How IP-based broadcast meets 5G for resilient and sustainable media distribution

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Foreword

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DVB is an industry-led consortium of broadcasters, manufacturers, network operators, software developers, regulators and others from around the world committed to designing open, interoperable technical specifications for the global delivery of digital media and broadcast services. DVB specifications cover all aspects of digital television from transmission through interfacing, conditional access and interactivity for digital video, audio and data. DVB dominates the digital broadcasting environment with thousands of broadcast services around the world using DVB specifications. There are hundreds of manufacturers offering DVB-compliant equipment. To date, there are over 1 billion DVB receivers shipped worldwide.

Abstract

The newest generations of technical standards for digital terrestrial television broadcasting have embraced IP-based approaches. At the same time, we have seen the inclusion of multicast and broadcast technologies in the most recent releases of the global mobile telecommunications standard, with the availability of 5G Broadcast being one significant outcome, along with the integration of 5G Multicast/Broadcast capabilities within the 5G Media Streaming system. While true convergence between broadcast and mobile technologies remains unlikely to occur, the preconditions for mutually beneficial interworking between the different systems seem now to have been mostly fulfilled. This paper describes the main evolutions of both broadcast and mobile technical standards as they have approached more closely the domains of the other, culminating most notably with the arrival of ATSC 3.0, DVB-I and DVB-NIP as game-changing systems, and the aforementioned new solutions from 3GPP. Having described the innovative aspects of the different systems, the paper highlights some of the collaborative initiatives that target interworking, whether at the system core, on the radio frequency level or on the service layer, involving the standards developing organizations behind the systems.

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1. Introduction

The world's broadcasting standards have been evolving towards IP (Internet Protocol) based approaches. At the same time, 3GPP (Third Generation Partnership Project), the overarching standards developing organization (SDO) for mobile telecommunications, has begun to incorporate multicast and broadcast capabilities, one outcome of which is 5G Broadcast. The latter has the potential to play a role in the terrestrial delivery of digital television among the already well-established digital terrestrial television broadcasting (DTTB) systems. These include the ATSC (Advanced Television Systems Committee) standards; those from the DVB Project, notably DVB-T2; the ISDB-T (Integrated Services Digital Broadcasting – Terrestrial) system from ARIB (Association of Radio Industries and Businesses) in Japan; and the DTMB (Digital Television Terrestrial Multimedia Broadcasting) system developed in China. On the other hand, most of the broadcasting standards attempted to include reception on mobile devices in scope, with the inclusion of IP-based technologies partly intended to help to serve this purpose.

Both broadcast and mobile telecoms systems offer unique advantages that are inherited from their own history and that are specific to their former targets, namely traditional one-way receivers (e.g., TV sets), and bidirectional IP-based mobile devices respectively. For instance, the high spectral efficiency of the latest-generation broadcast networks such as those based on ATSC 3.0 or DVB-T2/DVB-NIP (DVB Native IP) are well established, as well as the lower carbon footprint of broadcast compared to unicast streaming. On the other hand, 5G Broadcast brings the ability to deliver linear television services directly to mobile devices, and its use in combination with unicast enables novel use cases.

While convergence between the broadcast and mobile systems (and even among the broadcast systems themselves) has proved elusive, those on both sides have long recognized the potential for mutual benefits if ways could be found to interwork, if not actually converge. Several efforts have already targeted this goal, most failing to reach the market due to a lack of ecosystem support rather than technical issues. Still, bridges between the two industries continue to flourish.

This paper outlines the various initiatives in this direction, clarifying their rationale and implications, and providing some perspective on their possible future. For this purpose, after a short history of broadcast and 3GPP standards' evolution towards IP-based and broadcast approaches respectively, this paper gives an overview of the various solutions initiated by the two worlds to interwork. Emphasis will be placed on the most recent endeavors and solutions stemming from the game-changing capabilities offered by the second-generation terrestrial broadcast systems – in particular ATSC and DVB – and the LTE (long term evolution) based ones from 3GPP. Can they complement each other and eventually converge towards a more resilient and sustainable media distribution landscape?

2. Broadcasting Standards' Road to IP, Multimedia and Mobile

While broadcast systems initially targeted fixed television, most of them progressively evolved to also deliver broadcast services to mobile devices, from as early as the first-generation DTTB standards.

2.1. First-Generation DTTB Standards: The First Building Blocks

In the early 2000s, a 'mobile TV wave' broke out in the world of broadcast standards on every continent, first with DVB-H and DVB-SH in Europe, T-DMB in Korea, 1-Seg in Japan, then MediaFLO followed by ATSC-Mobile in the United States and CMMB (China Mobile Multimedia Broadcasting).

In Europe, although DVB-T, the terrestrial transmission system from DVB, had the ability to serve fixed, portable and mobile devices, DVB-H, published by ETSI in 2004, was developed to better meet the specific requirements of handheld, battery-powered devices with embedded antennas. Building on DVB-T, DVB-H adds specificities like time slicing, IP-datagram-based transmission via DVB-MPE (Multiprotocol Encapsulation) into the MPEG-2 TS (Transport Stream). DVB-MPE is a data link layer optimizing the transport of IP packets over DVB networks. In 2007, this was complemented by DVB-SH (Satellite services to Handhelds), a system that intended to provide IP-based media content and data for broadcast services over a hybrid satellite and terrestrial infrastructure. DVB-H later evolved into DVB-NGH (Next Generation Handheld), providing improved spectral efficiency and better modulation flexibility.

Elsewhere in the world (Figure 1), ISDB-T, the Japanese system (a version of which is also used throughout most of South America and a handful of other countries), provides that one of the 13 segments used per transmitted channel is dedicated to mobile reception, hence the name of its mobile extension: 1-seg (or One-Seg). The Chinese standard CMMB is another mobile television and multimedia standard announced in 2006 and equivalent to DVB-SH. In the same way, in 2009 the American standard ATSC 1.0 was officially expanded with the ATSC-M/H (Mobile/Handheld) extension that includes additional channel coding mechanisms to improve robustness against Doppler shift and multipath radio interference.

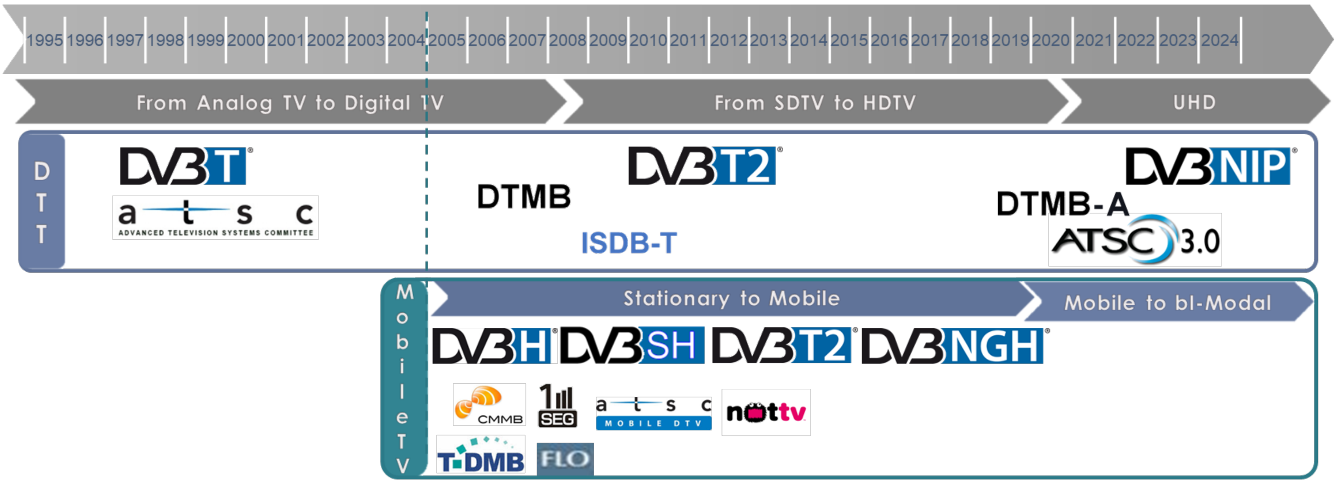


Figure 1: The main DTTB standards and their mobile extensions

Market-wise, some free-to-air mobile television services were available in Asia, in particular in Korea with T-DMB and Japan with 1-seg, while several DVB-H/SH trials – and a few commercial deployments – took shape in Europe (Italy, Austria, Ireland, Netherlands, Switzerland) as well as in Ukraine, India, Singapore, Philippines, Malaysia, Vietnam, China, United States, Jamaica, Kenya, Iran, South Africa.

