5th Generation Mobile Networks, a New Opportunity for the Convergence of Mobile Broadband and Broadcast Services

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Abstract

This paper analyzes the challenges and opportunities that the upcoming definition of the future Fifth-Generation (5G) mobile networks brings to the mobile broadband and broadcast industries to form a single converged network. It reviews the state-of-the-art on mobile and broadcast technologies and the current trends for convergence between both industries. This paper describes the requirements and functionalities that the future 5G must address in order to make an efficient and flexible cellular–broadcasting convergence. Both industries would benefit from this convergence by exploiting synergies and enabling an optimum use of spectrum based on coordinated spectrum sharing.

1. Introduction

The mobile communications sector is characterized by a worldwide rapid increase in traffic demands due to the continuously evolving requirements and expectations of both users and operators. In 2013, global mobile data traffic grew 81 percent and it is expected that this will increase nearly 11-fold between 2013 and 2018 [1], primarily driven by the increasing usage of mobile video services on devices with high screen sizes like smartphones and tablets.

The most representative video service is mobile TV, which is often identified with linear TV and broadcast (point-to-multipoint) distribution. However, the mobile user behavior is different from traditional fixed TV because contents are mainly consumed on-demand with unicast (point-to-point) connections. The convergence of linear TV and on-demand content represents a challenge that requires a combined broadcast/unicast delivery model.

Both mobile and broadcast industries have developed several mobile broadcast technologies to support large-scale consumption of mass multimedia services on mobile devices. So far, the adoption of mobile TV services has not fulfilled the initial expectations due mainly to the lack of a successful business model and the high costs associated to the deployment of new mobile broadcasting networks. However, both industries are currently taking steps towards possible broadcast solutions to provide mobile TV services.

On the one hand, mobile industry has adopted Long Term Evolution (LTE) and its evolution LTE-Advanced (LTE-A) [2], as worldwide Fourth-Generation (4G) cellular technologies. Both LTE and LTE-A support broadcast transmissions by means of the evolved Multimedia Broadcast Multicast Services (eMBMS) [3], which is commercially known as LTE Broadcast. eMBMS allows Mobile Network Operators (MNOs) to cope, to some extent, with the increasing demand of mobile video data using point-to-multipoint transmissions. As this broadcast solution is supported over the same frequency carrier as unicast services, the eMBMS deployment costs are significantly lower than other broadcast alternatives. However, it also entails the use of dense networks compared to terrestrial broadcast networks and the reduction on system capacity for unicast services, which hampers the eMBMS business model.

Nowadays, while MNOs are investing on 4G network deployments, the mobile industry is already working on the Fifth-Generation (5G), the future mobile communications beyond 2020. The three main requirements for 5G wireless networks are [4]: to support massive capacity and connectivity; to carry a diverse set of services, applications and users with extremely diverging requirements; and to make a flexible and efficient use of the available spectrum, whether contiguous or not, supporting wildly different network deployment scenarios.

Concerning broadcast industry, traditional Digital Terrestrial TV (DTT) networks are more efficient for the delivery of very popular data, such as live video services, at high quality to a large number of subscribers. While traditional broadcasting systems use High Power High Tower (HPHT) networks to cover large areas, cellular networks need thousands of base stations to cover the same extension.

Moreover, the growing interest of broadcast industry to enable mobile TV services to smartphones and especially tablets has renewed the interest in mobile broadcasting after the failure of first-generation mobile broadcast technologies such as DVB-H (Digital Video Broadcasting Handheld) in Europe, Media FLO and ATSC-M/H (Advanced Television Systems Committee Mobile/Handheld) in North America, or CMMB (China Mobile Multimedia Broadcasting). Furthermore, broadcasters can benefit from the capacity and coverage improvements brought by new generation broadcast standards as the Second-Generation Terrestrial DVB (DVB-T2), DVB Next Generation Handheld (DVB-NGH) or the upcoming ATSC 3.0.

So far, the highly fragmented DTT market has demotivated manufacturers to include broadcast TV capability in mobile devices. However, the current interest in developing a worldwide new-generation broadcast terrestrial standard targeting both fixed and mobile reception could favor economies of scale thus allowing for its implementation on mobile devices [5].

The scenario in case the broadcast industry agrees on a worldwide broadcast terrestrial standard and the mobile industry includes a multicast/broadcast transmission mode in the future 5G system, would end up with two complete different industries, with different network infrastructures and business models competing for market and spectrum.

This paper discusses a different approach by which the definition of the future 5G mobile broadband communication system could bring together the cellular and broadcast industries to form a single fixed and mobile converged network. Next section presents the state-of-the-art on the evolution of mobile and broadcast technologies. Afterwards, the first approaches for the cooperation between mobile broadband and broadcast are described. They are the starting point for the definition of a joint solution within 5G. Finally, the challenges of the definition of such a converged solution are discussed.

2. Evolution of mobile communications and terrestrial broadcasting standards

Figure 1 shows the mobile communications and DTT standards landscape. On the one hand, mobile industry evolves towards the future 5G mobile broadband communications, whereas broadcast industry evolves towards a global DTT standard.

