area, so that e.g. regional and nation-wide MBSFN areas can coexist. Overlapping MBSFN areas can be implemented using frequency or time multiplexing. Time multiplexing means that MBSFN areas are separated by different sub-frame patterns.

The relationship between MBMS Service Areas, MBMS Service Area Identities (MBMS SAIs), and MBSFN areas is illustrated in Fig. A2-6. MBMS Service Area A consists of MBMS SAI #1 and MBMS SAI#2. MBMS SAI#1 covers MBSFN areas 1a and 1b. The MBMS services that are provided in MBSFN area 1a and 1b, belonging to the MBMS SAI #1 do not have to schedule the MBMS data synchronously. The synchronization requirement is only valid within the same MBSFN area.

Within an MBSFN area there can be reserved cells that do not contribute to the MBSFN transmission. UEs in cells at the border of an MBSFN area will suffer from a high level of interference if the neighbor cells not belonging to the MBSFN area transmit different signals in the sub-frames used by the MBSFN area. Such border cells inside the MBSFN area may therefore be configured. Such that UEs located in these cells do not expect the availability of the MBMS service, due to the lack of essential MBMS signaling. Such cells at the border can thereby serve as an interference guard zone. Thanks to the low height of the eNB antenna towers and the low transmit power, typically only a few rings of cells around an MBSFN area are needed for the guard zone, depending on the used MCS. Therefore, the sub-frames can be reused for another MBSFN area or unicast traffic already a few km or few tens of km away.

FIGURE A2-6

MBMS related area concept

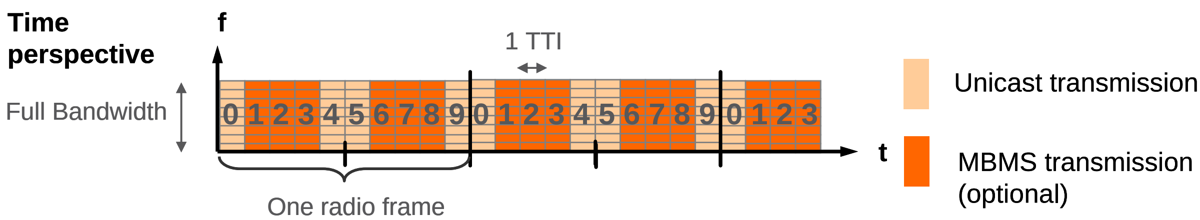


A2.9 eMBMS / unicast multiplexing

MBMS data transmission in MBSFN mode is time multiplexed with LTE unicast traffic. This is an advantage over WCDMA based MBMS transmission, where the use of MBSFN was confined to a dedicated carrier. Up to 6 of the 10 sub-frames of a radio frame are configurable for MBMS in the FDD mode and up to 5 in the TDD mode. Figure A2-7 shows which of the sub-frames can be used for MBMS transmission and which are reserved for unicast. The MBMS sub-frames use MBSFN transmission whereas in unicast sub-frames each cell can transmit different information. In FDD mode, the sub-frames that are allocated for MBMS in the downlink can be used for unicast transmission in the uplink. Sub-frames reserved for MBMS but with no content to transmit e.g. due to varying content bit rate can be used for certain transmission mode of unicast transmission. Different MBSFN sub-frame patterns must be allocated to different MBSFN areas. Due to time multiplexing, a UE can receive MBMS services and simultaneously use unicast services. This enables interactive multicast services as well as hybrid multicast/unicast delivery of content. The latter means content is delivered using eMBMS only in areas where the average number of users per cell interested in the content is high, otherwise it is delivered in unicast mode.

FIGURE A2-7

Time multiplexing of MBMS and unicast transmissions



A2.10 User counting for MBSFN activation

The audience density can either be predicted from the density seen for similar content in the past (e.g. earlier episodes of the same TV series) or based on real-time user counting. The user counting procedure enables the MCE to autonomously activate/deactivate MBMS services in a predefined MBSFN area depending on user interest. The counting procedure is triggered by the MCE if the network operator has configured it to do so. Counting is possible for Release-10-compatible MBMS UEs in so called RRC_CONNECTED mode, i.e. for UEs that already have a signaling connection with the LTE network, e.g. because the UE has recently received or transmitted unicast data. The fraction of UEs that can be addressed this way is typically high enough to enable statistically significant estimation of the total number of UEs in each cell that are interested in the considered MBMS service.

If the number of UEs responding to be interested in a service exceeds an operator-set threshold, the MCE can enable the preconfigured MBSFN area so that the service gets multicasted. The actual reception of the multicast is also possible in the RRC_IDLE mode where the UE does not have any signaling context with the network. If the threshold is not exceeded, then the number of users interested in the service is considered to be so low that delivering the service in unicast mode only in the cells with interested users is more efficient from a radio resource perspective.