However, DVB-H was acknowledged as a failure, alongside its main competitors 1-seg, T-DMB, ATSC-M/H and MediaFLO (a proprietary technology developed by Qualcomm). Rather than being technology-bound, the lack of market acceptance was mainly due to the lack of receiving devices resulting from the fact that first-generation standards were not suitable for mobile usage and therefore there were no available devices in the market including built-in tuners and UHF antennas, which could have made for an easier transition towards multimedia broadcasting. The lack of a business model was an additional factor. Indeed, mobile television broadcasting requires deep collaboration between the broadcasting and telecommunications industries, which, at that time, could not foresee tangible mutual benefits.

2.2. Second-Generation DTTB Standards: Paving the Way for Multimedia Broadcasting

Despite the unconvincing first attempts to introduce mobile television in the broadcast world, the second-generation terrestrial broadcast systems were developed with similar hopes.

2.2.1. DVB-T2

The DVB-T2 standard, first published by ETSI in 2009 and currently available as TS 102 755 v1.1.1 [1] is already widely deployed throughout the world, not only in Europe but also in most of the African and ASEAN countries, parts of Latin America, and India. It builds on DVB-T but offers increased flexibility in system parameter choices, for example the COFDM (Coded Orthogonal Frequency Division Multiplexing) options. It also introduces the LDPC (Low-Density Parity Check) code for more efficient Forward Error Correction (FEC), and it significantly reduces overhead, allowing throughput close to the theoretical maximum channel capacity (known as the Shannon limit). DVB-T2 also introduces Physical Layer Pipes (PLP), allowing various combinations of COFDM constellation and code rate parameters to co-exist in the same radio frequency channel, resulting in the possibility of simultaneously transmitting signals with various robustness/bandwidth ratios.

Although DVB-T2 offers efficient and reliable audio/video and data transmission for both fixed and mobile devices, a DVB-T2-Lite profile was introduced in the third version of the standard published in 2011 (EN 302 755 v1.3.1), specifying a constrained set of system parameters. Combined with the use of PLPs, various parameter combinations can cover different needs for multimedia broadcasting. For instance, this gives the flexibility to transmit a high bitrate signal – with lower robustness – for fixed reception alongside a signal with high robustness – but offering lower bitrate – for indoor reception.

However, in contrast to outdoor versus indoor reception, which DVB-T2 can accommodate with the use of dedicated PLPs, fixed versus mobile transmission implies specific requirements demanding different waveforms. Since all PLPs of the same T2 frame must share the same waveform (FFT size, Guard Interval (GI)), the only way to respond to these needs is to rely on the use of Future Extension Frames (FEFs), introduced in DVB-T2 v1.1.1. FEFs offer the possibility of combining, in a mixed configuration mode, signals with two different waveforms (i.e., each with their own FFT and GI parameters). In practice, this results in the possibility of deploying possible future enhancements of DVB-T2 (or some other future standard) without disrupting the operation of legacy receivers. The DVB-T2 FEFs can thus be used for the simultaneous transmission of different waveforms, for instance one adapted to stationary applications for UHD reception (e.g. with FFT of 32K and GI of 1/16) carrying a DVB-T2 Base profile, and one adapted to the constraints of mobile reception with fast moving antennas (e.g., FFT of 8K and GI of 1/8), carrying a T2-Lite profile, as was evaluated during a field trial carried out by Abertis in Spain in 2013 [2].

Although FEFs represented a technical breakthrough, their use was leveraged in only a few of the numerous DVB-T2-Lite implementations and trials that emerged worldwide (Spain, Italy, Denmark, South Africa, India, Singapore, Thailand). Some deployments used the DVB-T2 Base profile instead of DVB-T2-Lite one, with satisfactory results. This was the case, for instance, in India and Singapore, where a handful of mobile DVB-T2 receivers were available until recently (e.g., Samart I-Mobile).

Still, the FEF feature is likely to play an important role in how DTTB systems interwork with 3GPP systems in future, all the more since most evolved digital broadcast standards support this feature, as is the case for ATSC 3.0, introduced below.

2.2.2. ATSC 3.0

As another second-generation DTTB system, ATSC 3.0 is effectively the successor of ATSC 1.0 (ATSC 2.0 not having ever been fully launched), which is used in the United States, Canada, Mexico, and South Korea. ATSC 3.0, released in 2019, is specified in several distinct documents, which allows for the independent evolution of the various aspects of the standard. Unlike DVB-T2, it is not backwards compatible with its predecessor. However, it provides flexibility in the physical layer to cover a large range of service options thanks to a few additional tools that were not included in DVB-T2 for the sake of backward compatibility with DVB-T and the large installed base of antennas, as well as for cost efficiency of the required infrastructures and receivers.

The physical layer of ATSC 3.0, defined in A/322 [5], was built upon the same basic architecture as DVB-T2, using COFDM modulation and LDPC codes. ATSC 3.0 includes additional tools such as non-uniform constellations, advanced LDPC codes, and MIMO (Multiple-Input and Multiple-Output). This increased complexity results in a much higher payload capacity compared to the first-generation ATSC standard (ATSC 1.0/2.0) and its mobile/handheld extension (ATSC-M/H). It also achieves a small improvement in performance compared to DVB-T2, being very slightly closer to the theoretical Shannon limit, in addition to providing a wider operating range in terms of signal-to-noise ratio (SNR) as outlined in [3] and depicted in Figure 2.

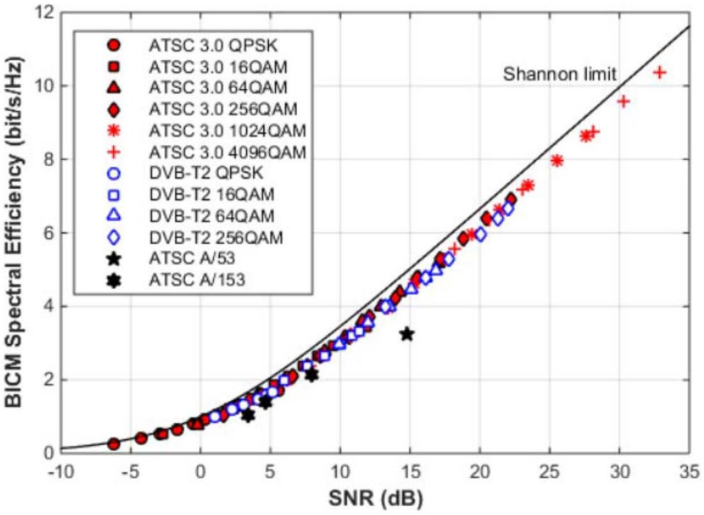


Figure 2: ATSC 3.0 modulation performance [3]

The transport layer, defined in A/331 [6], is where the most significant difference between ATSC 3.0 and DVB-T2 lies. While the latter uses the widely adopted MPEG-2 transport stream (MPEG-2 TS) format, ATSC 3.0 introduces a fully IP-based core with a view to facilitating integration with the emerging trend towards the use of IP (Figure 3).