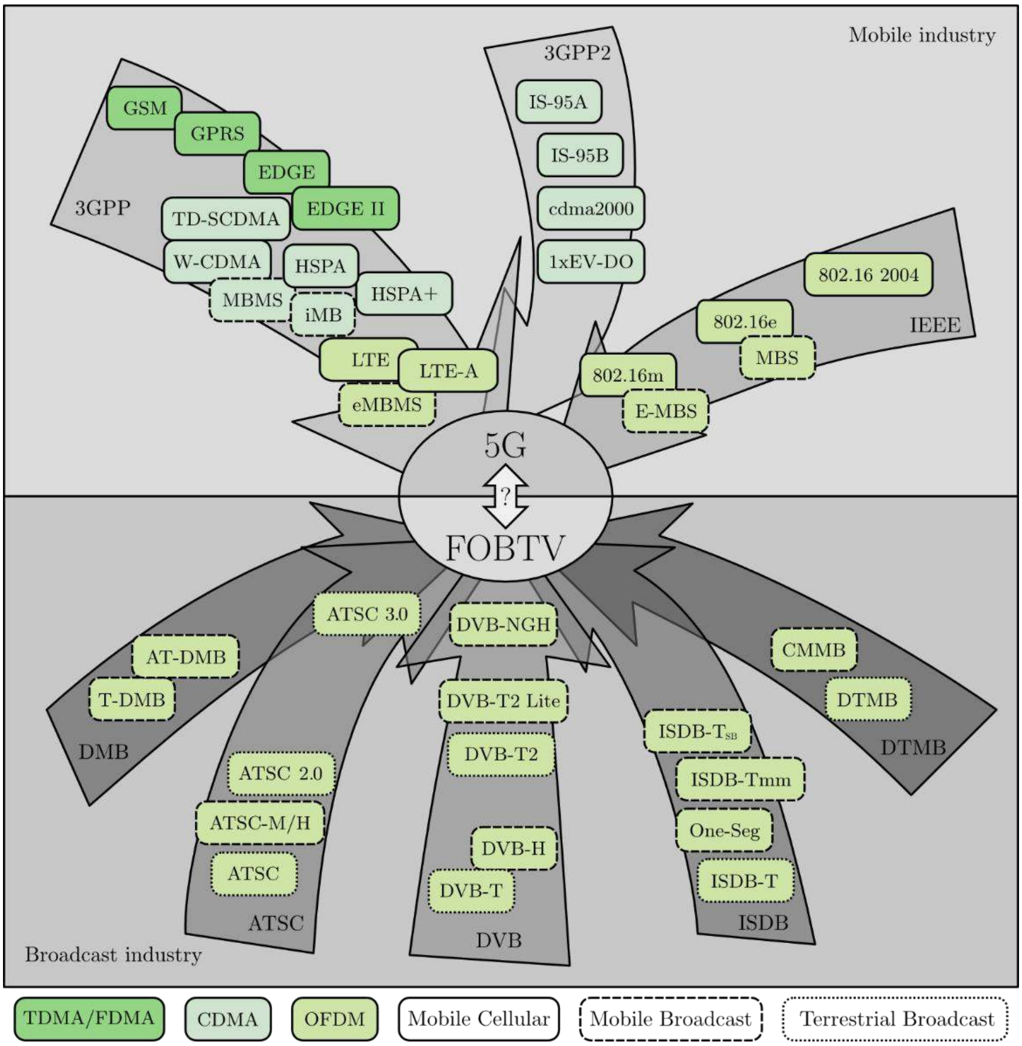

Figure 1. Mobile communications and DTT standards landscape.

2.1. Mobile industry: evolution towards the future 5G system

From the second-generation (2G) of mobile cellular networks, the mobile communications sector has seen many competing radio standards mainly developed by the 3GPP, the 3GPP2 and the IEEE. However, the dynamics of 4G is changing this landscape since all existing mobile cellular systems are converging towards a single technology, that is, LTE. LTE was designed from the beginning with the goal of evolving the radio access technologies under the assumption that all services would be packet-switched. Unlike previous technologies, LTE adopted Orthogonal Frequency Division Multiplexing (OFDM) as its radio access technology, which is the one dominating the latest evolutions of all mobile radio standards. This change was accompanied by an evolution of the non-radio aspects of the complete system towards a flat and all-IP system architecture. It is worth noting that the latest cellular generation developed by the IEEE, known as 802.16m, has similar targets to the evolution of LTE, that is, LTE-A. However, the IEEE 802.16 family has not been designed with the same emphasis on mobility and compatibility with operators' core networks as the 3GPP technology family.

Concerning the state of the art on 4G network deployments, the number of commercial LTE networks and handsets is increasing very rapidly worldwide. By the end of 2013, 260 operators had commercially launched LTE services in 95 countries and this number is expected to reach around 350 LTE networks by the end of 2014 [6]. This worldwide adoption gives to eMBMS, the broadcast mode of LTE, the edge over all its mobile broadcast competitors to provide mass multimedia services to mobile devices. The main advantages of eMBMS are the end-to-end IP architecture that enables the coexistence of unicast and broadcast services with high capacity, high bandwidth and high scalability. Moreover, the deployment costs are significantly lower than other broadcast alternatives due to its easy integration with LTE infrastructure and mobile device chipsets.

Currently, LTE Broadcast is set to open new business models for MNOs and 2014 is also expected to be an important year for LTE Broadcast. Several MNOs have already deployed their eMBMS networks completing successfully the first trials by the end of January 2014. As some examples, Verizon Wireless used the Super Bowl in New York as a test case for the LTE Broadcast technology and the Australian operator Telstra completed a live demonstration of LTE Broadcast solution in a stadium environment during a cricket match in Melbourne. In addition, Korea Telecom completed the world's first commercial launch of LTE Broadcast services using eMBMS technology and, later on, Vodafone Germany and KPN made the Europe's first trials of LTE Broadcast in a football stadium.

Although MNOs are currently investing on 4G network deployments, the mobile industry is already working on the definition of the future 5G mobile communication system. Following the current requirements and expectations from both users and operators, it is expected that the future 5G wireless networks also include the efficient provision of mass mobile multimedia services through one or several broadcast transmission modes.