If the MCE based counting procedure is not used, the set of cells to include in an MBSFN area and the services to be multicast in an MBSFN service area need to be configured manually by the network operator. The decisions need to be taken based on audience density information from the past. Such information can be gathered in the BM-SC from UE reception reports which can optionally include a cell ID of a cell that has been used for reception.

A2.11 Service acquisition and continuity in multi-carrier networks

An MBMS service that is provided via MBSFN is generally provided only on one frequency, while multiple frequencies can be deployed in a geographic area to cope with increasing unicast and MBMS traffic.

In order to provide the UE with sufficient information to find the frequency where an eMBMS service of interest is transmitted without having to scan all frequencies, in LTE Release 11 so-called MBMS assistance information is provided to the UE by both the USD (from the service layer) and the network. The USD of a service contains information in which MBMS SAIs and on which frequencies the service is provided. Each cell in the network broadcasts in its system information the MBMS SAIs of cells for its own frequency and for the frequencies used by overlapping (or neighboring) cells. If the UE finds a match between the MBMS SAI in the USD of the service of interest and in the system information, it can deduce that the service is locally available on a certain frequency. Based on the MBMS SAI information, the UE in RRC_IDLE can prioritize this frequency as that of the only cell to monitor, and the UE in RRC_CONNECTED mode can send its MBMS interest indication to the network. This interest indication contains a list of one or more MBMS frequencies according to the UE’s interest and capability of parallel MBMS reception on different frequencies, and also a priority bit. In case the cell transmitting the eMBMS service of interest is overloaded in the unicast sub-frames and a user wants to simultaneously receive the eMBMS service and other unicast services, the network can then decide based on the priority bit to keep the UE on the current cell even though the user then can experience reduced unicast performance, rather than handing over the UE to another cell which would imply the loss of the eMBMS service of interest for the user, unless the UE is capable of receiving on 2 cells (one per frequency) simultaneously.

A2.12 Quality of service

For unicast services, LTE provides a QoS framework. A service is associated with a QoS class identifier (QCI)[25]. Each QCI implies specific values of maximum transfer delay and the maximum Service Data Unit error rate. The LTE radio network then tries to ensure these QoS requirements are met, by appropriate prioritization in the UE scheduling and choice of retransmission rate , provided that the quality of the radio link enables this.

For eMBMS, the LTE sub-frames are reserved in a periodic pattern. This means eMBMS does not compete for radio resources with unicast traffic on a best-effort basis. Each service is mapped to a guaranteed bit rate bearer (GBR). The MCE allocates the required density of eMBMS sub-frames to achieve a total bit rate that supports the sum of the bitrates for all services that are multiplexed on one MCH, given the chosen modulation and coding scheme (MCS) of the MCH and AL-FEC code rate of each service. These parameters need to be configured to achieve the targeted low AL-FEC block loss rates with the targeted high geographical coverage. The BM-SC applies rate control to each service in order to not exceed the guaranteed bitrates in each synchronization sequence.

After the transmission of a file has finished, a file repair procedure can ensue where UEs not having received a sufficient number of packets to enable successful AL-FEC decoding can request delivery of additional packets. This is not useful in the case of DASH based streaming because this kind of retransmissions takes too long and would not arrive at the UE in time for the continuous playout, and the loss of a DASH segment only leads to a temporal loss of the playout. The file repair can however be very efficient for the distribution of large files and where integrity is a must.

Due to the unidirectional nature of eMBMS services, the network operator cannot easily know from the session if end-user devices have correctly received the data or the user experience of a streaming session was good.

Gathering of quality of experience (QoE) metrics from receiving MBMS clients to the BM-SC were defined for this purpose[26]. The service announcement information configured by the operator describes the parameters for QoE metrics. The announcements can be configured such that only samples of end-user devices report them. In the case of DASH, the QoE metrics indicates the number of lost HTTP streaming segments.

Finally, from Rel-12 onwards also on the part of MBMS, LTE supports UE radio link quality reporting for network optimization, e.g. for the detection of coverage hole. This feature is called minimization of drive tests (MDT).

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[25] 2 Standardized QCI characteristics:

3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Policy and charging control architecture (Release 13).

Technical specification 3GPP TS 23.203 V13.3.0 (2015-03).

[26] Lohmar, Sissingar, Kenehan, Puustinen; "Delivering content with LTE Broadcast" in Ericsson Review 2013-1, 11 Feb 2013 http://www.ericsson.com/res/thecompany/docs/publications/ericsson_review/2013/er-lte-broadcast.pdf.

A2.13 Standardization Outlook

LTE is continuously further developed by 3GPP in a release cycle. A cycle takes about 1.5 years. At the end of 2014 3GPP is in the process of finalizing Release 12.