ATSC 3.0 services are divided into categories such as linear ones (audio/video or audio), applications, service guide, and emergency alerts. According to the type of service (e.g., real-time or not), they are delivered using either:

- DASH (Dynamic Adaptive Streaming over HTTP) segments over ROUTE-DASH (Real-Time Object Delivery over Unidirectional Transport),
- or MPU packets (Media Processing Units) over MMTP (MPEG Media Transport Protocol).

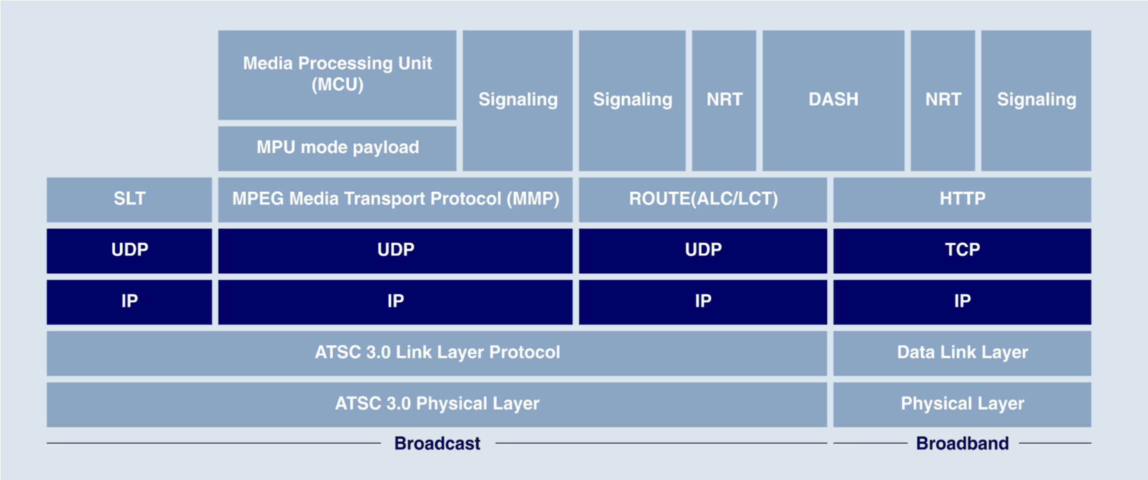


Figure 3: ATSC 3.0 protocol stack [6]

This fully IP-based approach makes it easier to combine over-the-air (OTA) broadcast signals with content received via broadband networks. In addition, together with its increased spectral efficiency and robustness compared to the first-generation standard, ATSC 3.0 marks a further step towards a system more suited to mobile broadcasting.

This is why ATSC positions its latest terrestrial broadcasting standard as a candidate for direct broadcasting to mobile devices, sometimes described using the term direct-to-mobile (D2M). D2M is the name given by the government of India to its policy seeking the ability to deliver content – received directly on mobile phones – to the millions people lacking internet connectivity in rural areas, with the fulfilment of educational needs being a primary goal. At the time of writing, no candidate technology has been selected for D2M in India, but trials have been carried out with ATSC 3.0 and 5G Broadcast Release 17 (described later in this paper), together with RF performance comparisons [4]. The latter study has shown that higher spectral efficiency was demonstrated by ATSC 3.0 (and by extension DVB-T2) compared to 5G Broadcast, and that the latter would require more transmitting sites for the same coverage: from 40% to 150% more sites would be needed, depending on the bitrate, channel environment and receiver capabilities and mobility.

Despite the generally higher RF performance demonstrated in [4] by ATSC 3.0, similar difficulties as were experienced with the first-generation DTTB standards are hindering its market adoption as a mobile broadcasting system. There remains a lack of receivers embedding broadcast-capable chipsets. The integration of ATSC 3.0 receiving capabilities in smartphones requires hardware changes that would impact their cost, and such integration is also likely to impact mobile operators' data revenue and business plans. Additionally, the infrastructure for transmitting ATSC 3.0 in India is not yet present, creating further challenges for device makers, only like to adjust production when the entire ecosystem is in place. At the time of writing, the only ATSC 3.0-capable smartphone is the Mark ONE prototype, developed by ONE Media, not yet available as a product on the market.

ATSC 3.0 also positions itself as a candidate system for harmonization with 5G, and several efforts towards global convergence of the main DTTB systems were initiated by ATSC, as will be described later in this paper.

2.2.3. DVB's IP-Centric Solutions

The past five to ten years have seen DVB focusing heavily on IP-centric solutions to facilitate the migration of broadcasters to IP-based distribution and consumption that, beyond representing a significant challenge, brings a new wave of opportunities for the broadcast industry. The different topologies and market specificities from country to country came as an additional challenge, especially considering the large number of countries using DVB technologies, implying heterogenous ways to manage such migrations. This particularly complex issue gave birth to the DVB-I service discovery solution [7], used in conjunction with DVB-DASH [8] for service delivery via internet, as described hereafter.

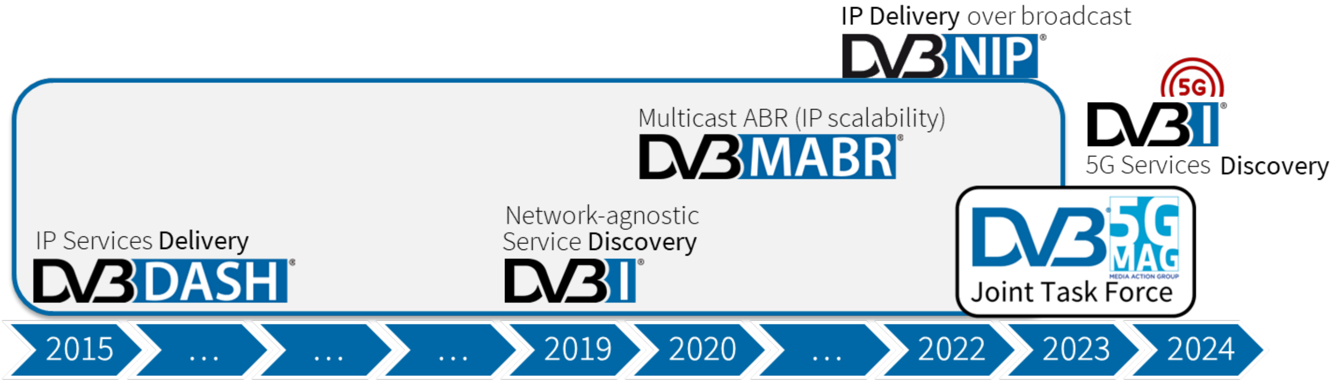


Figure 4: DVB's IP-centric set of solutions

2.2.3.1. DVB-I Service Discovery

Unlike DVB-T2 and ATSC 3.0, both broadcasting standards used for the *delivery* of services, DVB-I (Internet) is a service layer specification. Initially published in 2019 as TS 103 720 v1.1.1, its latest version is DVB BlueBook A177r6 [7], which will in due course be published by ETSI as TS 103 720 v1.2.1. DVB-I defines the metadata for the *discovery* – via the internet – of services and service lists that are available through either broadband or broadcast networks. This metadata, provided in a common XML format, is used by receivers such as connected TVs, smartphones, or tablets to populate the channel list and retrieve the electronic program guide (EPG) for linear services as well as for on-demand content. Conceptually, it is equivalent to DVB-SI (DVB Service Information) and PSI (Programme-Specific Information) carried in a broadcast MPEG-2 TS.