2.2. *Broadcasters: evolution towards a global terrestrial standard*

The need for replacing analogue TV to make a more efficient use of the broadcast radio spectrum and to improve the quality of TV services motivated the development of DTT systems [7]. There are five digital TV standardization organizations in the world: ATSC in North America, DVB in Europe, Digital Terrestrial Multimedia Broadcast (DTMB) in China, Integrated Services Digital Broadcasting (ISDB) in Japan and Digital Multimedia Broadcasting (DMB) in Korea.

DVB standards are the most adopted worldwide being currently two of these standards, DVB-T2 and DVB-NGH, the most advanced DTT systems for fixed and mobile devices, respectively. DVB-T2 provides at least 50% capacity increase over the other existing standards and its evolution to handhelds, DVB-NGH, includes the use of multiple antennas at transmitter and receiver side and other enhancements with respect to DVB-T2.

Despite the fact that DVB-NGH outperforms previous DTT systems to support large-scale consumption of mass multimedia services in mobile devices, there are no plans for its commercial deployment. So far, in many countries, mobile TV services either did not reach the market or were launched and promptly stopped. The only successful stories among the mobile broadcasting systems are One-Seg in Japan and Terrestrial-DMB (T-DMB) in South Korea. However, in these two cases, the transmission of mobile broadcasting services is requested by the national regulators.

The high fragmentation of the DTT market and the need for taking benefit from the economies of scale have recently motivated the approaches and wishes of cooperation among the different broadcasting standard developing organization. The Future of Broadcast TV (FOBTV) initiative was launched in 2012 with the aim of creating a common working scenario for the future generation of broadcast terrestrial systems to avoid competing standards, overlap, and inefficient deployment of new services. For example, since mobile devices are likely to move across borders, it is highly desirable that the specification contains core technologies that will have broad international acceptance and enable global interoperability.

The latest milestone in the development of the next-generation digital broadcast technologies is the ATSC 3.0 standard, which will replace the current systems used in the USA and aims at being a global standard. Figure 2 shows the development timeline of ATSC 3.0, which involves not only the physical layer, but also the management and protocols, and applications and presentation layers. In September 2013, eleven detailed physical layer proposals were received [8], taking many of these technical proposals the DVB-T2 and/or DVB-NGH standards as baseline. Therefore, it is likely that the upcoming physical layer of the ATSC 3.0 had significant similarities with the last DVB standards.

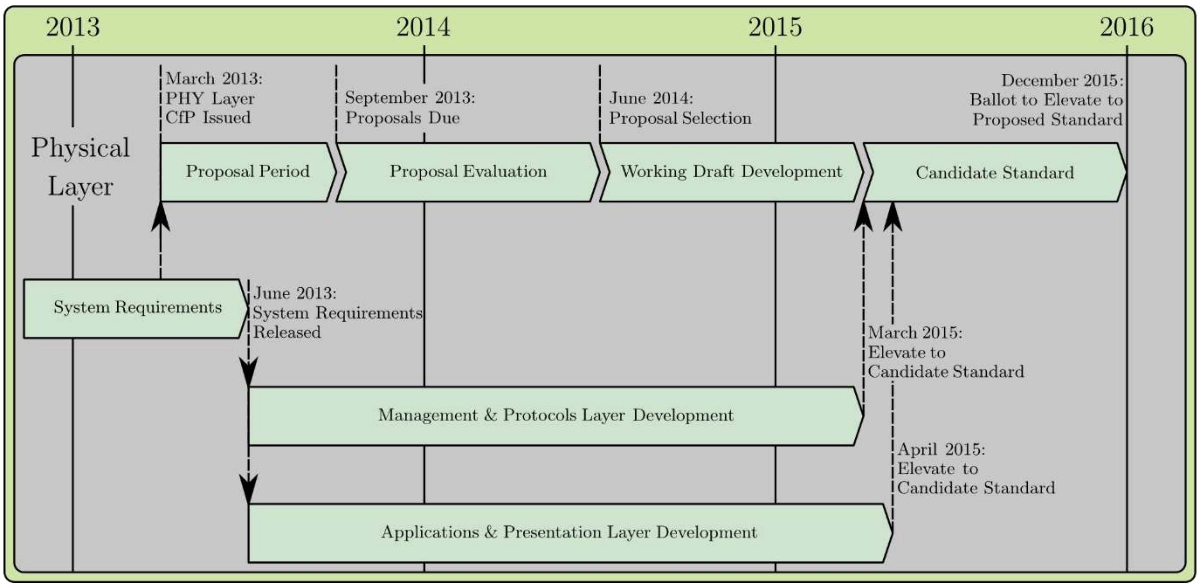

Figure 2. ATSC 3.0 Standard Development Timeline.

3. First attempts for the mobile broadband-broadcast cooperation

The worldwide adoption of LTE and LTE-A as 4G technologies gives eMBMS a head start over all its mobile broadcast competitors to provide mobile TV services to smartphones and tablets. eMBMS is currently only supported in a mixed carrier mode, where broadcast and unicast data share the carrier capacity. In particular, up to 60% of the total LTE resources can be reserved for eMBMS. The subframes are named MBMS over Single Frequency Network (MBSFN) subframes, and use ODFM symbols with a longer cyclic prefix (CP) of 16.67 µs. The use of this longer CP allows the construction of SFNs between multiple cells with a maximum of 5 km inter-site distance. For MBSFN dedicated carrier deployments, it is possible to double the CP length to 33.33 µs (10 km SFN distance). Although the physical layer features of MBSFN dedicated carrier are already defined, it is not supported in current releases of LTE and LTE-A.

From the broadcasters' point of view, current eMBMS features do not address all mobile broadcast use cases, since its low delay spread tolerance entails that eMBMS only can be deployed on dense networks. Traditional broadcast networks are more efficient for broadcasting TV services to a large number of subscribers due their HPHT networks, which cover large areas. Typical SFN distances used in traditional broadcast networks range between 50 and 90 km.