The work is organized in the form of work items. The main work items where unicast video delivery can benefit from are improvements in the areas of (distributed) multi-antenna (MIMO) methods and small cell support (including 256QAM) for traffic hotspots. For eMBMS enhancements there is a proposed work item to cover longer cyclic prefix to support larger inter-site-distances, support of eMBMS on dedicated carriers, i.e. using 100% of carrier resources for eMBMS, and MIMO. 3GPP RAN work items can be adopted by the 3GPP RAN plenary which meets every 3 months. Apart from the dedicated eMBMS work item proposal, discussions have started whether 3GPP should work on supporting eMBMS on the so called new carrier type (NCT) which is mainly being developed for performance increase and energy saving for unicast services, but also presents an opportunity to increase the limit of the percentage of sub-frames usable for eMBMS from 60% to 80%.

Annex 3

Demonstration trials of audio-visual over IMT

Case 1: Operator trials in Melbourne

Telstra has been actively assessing LTE eMBMS (LTE- B) capability within its Technology, Networks and Products groups since 2013, through performance modeling, technology trials, live proof-of-concept activities, and internal service demonstrations. In particular, these activities have included live trials of real football and cricket events within large stadium environments (>100k seats), along with delivery of premium content associated with the ongoing games.

Telstra has conducted trials of LTE-B technology at several locations in the city of Melbourne. For example, following successful lab demonstrations, Telstra performed the first live event LTE-B trial in the world of the T20 cricket match at Melbourne Cricket Ground in Jan 2014, marking a significant step in developing the technology for commercial use. During the trial, participants used LTE-B enabled devices to access three channels of dedicated content – Channel Nine's live coverage, a separate highlights replay service, and continuous match/player statistics – being examples of how this technology could be used in the future. Demonstration services based on HD video are currently available at the Telstra 'experience centre'. Telstra has also enabled a world first production deployment of LTE-B in Oct 2013 in a confined area. The current focus is to continue to the trials and demonstrate the LTE broadcast technology to maintain industry awareness (user and content provider awareness), help develop the eco-system, understand requirements for spectrally efficient network design and network integration. Telstra is using the knowledge gained from these trials to further refine network planning, and to enable ongoing collaboration with manufacturers and content owners to develop devices and applications in preparation for a future commercial service launch.

Telstra launched its 3G (UMTS) network in 2006. Since then data usage on that network has grown significantly – nearly doubling year-on-year. While it is gratifying that customers are finding such benefit from the network that usage grows so strongly, the challenge for Telstra is how best to configure and expand the network to cater for that demand growth. Fortunately for network operators the IMT technology continues to evolve and provide further solutions. In 2011, Telstra further launched its 4G (LTE) network. This allowed Telstra customers to access the next generation of mobile network technology, for more efficient delivery (bps/Hz) along with higher data speeds – and at the same time added a whole extra channel for their data to be carried on. With the uptake of 4G, Telstra is now seeing traffic on its 4G network approaching a growth rate of close to doubling every three to four months. While the 4G network is still relatively new, operators need to look for solutions that will allow them to sustain this growth month-on-month and year-on-year. This is where LTE-Broadcast is expected to play a major role. Experience shows that many customers are often seeking the same content delivered to their mobile phone at the same time. This might be a copy of the newspaper in the morning, a new operating software upgrade, or live-feed of a sporting contest. If a large number of people in a mobile network cell area request such content, it clearly becomes inefficient to deliver it using a unicast approach. Through Telstra's LTE-Broadcast trial, it has today demonstrated that it's possible to use one common stream of data, to deliver the same content to multiple users – keeping the rest of the network free for other customers.

Each wireless network is deployed on the basis of a finite amount of spectrum – and when a network is fully loaded it's usually not possible to simply add more spectrum to carry extra traffic. Thus, in the absence of any other solution, all active customers on that network will consequently experience lower speeds. Therefore, one aim of the trials conducted by Telstra was to assess the potential of LTE-B for off-loading traffic in busy areas. When a large number of people gather in one place (e.g., event arenas), a major spike in the demand for data is often observed that will stretch the capabilities of a unicast network and affect the experience of all customers. LTE-B offers network operators the ability to deliver content more effectively and provide all users the same high quality service using one single stream of data. In this way, capacity is freed up on the remainder of the network to carry other data, voice and text messages. Possible future uses of the broadcast technology, some of which have been tested in the T20 trial, include people listening to live commentary, getting real time match statistics and being able to watch replays and game highlights on their smartphone or tablet interactively.