DVB-I is also an umbrella term that is sometimes used to refer to the services that are discovered using the DVB-I discovery mechanism and delivered via the internet, typically using DVB-DASH (Dynamic Adaptive Streaming over HTTP) [8]. DVB-DASH is a profile of the MPEG-DASH standard to support Adaptive Bit Rate (ABR) streaming over HTTP with a high degree of interoperability and low-latency support. However, DVB-I services are not limited only to DVB-DASH delivery: DVB-I services include any service that can be discovered using DVB-I and is available via one or more delivery mechanisms, called service instances, including DVB-DASH, DVB broadcast and 5G technologies, as will be described later.

Concretely, DVB-I allows services delivered from any network type (broadcast and broadband networks) to be discovered in a fully transparent manner on the end-user side (Figure 5). This network-agnostic approach allows broadcasters to adopt a flexible and hybrid use of the most appropriate or cost-effective delivery network according, for instance, to the popularity of services or to the country's topology and whether services target high-density or more rural areas. It also allows countries to evolve at their own pace in their migration journey and include new networks in the content delivery 'mix' as they become relevant. The combination of existing broadcast networks (terrestrial and satellite DVB-T/T2/S2) with the broadband infrastructure can be leveraged to foster interactivity and innovative ways to monetize content.

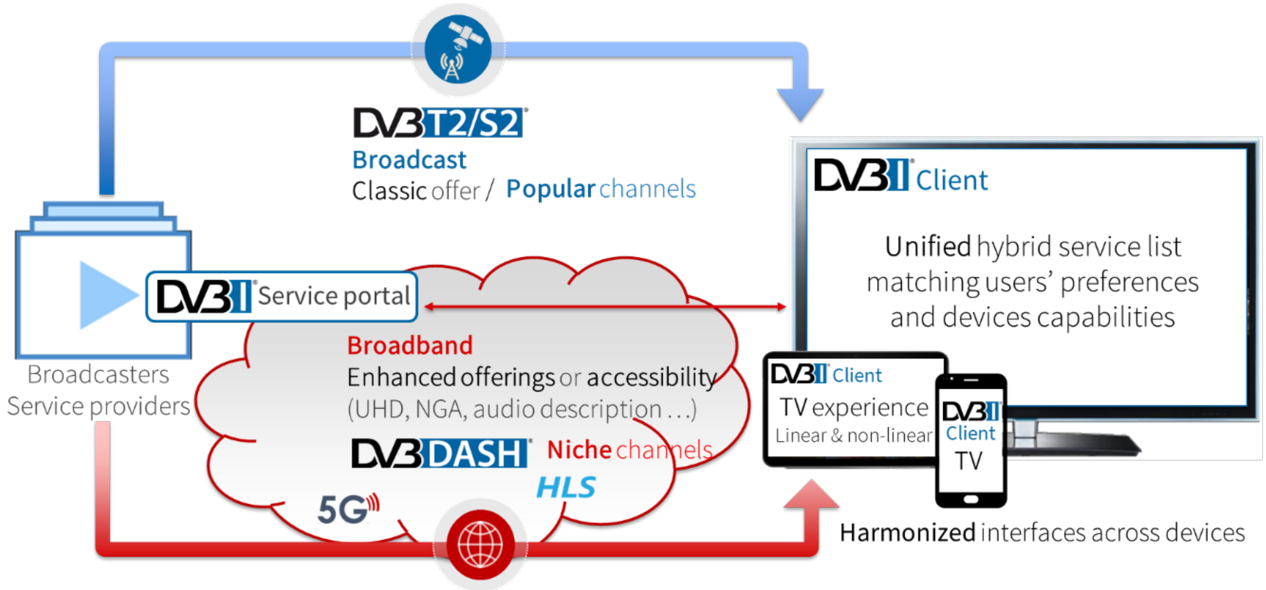


Figure 5: DVB-I use for IP migrations or for offerings enhancements

DVB-I is running in Italy following a series of trials, including one started in 2019 by the broadcaster Mediaset. In Germany, a trial started in 2022 with 71 services and involving 21 participants, including public and private broadcasters alongside service providers and device manufacturers. Further trial activities have taken place in Ireland, Spain, France, and Iran, and DVB-I is also actively considered in several places outside Europe.

DVB-I was recently enhanced to also support 5G technologies and it is now acknowledged as having a role to play in the ways the 3GPP system can interwork with non-3GPP ones, as will be elaborated later in this paper.

2.2.3.2. DVB Native IP Broadcasting

In February 2022, DVB's IP-centric solutions were extended with a further landmark specification, DVB Native IP broadcasting (DVB-NIP), currently published as DVB BlueBook A180r2 [9] and in the process of being published by ETSI as TS 103 876. DVB-NIP defines a protocol stack for satellite and terrestrial television broadcasting entirely based on IP and no longer relying on the MPEG-2 TS layer. DVB-NIP reuses DVB's already existing IP-based standards such as the Multi-Protocol Encapsulation (DVB-MPE) introduced in the first generation of DVB standards, or the Generic Stream Encapsulation (DVB-GSE), introduced in the second generation and providing more efficient encapsulation of IP over a generic physical layer. Figure 6 below gives an overview of DVB-NIP protocol stack.

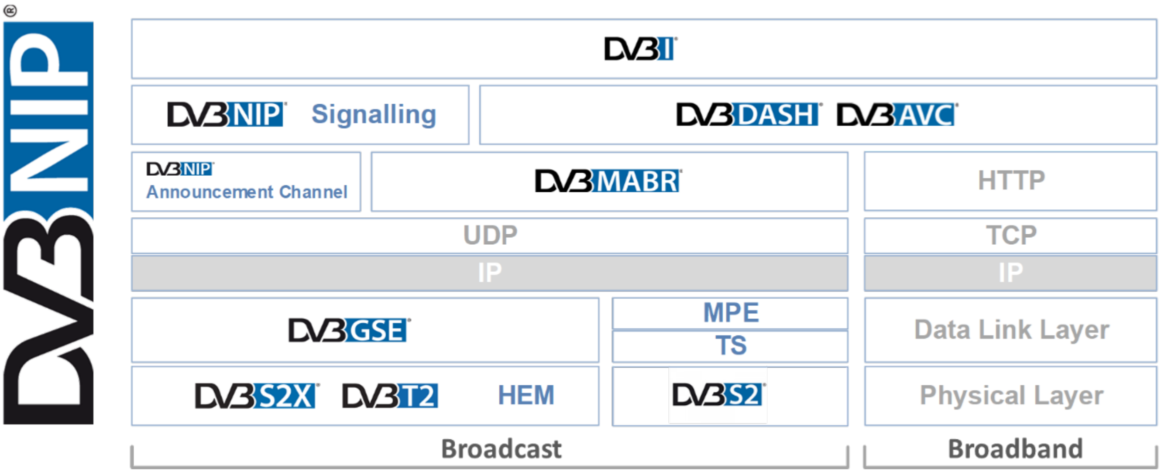


Figure 6: DVB-NIP protocol stack

- **Audio/video coding**: Like DVB-T2, DVB-NIP relies on the same audio and video coding (DVB-AVC) technologies, ensuring interoperability at the audio/video coding layer among the various DVB networks and platforms, through the definition of conformance profiles for codecs. This includes for instance – historically – profiles of MPEG-2 and H264/AVC, then H265/HEVC, initially for High Definition then also for Ultra-High-Definition Television (HDTV and UHDTV), including 8k (UHDTV-2), and more recently, profiles for Versatile Video Coding (H266/VVC) and AVS3, the third-generation codec from the AVS (Audio Video coding Standard) Workgroup of China were also defined.
- **Audio/video Packaging**: DVB-NIP relies on DVB-DASH, where specific profiles of MPEG-DASH are specified for use with the audio and video conformance points defined in DVB-AVC for appropriate and highly interoperable use within the DVB ecosystem,
- **Multicast distribution**: DVB-MABR (Multicast ABR) specifies how linear DVB-DASH services can be carried simultaneously to large audiences using multicast, using either a profile of 3GPP FLUTE or a profile of ATSC ROUTE (with DVB-specific extensions), and optionally, profiles of MSYNC or NORM multicast protocols.
- **Link layer adaptation**: While DVB-GSE is used by default, the standard also includes an optional backwards-compatible mode that uses DVB-MPE to carry the IP packets within an MPEG-2 TS, for example to support the migration of existing terrestrial (DVB-T2) or satellite (DVB-S2) networks.
- **Transmission/physical layer**: This remains identical to DVB's second-generation standards: transport relies on either DVB-T2, DVB-S2 or S2X transmission. This makes transitions from existing DVB networks to DVB-NIP ones straightforward and cost efficient.