This section gives an overview about possible ways of complementing wireless broadband systems using terrestrial broadcast networks.

3.1. Technical approaches for 3GPP and DVB cooperation

In November 2010, the DVB forum contacted 3GPP to consider a potential collaboration in the area of mobile broadcasting. A joint workshop took place in March 2011 with presentations from 3GPP and DVB standardization activities and, two months later, the creation of a study item was proposed to the 3GPP [9]. This proposal introduced the concept of Common Broadcasting Specification (CBS) to be used in 3GPP mobile communications networks and DVB-basedbroadcasting networks.

Although this proposal was not accepted by 3GPP due to lack of support from MNOs, broadcast industry and academia continued working on 3GPP and DVB cooperation and several technical approaches have been recently proposed. The main assumption is the evolution of the broadcast capability of current 3GPP eMBMS in terms of capacity, coverage and quality of service to match traditional broadcast networks.

Firstly, the French M3 project evaluated and analyzed convergence possibilities of the CBS physical layer providing broadcast capabilities to the 3GPP LTE and DVB-NGH systems [10]. This technical proposal addressed key topics such as broadcast system architecture, modulation, system parameters, channel coding, time interleaving and reference pilots. In particular, it proposes the use of time interleaving schemes at the physical layer based on enlarged transmission time interval and time slicing concept to exploit time diversity. Moreover, it proposed some eMBMS enhancements in order to integrate typical requirements from broadcasters such as the use of longer CP and optimized downlink-only system, which would also allow for an efficient use of HPHT networks to provide mobile video services.

Initially, CBS was assumed to be transmitted on a dedicated carrier either by MNOs, using mobile cellular networks, or broadcasters using HPHT networks. However, CBS could also be transmitted in-band with LTE/LTE-A unicast, as it is the case in the current eMBMS specifications, or in-band with DVB-T2 broadcast, by using the Future Extension Frames (FEF) concept shown in Figure 3.

Precisely the FEF concept together with the LTE-A carrier aggregation concept are the basis of the other proposal for 3GPP and DVB cooperation, known as "Tower Overlay over LTE-A" [11]. On the one hand, DVB-T2 framing structure defines two types of frames: T2 frames and FEFs. T2 frames contain preambles P1 and P2, which provide control information to DVB-T2 receivers, and T2 data symbols. FEF starts with P1 and the rest can be used for either extensions of the standard or other technologies, which allows time multiplexing various signal formats on the same frequency carrier. The use of FEF does not have an impact on existing DVB-T2 receivers since they work like in a discontinuous transmission. On the other hand, carrier aggregation, one of the key features of LTE-A Release 10 [2], allows for the use of wider bandwidth and consequently increases transmission capacity by means of the aggregation of up to 5 carriers –one primary cell and up to four secondary cells–, which can belong to either continuous or discontinuous spectrum.

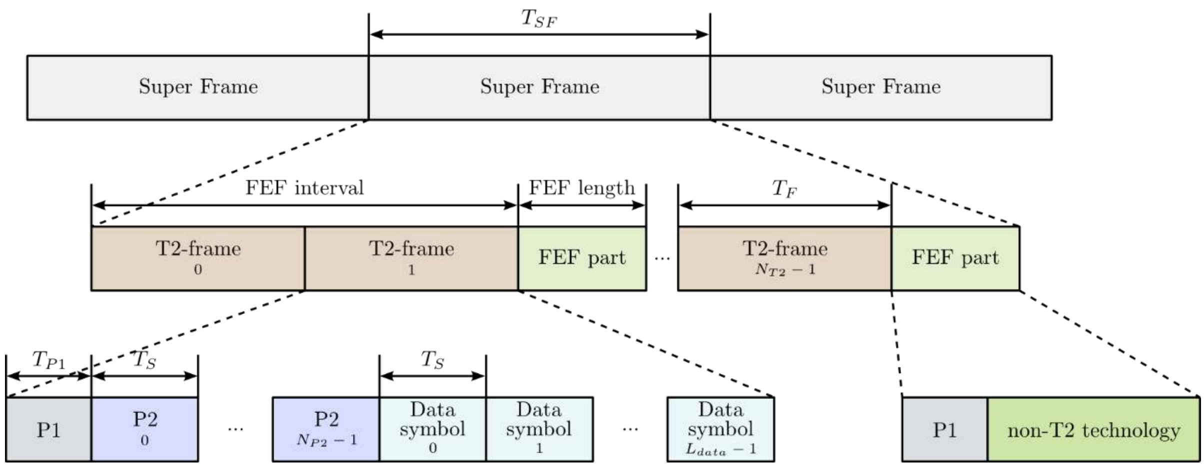

Figure 3. The DVB-T2 frame structure, showing the division into super-frames, T2-frames and FEF.

Figure 4 shows the Tower Overlay over LTE-A system concept. Based on FEFs and carrier aggregation, it proposes the use of a hybrid carrier integrating an eMBMS dedicated carrier into a DVB-T2 data stream, which can be transmitted using existing HPHT networks for broadcast service delivery to both fixed and mobile devices.

The feasibility of this approach requires some extension or changes in both systems. Regarding DVB-T2 networks, they need to be extended to support the modulation of LTE Broadcast signals and their integration into FEFs. It implies the use of hybrid modulators. Concerning LTE/LTE-A networks, it is required to complete the definition of a MBSFN dedicated carrier within eMBMS standard and to support larger CPs. The integration of a dedicated MBSFN carrier into the existing LTE system can be achieved by carrier aggregation, which allows the simultaneous reception of both broadcast and unicast services by using a normal LTE-A unicast carrier as primary cell and the MBSFN dedicated carrier as secondary cell. The reception on the dedicated broadcast carrier should be enabled by proper signaling located in LTE-A unicast carrier. Moreover, the Tower Overlay resources could be shared by multiple MNOs if all of them inform in their unicast carriers about the availability of dedicated carriers for broadcast services.