The current focus is to continue the trials and demonstrate the LTE broadcast technology to maintain industry awareness and help develop the eco-system. A number of other live events (e.g., Spring Racing Carnival, major conferences) are currently targeted for demonstration of the LTE-B capabilities. In addition, data file download opportunities such as digital signage (e.g., billboards), content delivery to a particular industry vertical and portable LTE-B for music festivals in unconnected places are also being explored. Collaboration and sharing of experiences with operators in other countries is also seen as vitally important, along with device and chipset manufacturers, as well as the major network vendors, to further develop the LTE broadcast eco-system.

Case 2: Field test in Germany: integration of broadcast and mobile broadband in LTE/5G (IMB5)

In 2014 a research project called IMB5 started, funded by BFS (Bayerische Forschungsstiftung), with the objective to create technological models for the convergence of broadcast and mobile broadband by:

– Testing the capabilities and limitations of current LTE eMBMS for nationwide broadcast infrastructure.
– Creating an optimized system architecture for eMBMS based networks.
– Defining input for modifications of the 3GPP standardization of eMBMS.

Some further detail of the project:

Background and motivation

Today, terrestrial television (stationary and mobile reception) as well as mobile broadband use separate and different network infrastructures and are competing for scarce spectrum resources in the UHF band. The aim of the project IMB5 is therefore, with the help of theoretical and practical studies, to develop proposals how cellular phone and terrestrial television could be brought together in a new converged system. A converged system of terrestrial television and cellular communications could bring significant benefits to the consumer. Linear and on-demand broadcasting content could be received everywhere on mobile devices via a converged single air interface. The integrated IMT uplink channel together with touch screen, microphone and camera enables new forms of interactivity via integration of spectators in live programs with image and sound. This project allows companies in the broadcasting and mobile communications business, and also media and automotive companies to come together and also, the results of this project could serve to clarify the issues in the areas of regulation and business models.

Currently, the terrestrial broadcasting coverage is nation-wide or regional. In many countries, radio and television programs of the public service broadcasters and private broadcasters are made available to the customers free of charge; in Germany the terrestrial distribution is financed by ARD, ZDF as well as the participating private broadcasters. In addition to fixed reception, portable and mobile reception of television programs is supported. The number of users is in the range of four to ten million, depending on whether laptops, secondary devices, portable receivers and multi-standard displays in motor vehicles are counted or not. However, for various reasons, the DVB-T standard is not implemented in smartphones and tablets. Currently the German mobile operators are expanding LTE-capable IMT networks. With the planned roll-out of LTE Release 9, new application areas become available eMBMS can be operated in a Multicast Broadcast Single Frequency Network

(MBSFN). The parameters are optimized for LTE networks. In order to use LTE or a successor of LTE/eMBMS for wide-area TV services it is necessary to examine and improve the currently specified eMBMS-mode. The IMB5 project intends to realize this by carrying out theoretical investigations and simulations on the system and link level. In parallel, a test bed will be established to validate the current eMBMS capability in practical field tests. The results and experience gained in this project could be utilized for the development of new standards to enable the integration of broadcasting and mobile communications in a common standard and a common multimedia distribution network.

Objectives

The aim of the IMB5 project is to explore the possibilities of the currently defined eMBMS from 3GPP Release 9 to identify the existing limitations of its suitability and overcome the inadequacies for a nationwide terrestrial television infrastructure. As on-demand services are increasing, a key objective in this project is the combination of linear and on-demand content. Different scenarios will be studied to demonstrate whether eMBMS (defined in the standard mode, which provides both multicast and broadcast operation) is suitable for broadcast-specific applications. The scenarios considered are not only pure broadcasting scenarios but also a push mode in which the content is transmitted to a terminal, and the consumer can watch it at any time. Telematics services in push mode can also be used to deliver services like traffic information. Traffic control and driver information via a nationwide eMBMS coverage could result in a significant cost reduction.

A long-term goal is to define a common standard that is suitable for terrestrial television and mobile broadband. A mobile device (smartphone, tablet PC, etc.) would receive the same television and broadcasting content and in addition provide a basis to enable innovative services that require a return channel. The development of a globally applicable standardization proposal for the transmission of both linear and on-demand content, enables cost-effective mass production of uniform global receivers for the benefit of consumers, device manufacturers, network operators and content providers. In addition to the globally harmonized standard, another objective is the optimization of network structure and topology. For instance it is crucial to distribute public service broadcast content only once per region and not once per network operator This may provide new momentum to the transmission of broadcast content and thus help to resolve the current debate around future use of the UHF band.

In addition to the theoretical discussion of these issues, the focus of the project is a practical realization of such a network structure in the form of a field trial. Using test installations the theoretically acquired knowledge is applied and verified in practice. In parallel, findings on incurred costs will be fed into a cost analysis, which subsequently will be suitable for a comparison of different network structures. This is accompanied by the objective of limiting the necessary capital and operating costs of such a future integrated network on a commercially reasonable level.