In the end, in its terrestrial flavor (DVB-NIP/T2), DVB Native IP is close to ATSC 3.0, both in terms of RF performance (as detailed in [3]) and in terms of the capabilities offered by a fully IP-based core.

DVB-NIP can cover, with the same broadcast signal, both consumer applications such as terrestrial broadcast and satellite Direct to Home (DTH), or professional content distribution applications (to CDN caches, to mobile base stations or broadcast tower sites, public hotspots, transportation, etc.). Rather than being promoted as a suitable standard for direct mobile broadcasting – for which the resistance to the necessary integration of specialized hardware in receivers is likely to persist – DVB-NIP is being considered as a means of serving legacy mobile devices through Wi-Fi hotpots using DVB-NIP gateways. This has already been successfully deployed in Peru, and trials have emerged in several places in the world, including Latin America, Europe, North Africa, Asia and India, where this use case was also demonstrated live from Delhi's Pitampura high-power terrestrial tower – upgraded from DVB-T2 to DVB-NIP/T2 – during BES 2023.

Possible ways for DVB-NIP to interwork with 3GPP networks, leveraging DVB-I as a network abstraction layer, are described later in this paper.

2.2.4. Global Evolution Towards Multimedia Broadcasting

Figure 7 gives an overview of the major second-generation DTTB systems. In addition to DVB-T2 and ATSC 3.0, the Digital Television Terrestrial Multimedia Broadcasting - Advanced (DTMB-A) system, mainly used in China, was also adopted by the International Telecommunications Union (ITU) in 2015 as a second-generation DTTB standard, and a DTMB-A mobile transmission was tested successfully during the Beijing Olympic Games. Finally, in Brazil, as a successor to ISDB-T, a brand new IP-based second-generation DTTB standard is being designed under the TV 3.0 project undertaken by the SBTVD (Sistema Brasileiro de TV Digital terrestre) Forum, targeting completion in 2025; and in Japan, ISDB-T is being developed into an enhanced IP-based version named Advanced ISDB-T, through ARIB (Association of Radio Industries and Businesses).

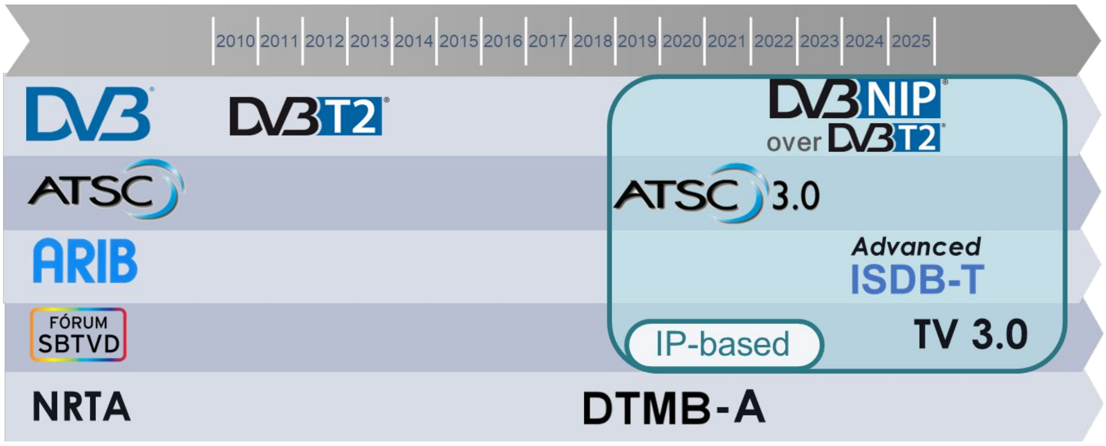


Figure 7: Overview of the main second-generation DTTB standards

Being designed for both fixed and mobile reception, second-generation DTTB standards make the distinction between digital terrestrial television and multimedia broadcasting systems vanish. At the same time, distinctions between digital terrestrial television and multimedia broadcasting receivers also progressively disappear since most televisions are now connected and all handheld devices – even low-cost ones – are equipped with HD or higher resolutions screens.

This paradigm shift sets the scene for the momentum towards alignment with mobile systems. Paradoxically, despite the many technological advances, major challenges remain for market adoption of broadcast capabilities in mobile devices, especially when originating from the broadcasting systems:

- Mobile devices must integrate specialized hardware to support the broadcasting standards that, furthermore, vary from region to region, which requires device manufacturers to build different models for each region, thus reducing potential economies of scale.
- The whole ecosystem would be required to adapt to a situation where the new broadcast-reception capability in mobile devices allows end users to consume zero-rated content over free-to-air broadcast networks, with substantial (probably negative) implications for the business models of mobile network operators (MNOs).

3. 3GPP’s Path Towards Broadcast and the UHF Band

While initially tailored for mobile point-to-point voice communications, the mobile industry – just like the broadcast industry – has faced a shift in user demand towards streaming and on-demand multimedia consumption, resulting in an increased level of traffic over networks and triggering the need for network adaptation. This led to cellular broadcast technologies whose evolution spanned across several generations and finally resulted in a practical 5G Broadcast system.

3.1. 5G Broadcast’s Foundations and Variants

As detailed in Figure 8, the support of broadcast/multicast technology in 3GPP dates to the days of 3G with the introduction of UMTS (Universal Mobile Telecommunications Service). Multimedia Broadcast/Multicast Service (MBMS) architecture and protocols were defined to support broadcast/multicast use cases with 2G and 3G networks. Commercial success did not follow, due to low media consumption at that time resulting in a lack of ecosystem support, but it provided the foundation for addressing broadcast/multicast services with 3GPP networks.

With the advent of 4G and the new LTE (Long-Term Evolution) standard, designed for wireless broadband communication, the MBMS system was enhanced, leveraging the strengths of LTE radio access technology. Those strengths include Orthogonal Frequency Division Multiplexing (OFDM), also used in the DVB-T/T2 and ATSC 3.0 systems, and Carrier Aggregation (CA). The relevant technical specification work was undertaken from 3GPP Release 9 to Release 16. The enhanced version of MBMS leveraging LTE was defined as eMBMS (evolved MBMS) in Releases 8 and 9, and Further evolved MBMS (FeMBMS), based on LTE-Advanced, was defined in Release 14. Also called “enhanced TV” (enTV) in the industry, FeMBMS expands to new services and meets most of the broadcasters’ requirements to enable digital terrestrial television broadcasting using cellular radio infrastructure.