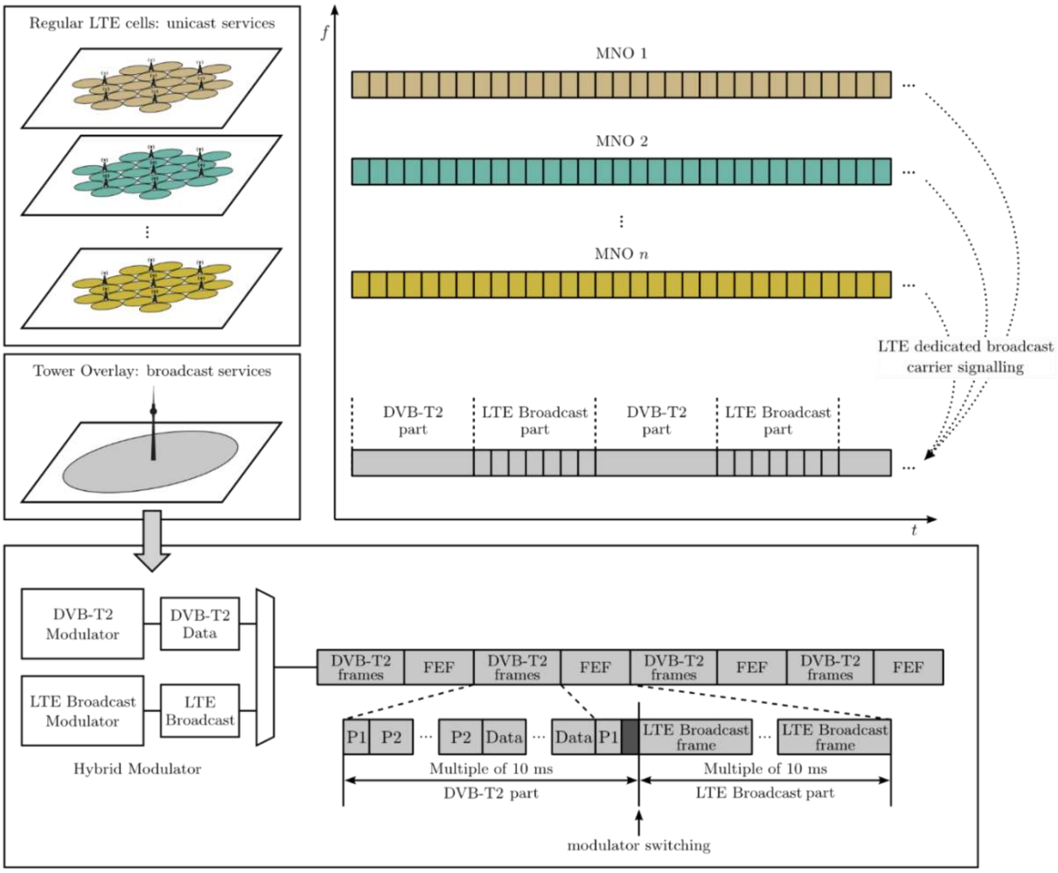

Figure 4. A Tower Overlay over LTE-A with the integration of an eMBMS dedicated carrier into DVB-T2 FEFs.

In order to comply with the timing regulations of both standards, special consideration is required on the length of the FEFs as well as T2 frames. Both LTE and DVB-T2 standards operate with different elemental periods defined as the inverse of their sampling frequency. To ensure a constant length of both frames types over a complete T2 superframe, the length of the two different parts in which the hybrid carrier is divided must be an integer multiple of 10 ms, that is, the length of a single LTE radio frame. This fulfills the requirements of the DVB-T2 standard regarding FEF and enables the synchronization between the LTE unicast carrier and the dedicated broadcast carrier. Thus, T2 frames, the initial P1 symbol of the following FEF and a synchronization buffer whose length is an integer multiple of the DVB-T2 elemental period are contained in the DVB-T2 part, whereas the LTE dedicated broadcast part consists of an integer number of LTE radio frames.

3.2. LTE Broadcast as ATSC 3.0 Physical Layer

Currently, ATSC is working on the development of the ATSC 3.0 physical layer. Since most of the proposals take DVB-T2 and/or DVB-NGH as baseline, it is likely that ATSC 3.0 will have significant similarities with these two DVB standards. However, one of the proposals from Qualcomm and Ericsson is based on LTE Broadcast and proposes some enhancements of this standard in order to use DTT infrastructure to address both fixed and mobile use cases applications [8].

A key motivation of this proposal is the announced intentions to deploy LTE Broadcast by multiple MNO worldwide, where Qualcomm and Ericsson support these efforts with end-to-end integrated solutions. Moreover, LTE Broadcast provides an all-IP solution and, with some enhancements on the physical layer, it could be adapted for traditionally fixed TV broadcast services.

Qualcomm proposed a work item to 3GPP in order to improve the eMBMS efficiency from radio access perspective [12]. In particular, it proposed the use of longer CPs for large SFN delay spread environment and the adoption of the MBSFN dedicated carrier option completing the upper layer support. The definition of a dedicated carrier would enable new MBSFN use cases, where the control information would be delivered on another –unicast or mixed– carrier. However, this work item has not started to date in Release 12.

Although the ATSC 3.0 physical layer is currently under development, it is likely that the proposal based on eMBMS goes in the same direction as the 3GPP work item proposal. That is, to complete the definition of eMBMS dedicated carriers and to define longer CPs to address deployment scenarios using HPHT broadcasting networks.