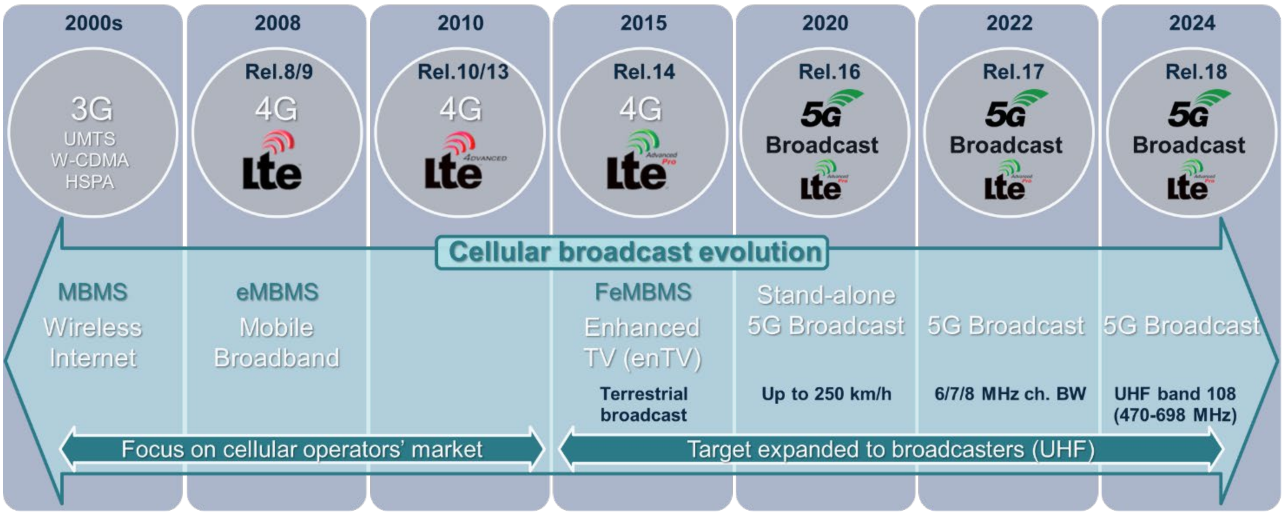


Figure 8: 5G Broadcast gestation across generations

Stand-alone 5G Broadcast

The requirements for stand-alone 5G Broadcast – i.e. relying on a broadcast-only network, for downlink-only traffic, and independent from cellular networks – were fully met in 3GPP Release 16 and include the UHF band 108 (470 to 698 MHz) since Release 18. This mode enables broadcast deployments using existing UHF spectrum and television broadcast infrastructure such as Medium-Power Medium-Tower (MPMT) and High-Power High-Tower (HPHT) networks.

3.2. 5G Broadcast Features and Value Proposition

Initially, the rationale behind 5G Broadcast was to enable broadcast operation for receivers/hardware compatible with cellular modems. Indeed, past experiences have shown that requiring a dedicated modem on mobile devices was a barrier to market adoption whereas easy integration into mainstream mobile devices was a prerequisite for market acceptance. This led to 3GPP's decision to evolve eMBMS to LTE-based 5G Broadcast instead of adopting radically new designs. Therefore, unlike with other broadcasting systems, the necessary additions to mobile device hardware for the support of 5G Broadcast are marginal since several building blocks are already present in 4G/5G modems.

Beyond its initial inclusion as part of the overall 5G system proposition, 5G Broadcast has been endorsed as a stand-alone terrestrial broadcast system specification via ETSI TS 103 720 [11] and most recently by ITU-R (the ITU Radiocommunication Sector), where it is defined as a worldwide standard within the ultra-high frequency (UHF) band. This standard specifically targets traditional broadcasters with a broadcast network infrastructure and UHF spectrum assets. In its current (Release 17) version, it supports:

- Single Frequency Networks (SFN) with large inter-site distance (up to 125 km);
- High mobility reception up to 250 km/h;
- "Transparent delivery", allowing the use of media codecs and protocols defined outside 3GPP; and
- 6, 7, and 8 MHz channel bandwidth in addition to the previously specified 1.4, 3, 5, 10, 15, 20 MHz.

In addition, 5G Broadcast primarily focuses on mobility use cases but for free-to-air broadcast, in stand-alone 5G Broadcast mode, it does not require the network to support unicast nor the device to have a SIM card or a cellular subscription. While unicast is not required, 5G Broadcast can alternatively be combined with unicast to deliver a hybrid user experience leveraging the best of unicast and broadcast technologies.

3.3. Prospects and Challenges for 5G Broadcast

Some of the promising use cases envisioned for 5G Broadcast include:

- **Dynamic offloading of unicast mobile networks to 5G Broadcast**: When the same content is consumed simultaneously by a large number of viewers over unicast cellular connections – which often results in a lowered quality of service and an increased cost for network operators – a seamless switch to the 5G Broadcast network could be beneficial. And when the broadcast network becomes unavailable – for instance when the user moves outside the 5G Broadcast coverage – the media player automatically goes back to unicast mode without interruption and without any user intervention.
- **Enhanced venue casting during events:** When many users in proximity simultaneously share limited network resources like a cellular tower, the cellular network faces a similar challenge. For these scenarios, 5G Broadcast could play a role by serving all users in the area with high-definition content from the event without overloading cellular towers nearby. This content could bring enhanced experiences, for instance with video feeds sent from various cameras located around the racetrack in the case of a race event, as was demonstrated by ORS during a MotoGP^{TM} event [10].

- **Emergency notifications**: During disaster events, the cellular network may become inoperative due to structural damage, especially because such networks are less physically resilient than HPHT broadcasting sites. In this case, the system designed to deliver emergency alerts to mobile devices within a specific geographic area – named CMAS (Commercial Mobile Alert System) – could alternatively be supported by the broadcast infrastructure, which could communicate with broadcast-capable devices. This is a priority for many public-safety agencies, and 5G Broadcast has become a prime candidate to enable such services and facilitate the delivery of emergency information and lifesaving instructions.
- **Vehicle to everything (V2X):** Another promising use case is V2X, where messages or alarms can be pushed to infrastructure and vehicles via broadcast.

For MNOs, such technologically advanced scenarios remain subject to some of the following requirements, depending on the way their execution is envisioned:

- **Collaboration with broadcast network operators**: A hybrid ecosystem needs to be put in place so that, for instance, highly popular live content could be delivered through 5G Broadcast when available and would not be counted as part of the user's data subscription.
- **Appropriate service layer**: The support of third-party services with a user-friendly/television-like service layer or application is another prerequisite for commercial success.
- **Content acquisition**: MNOs, as the service providers, may need to engage in expensive and complex content acquisitions.
- **New investments**: MNOs may need to invest in new infrastructure to add broadcast capability.

5G Broadcast demonstrations and small-scale trials have been undertaken in several countries, such as China, USA, France, Spain, Germany, Austria, and others. India is considering 5G Broadcast as a candidate technology for the Direct to Mobile (D2M) initiative.

3.4. 5G Media Streaming (5GMS)

To leverage new 5G features and capabilities for media distribution, from Release 16, 3GPP defines a 5G Media Streaming (5GMS) System [12] that enables media distribution over 5G networks by third parties other than MNOs. The 5GMS system allows 5G networks to provide technical and commercial opportunities for collaboration, beyond merely acting as a bit pipe. The 5GMS System supports value-added services such as content hosting, network assistance and dynamic network Quality of Service (QoS) policies, as well as reporting of consumption and Quality of Experience (QoE) metrics for analysis and optimization purposes. Such collaboration models facilitate video traffic monetization and revenue sharing between MNOs and content providers. While the first version of the 5GMS System focuses on media delivery over unicast, Multicast/Broadcast delivered using 5G New Radio (NR) is a key new feature introduced by 3GPP in Release 17, and the combination of this with 5GMS is specified in Release 18.

4. Ongoing Initiatives and Perspectives for Interworking

Unquestionably, both modern, IP-based broadcast systems and the broadcast-enabled 3GPP system offer advantages through their respective multi-faceted profiles, especially given the significant technological progress that was made by each to move towards ‘the other shore’. Still, both industries are facing several challenges when it comes to operating outside their initial scope, and some clear limits seem to be set in stone, especially regarding the physical layer. For instance, there have been initiatives for the integration of physical-layer elements of ATSC 3.0 into 3GPP systems to facilitate the implementation of ATSC 3.0

receiving capabilities in mobile phones, but any incorporation of non-3GPP elements has been so far limited to Wi-Fi or Bluetooth.