4. Challenges for a future mobile converged network

Historically, the business modeling for mobile broadcasting has not been attractive, being the absence of a clear and viable economical model that resolves the monetary conflicts between cellular and broadcast operators one of the main issues behind the failure of mobile TV services [13]. However, both industries are separately taking steps towards the definition of broadcast solutions to cope with future mass mobile multimedia services. Mobile industry has nowadays a good opportunity with eMBMS and its future evolutions, and broadcasters are facing the definition of a worldwide DTT standard capable of supporting both rooftop and mobile reception.

In this framework, it is quite likely that these two industries, with their different network infrastructures, will compete for market and spectrum. However, the abovementioned trends for cooperation highlight the mutual benefit of a complementary use of both networks. For example, broadcasters need more infrastructures to provide mobile services to indoor users. The definition of the future 5G system brings a new opportunity for convergence, which would benefit both industries alike.

4.1. Spectrum usage: from a problem to a solution

Future 5G mobile communications systems are required to make a flexible and efficient use of the available spectrum, whether contiguous or not, supporting wildly different network deployment scenarios [4]. In 2020, the envisaged spectrum requirements range between 1280 MHz and 1720 MHz [14]. However, the current spectrum allocated by International Telecommunication Union (ITU) is much lower than these values in the three ITU Regions. The last decisions of the ITU regarding spectrum reallocations focus on reducing this deficit. In particular, ITU decided in the World Radiocommunications Conference 2007 (WRC-07) to allocate part of the UHF band traditionally used for analogue TV broadcasting to International Mobile Telecommunications (IMT) technologies. This band, also known as digital dividend, ranges from 790 to 862 MHz in Region 1, and 698-790 MHz Region 2 and Region 3, and requires additional guard bands to avoid interferences between cellular and broadcast technologies. The worldwide allocation of the 700 MHz band to IMT technologies is on the agenda for the next WRC-15. Table 1 shows candidate bands for IMT under WRC-15 agenda [14].

Table 1. Possible candidate bands for IMT under WRC-15 Agenda Item 1.1.

Spectrum bands	Current user	WRC-15 target
Parts of 500-600 MHz [470-around 694 MHz]	TV broadcasting PMSE	Regional identification for IMT usage Need cooperation with broadcast industry
700 MHz [694-790 MHz]	TV broadcasting PMSE	IMT identification for Region 1 Proposed in WRC-12 and included in the WRC-15 AI 1.2
Parts of 1.4 GHz [1350-1525 MHz]	Digital Radio Fixed Service Scientific	Global identification for IMT usage Scientific use, only in a part of frequencies and some parts of regions
2700-2900 MHz	Radar	Global identification for IMT usage
3.4-3.6 GHz	IMT Satellite	Global identification for IMT usage
3.6-3.8 GHz	IMT Satellite	Global identification for IMT usage
Parts of 3.8-4.2 GHz	Satellite	Global identification for IMT usage
Parts of 4.4-4.99 GHz	Satellite	Global identification for IMT usage

By developing a single 5G standard to cope with both mobile a broadcast industry demands, an optimum usage of the spectrum based on spectrum sharing would be enabled. A coordinated spectrum access, as opposed to a competitive and mutually-interfering access, would also render infrastructure sharing and simplified international frequency coordination.

4.2. New opportunities and attractive business models

5G could smooth out current dissension between industry players and prepare for a new converged industry, with new class of services and new business models in which all parties, mobile network operators, content providers, broadcasters, spectrum holders and advertisers, could benefit from this convergence solution and offer a full alternative to terrestrial TV broadcasting as a universal service.

Regarding the mobile industry, the higher transmission efficiency of broadcasting as compared with unicast delivery would reduce network overload while diminishing the CAPEX associated with the ultra-dense deployment of transmission points. Moreover, the possibility of sharing spectrum would reduce the investment in spectrum auctions, improve the quality of service and enable new services and revenues. Concerning broadcasters, the definition of a worldwide DTT standard would boost economies of scale enabling the integration of mobile TV into handheld devices. This will make current broadcasting services grow in terms of scope and availability. In addition, the future 5G networks could also be used to provide TV services to fixed receivers, which would entail the implementation of mobile cellular chips into TV sets.

4.3. Requirements for successful convergence

Although last generations of terrestrial broadcast and mobile systems are quite similar in their fundamentals –e.g. they are OFDM-based–, the optimal radio configuration comprising signaling, procedures and transmission modes is different for broadcast services due to their particular features. Future 5G networks must address several requirements for a successful convergence of both industries.

Firstly, the converged solution in 5G shall include a flexible and scalable broadcast mode able to allow the transmission of mass multimedia services to mobile and stationary receivers through different network infrastructures. This broadcast mode shall support the efficient transmission of mobile HDTV services. In addition, it shall support the use of traditional broadcasting HPHT infrastructure to increase the coverage range and should be able to share the same frequency used for transmitting fixed Ultra-HDTV services using time multiplexing. The future air interface shall be flexible enough to accommodate different sharing scenarios by using dynamic profiles that could switch from unicast to broadcast mode. In this sense, some radio functions could be activated/deactivated/modified on demand depending on the specific needs of the service and the status of the network.

5. Conclusions

This paper has reviewed the state-of-the-art and the current trends on mobile multimedia broadcasting, and promoted the convergence of cellular and broadcast networks in the future 5G mobile networks. Although the integration of both networks is on the roadmap of both industries, there are still some challenges that have been identified throughout this paper. Potential technical enablers for such convergence are the Future Extension Frames of second-generation DVB-T2 networks, which allows combining in the same frequency broadcast and cellular transmissions via time multiplexing, or the carrier aggregation feature of LTE-Advanced, which allows temporarily using a broadcast frequency for cellular transmissions. However, the main issue is that LTE broadcast eMBMS technology does not incorporate a sheer broadcast mode and especially that it cannot be efficiently deployed in HPHT traditional broadcasting infrastructure due to their short guard intervals. Those considerations should be the starting point for the definition of a joint solution within the 5G framework.