While the riverbanks are getting closer but seem unlikely to merge, an appetite for collaboration remains and initiatives to bridge the divide continue to flourish. This paper will now explore some of the ongoing initiatives to enable the systems to interwork. Instead of replacing one system with another, these initiatives aim at creating an environment in which the systems can co-exist either independently or cooperatively.

4.1. ATSC's Global Harmonization Efforts

ATSC initiated several efforts towards global convergence of the main DTTB systems to "develop a common voice on international issues affecting the broadcast community" such as the threat of losing further spectrum [14]. To date, second-generation DTTB systems are the most efficient physical layers for one-to-many delivery and are acknowledged as the most sustainable means of delivering large amounts of content to many users [13]. In addition, they rely on highly resilient HPHT infrastructure. Therefore, it would seem to make sense for these valuable DTTB systems to speak with a single voice on the world stage, as part of a global initiative to modernize their technologies in a way that would facilitate interworking with other networks, such as those specified by 3GPP.

While a convergence at the physical layer has proved difficult – the major obstacle being the lack of uniformity in the use of the broadcast spectrum throughout the world owing to the historical adoption of either NTSC, PAL or SECAM systems, leading to the use of either 6 MHz or 8 MHz channels and resulting in varying payload capacities – efforts for subsystem-level convergence may be more practicable. Indeed, technical commonalities, for instance with common video schemes or common multicast protocol profiles, would allow effective interaction at the application or transport layers and facilitate interworking. This can be achieved, for instance, through cross-organization collaboration during the respective work towards next-generation technologies. With this goal in mind, while adding VVC to its suite of standards, ATSC liaised with DVB and other organizations, including SBTVD and 3GPP, in order to seek potential alignment of ATSC VVC profiles vis-à-vis other standards.

4.2. Interworking at the System Core – ATSC Broadcast Core Network

In line with moving towards a harmonized broadcast system that would be interoperable with 3GPP, a further area where ATSC is particularly active is the development of a Broadcast Core Network (BCN). According to ATSC's report on global convergence [14], the BCN project aims at designing core networking capabilities within the ATSC 3.0 broadcast system architecture in order to facilitate efficient interworking between broadcast towers beyond Designated Market Areas (DMAs) and potentially across heterogeneous networks. Indeed, the BCN is being designed to be agnostic to the DTTB system and to enable converged operation with other data-delivery networks, including 3GPP ones (LTE-based and NR-based 5G networks) and satellite. Such a system will enable new business opportunities that require sourcing content from multiple data networks to achieve efficient data-delivery options. The ultimate goal is to broaden the utility of the ATSC 3.0 broadcast facilities to new use cases beyond linear television program delivery, such as Internet of Things (IoT) datacasting, enhanced interactivity, data or content offload, vehicular data download including enhanced GPS signaling, or software updates to game consoles.

4.3. Coexistence at the RF Level – Time Division Multiplexing

The delivery of broadcast content via DTTB networks and via non-broadcast ones (e.g. 3GPP) may not be under the control of the same entity, as seen earlier, and additional complications may arise from regulatory, economic or technical issues, whether linked or not to the support of legacy receivers. In addition, it may not be feasible to free up an entire UHF channel to deploy 5G Broadcast. Instead, a transition approach may be foreseen, where the available bandwidth is flexibly allocated to 5G Broadcast with a granularity finer than a broadcast UHF channel.

In the United States, FCC (Federal Communications Commission) regulations state that in any broadcast channel, an ATSC 3.0 signal must be transmitted free-to-air to the public. For this reason, the success of 5G Broadcast in the US is subject to the possibility of sharing a broadcast channel between ATSC 3.0 and 5G Broadcast, whereby a basic service could be sent using ATSC 3.0 to roof-top antennas (e.g., targeting TV sets) while a 5G Broadcast signal could occupy the rest of the carrier for mobility applications. A technical analysis of coexistence between LTE-based 5G Broadcast and ATSC 3.0 has been carried out by ATSC, and resulting recommendations were communicated to 3GPP's Technical Specification Group in charge of the Radio Access Network (RAN).

This principle relies on the use of an advanced feature that most second-generation broadcast standards support, whereby future enhancements can be introduced without disrupting the operation of legacy receivers. In the case of DVB-T2, this is done using Future Extension Frames (FEFs), as detailed earlier in this paper and defined in [1]. In the case of ATSC 3.0, the concept of a "bootstrap signal", defined in [15], enables the introduction of "gaps" in the RF transmission for the same purpose. By leveraging these features, either ATSC 3.0 or DVB-T2 waveforms could coexist with 5G Broadcast waveforms in the same radio channel via Time Division Multiplexing (TDM), with a given device receiving only its corresponding waveform.

While it is expected that DVB-T2 FEFs will support Time Division Multiplexing of a DVB-T2 waveform with a 5G Broadcast one (subject to testing their proper implementation by legacy receivers), some gaps were identified between ATSC 3.0 and 5G Broadcast frame structures:

- The ATSC 3.0 frame as defined in [5] has a minimum length of 50 ms.
- The LTE-based 5G Broadcast periodic synchronization signal, named Cell Acquisition Subframe (CAS), has a periodicity of 40 ms.

Therefore, it is not possible to transmit a full ATSC 3.0 frame without conflicting with the requirement to also transmit a 5G Broadcast CAS every 40 ms. Thus, the technical analysis resulted in a recommendation to either modify the ATSC 3.0 waveform with the definition of "short frames" (shorter than 40 ms) to enable the transmission of an ATSC frame between two CAS, or alternatively, to allow for "CAS muting" in the 3GPP physical layer specifications (Figure 9).

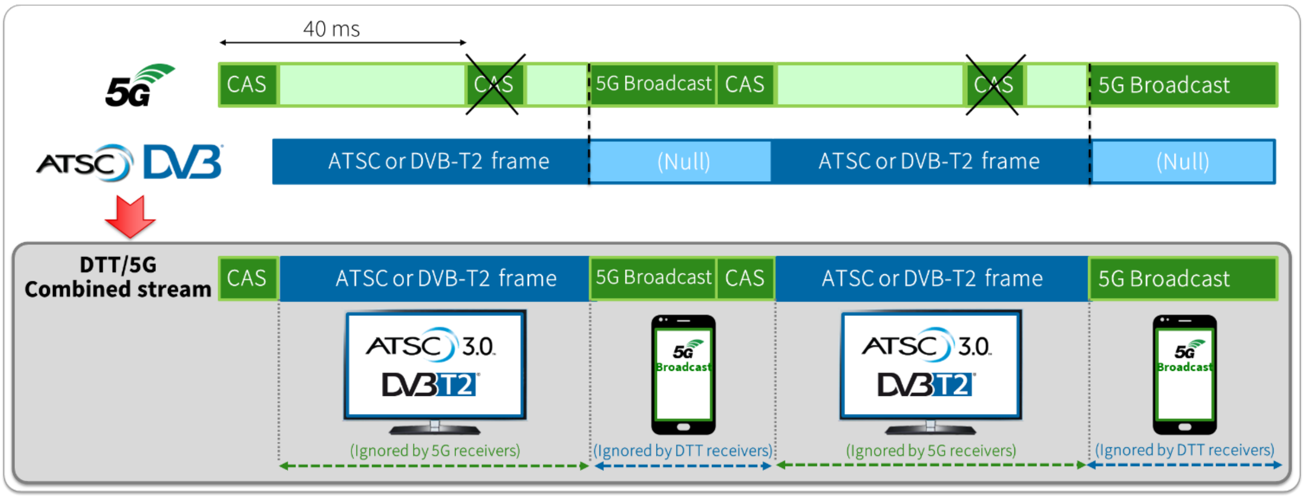


Figure 9: Principle and example of Time Division Multiplexing

A work item description was submitted to 3GPP RAN#102 (December 2023) to address this issue in Release 19 in the context of an "LTE-based 5G Broadcast Phase 2". Its consideration was deferred to September 2024, subject to evidence of significant support and commercial needs duly provided.