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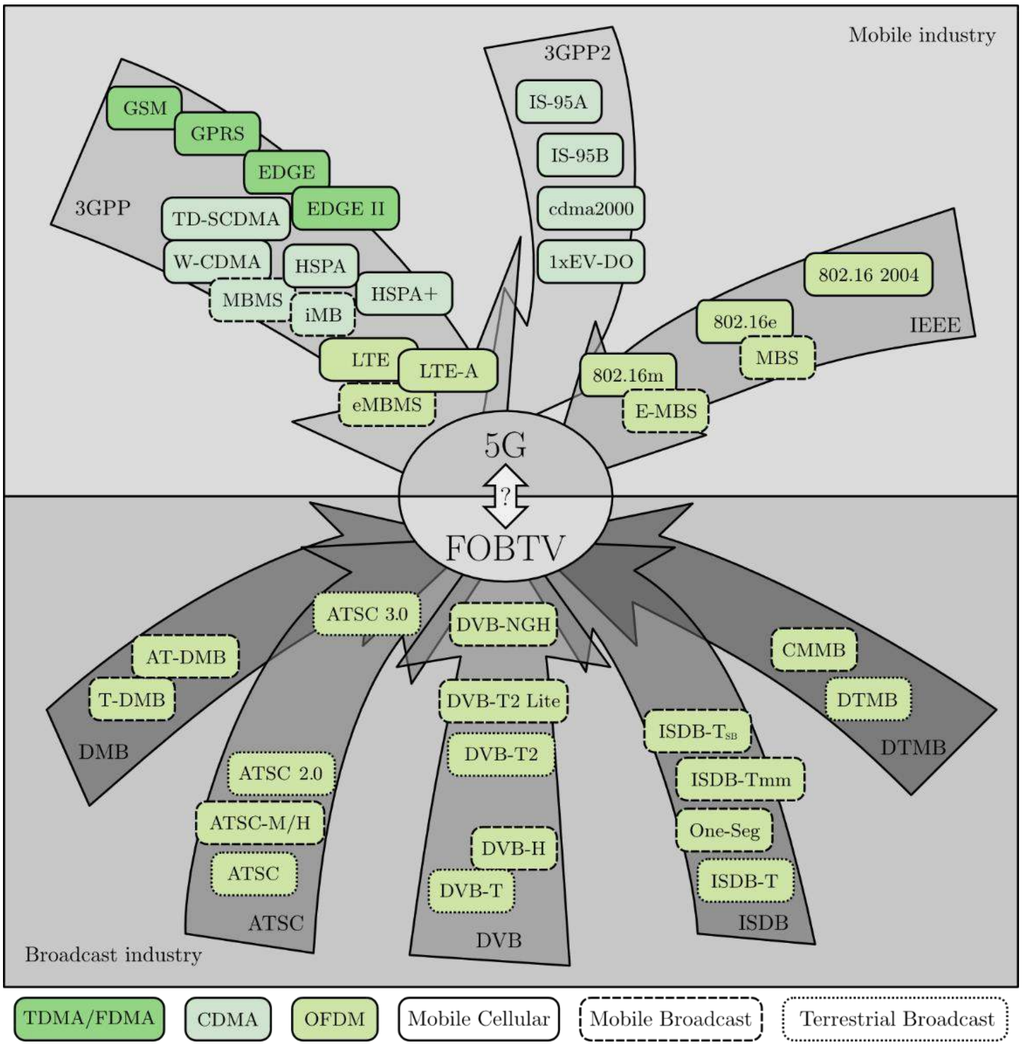

Figure 5. Mobile communications and DTT standards landscape.

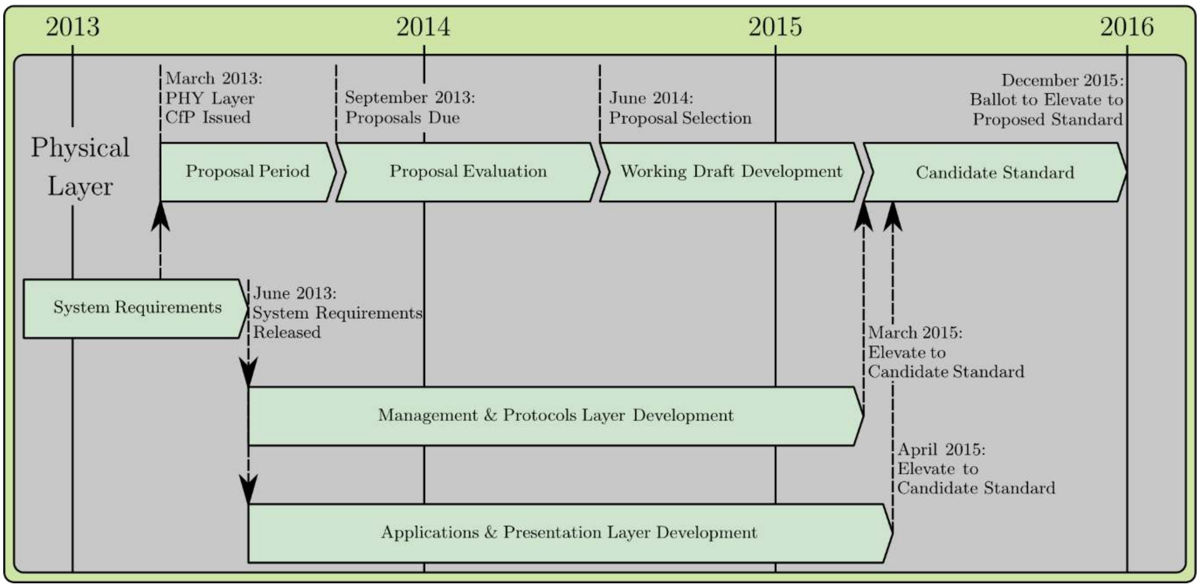

Figure 6. ATSC 3.0 Standard Development Timeline.

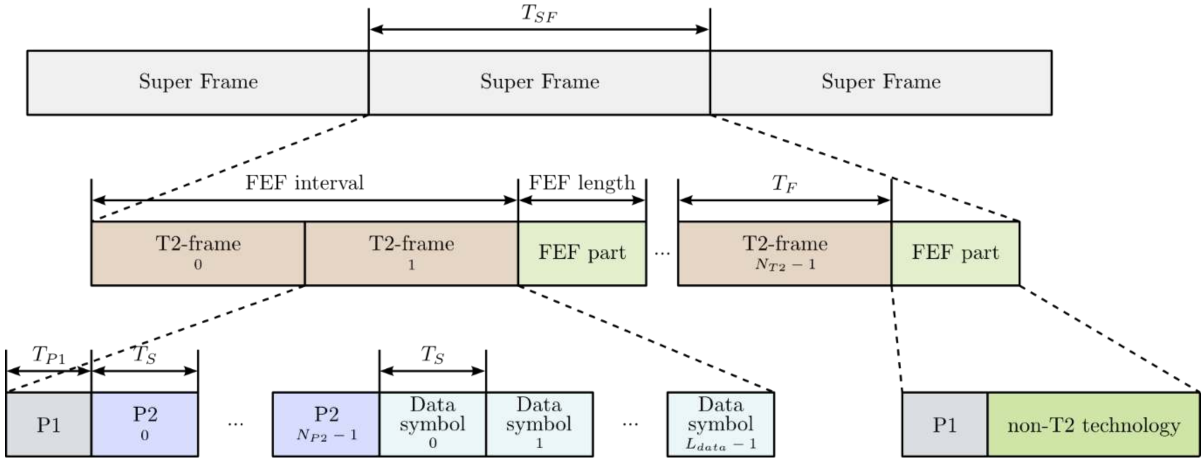

Figure 7. The DVB-T2 frame structure, showing the division into super-frames, T2-frames and FEF.

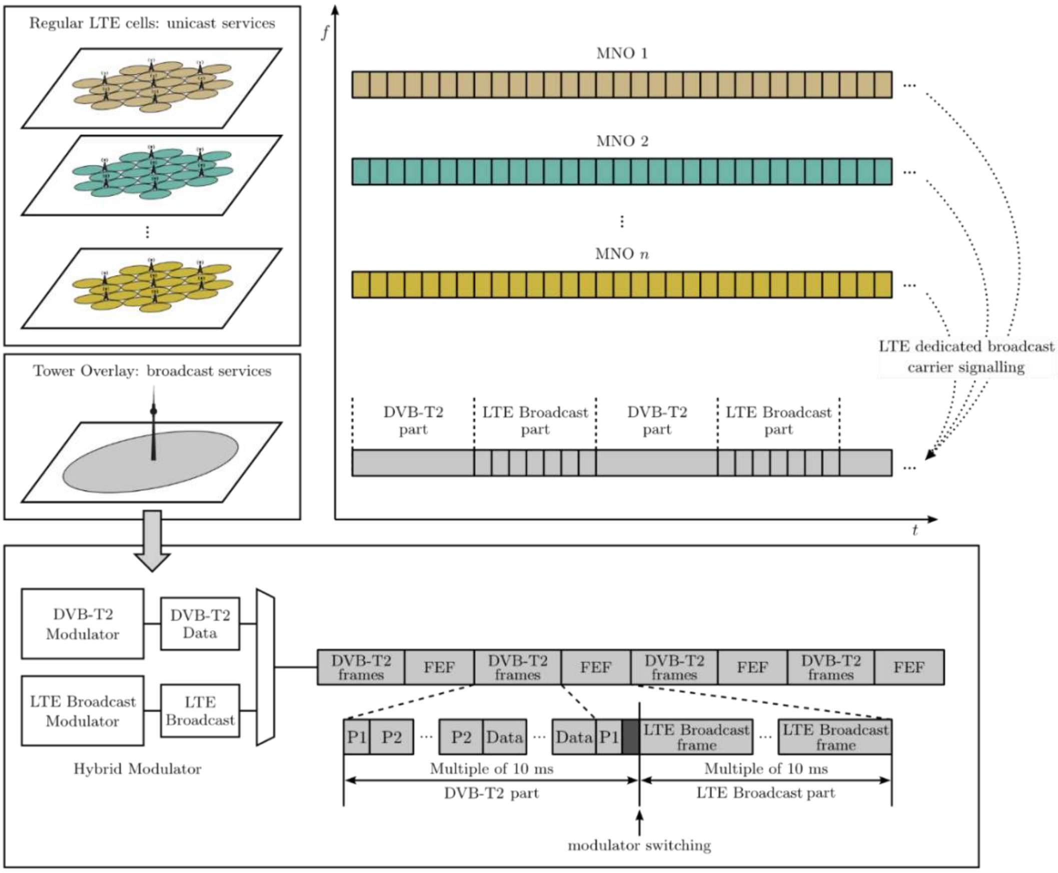

Figure 8. A Tower Overlay over LTE-A with the integration of an eMBMS dedicated carrier into DVB-T2 FEFs.