For DVB-T2 (or DVB-NIP/T2) markets, the exploration of the technical feasibility of such a concept, which would primarily involve investigating how legacy receivers handle such implementations, will also depend on the market's appetite. The coexistence of DVB and 3GPP transmissions on the same RF channel could facilitate the introduction of 5G Broadcast services alongside existing DVB-T2 ones. A use case of particular interest could be the possibility for the Commercial Mobile Alert System (CMAS) to be operated from the resilient broadcast infrastructure using 5G Broadcast on UHF channels that are otherwise used for regular broadcast transmissions.

4.4. Interworking at the Service Layer – DVB-I over 5G

Service layer collaboration, for instance between broadcast and broadband, appears when broadcast content is interlinked with other content received over bi-directional broadband networks. Typical applications of service layer collaboration between broadcast and broadband are the Interactive Broadcast-Broadband (IBB) systems such as HbbTV (Hybrid Broadcast Broadband Television), Hybridcast, HTML5-based Smart TV Platform, or Ginga middleware. Such systems maximize the user experience by providing high quality, flexible, interactive and personalized services such as additional information on available services (enhanced EPG), additional services for minorities or with improved accessibility features, and access to non-linear broadcasting (catch-up TV).

The DVB-I service layer, introduced earlier in this paper, is the most recent of such systems to be released. It can be combined with the use of HbbTV – e.g., DVB-I services may contain HbbTV applications or HbbTV applications can run DVB-I clients – and its most recent update made possible collaboration with non-DVB networks, such as 3GPP ones. One potential benefit is the ability to support integrated DVB-I hybrid services, i.e., services for which the basic broadcast distribution is augmented with 5G unicast for extended service coverage, lower distribution costs, improved quality, or additional user experiences.

For this purpose, in July 2021, DVB first published commercial requirements for the support of DVB-I services over 5G networks, in DVB Bluebook C100 [16]. This document provides a set of 70 technical and procedural requirements, which were developed based on six guiding use cases. The requirements ask for specifications to support different Release-16-based 5G operation modes, including 5G Broadcast and 5G Media Streaming (5GMS), for the support of:

- DVB-I Services to be delivered over a 5G Broadcast System as defined in TS 103 720 [11].
- DVB-I Services to be delivered over a 5GMS System as defined in TS 126 501 [12].
- A DVB-I Service to be delivered over regular unicast, 5G Broadcast and 5GMS at the same time, as independent service instances (potentially provided with different bitrate, latency, etc.).
- Hybrid DVB-I Services to be delivered using 5G networks, defined as:
  - The DVB-I service is described in a DVB-I service list.
  - A basic DVB-I service is distributed via 5G Broadcast.
  - The service is augmented by ordinary unicast or 5GMS.

A Joint Task Force (JTF) was convened between DVB and the 5G Media Action Group (5G-MAG) to produce a Technical Report mapping the commercial use cases and requirements from DVB BlueBook C100 [16] into deployment guidelines. This Technical Report was published by ETSI in July 2023 as TR 103 972 v1.1.1 [17]. In clause 5.1 of the document [17], a DVB-I over 5G reference architecture is defined, whose main approach is to leverage existing and well-defined interfaces, reference points and APIs defined in DVB and 5G specifications to connect and establish services.

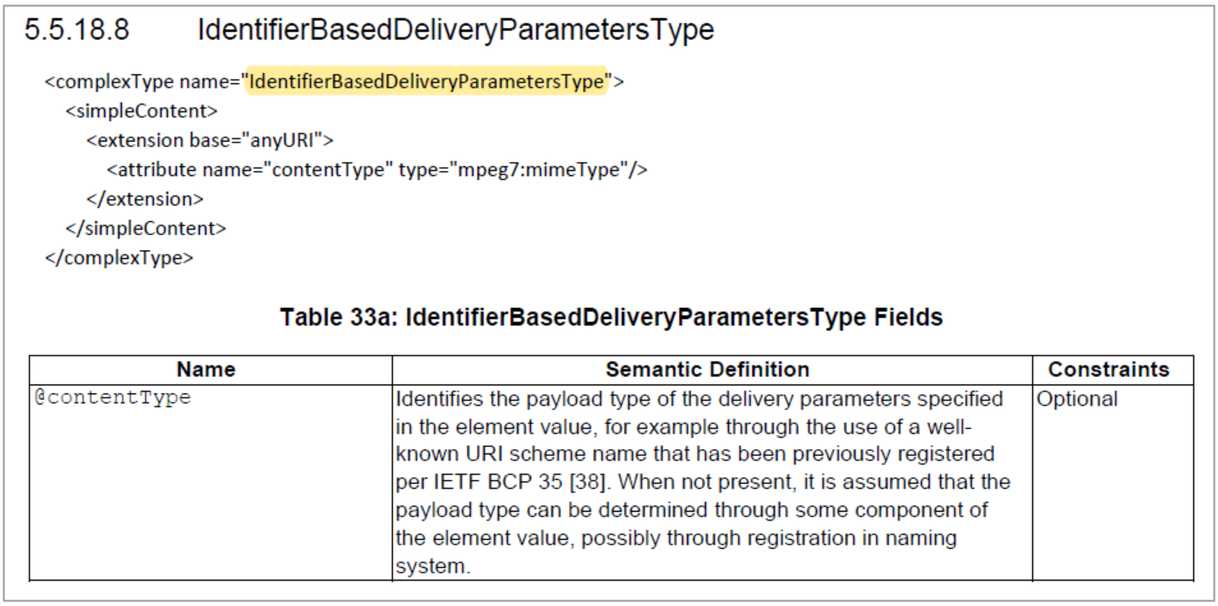
Based on this reference architecture, the commercial requirements for DVB-I over 5G were summarized in a set of three scenarios, described hereafter. For each of them, the Technical Report [17] includes references to relevant specifications to assist implementation, and recommended configurations are documented. Gaps identified in existing DVB, 3GPP or ETSI specifications are also documented as recommended changes to the relevant specifications, however they are minimal, thanks to the original DVB-I design to provide a television service platform independent of the access layer.

4.4.1. Stand-alone DVB-I Service Using 5G Broadcast

While a pure 5G Broadcast service may not be the primary deployment choice, because 5G Broadcast receivers will typically be capable of connecting through unicast, the possibility of providing a basic self-contained DVB-I service via 5G broadcast is useful, for example for receivers that are out-of-coverage or without a subscription, or in case of overload of the unicast system.

For this scenario, the following gaps were identified in DVB-I [7] and 5G Broadcast [11] specifications:

- In the DVB-I specifications [7], there is a need to create a generic Service Locator that points to a 5G Broadcast Service using a MBMS/3GPP URL. This was implemented in clause 5.5.18.8 of the latest revision of the DVB-I BlueBook A177r6 [7] as shown below (Figure 10).
- In the 5G Broadcast specifications [11], there is a need to create a service class for DVB-I information.



5.5.18.8 IdentifierBasedDeliveryParametersType

```
<complexType name="IdentifierBasedDeliveryParametersType">
  <simpleContent>
    <extension base="anyURI">
      <attribute name="contentType" type="mpeg7:mimeType"/>
    </extension>
  </simpleContent>
</complexType>
```

Table 33a: IdentifierBasedDeliveryParametersType Fields

Name	Semantic Definition	Constraints
`@contentType`	Identifies the payload type of the delivery parameters specified in the element value, for example through the use of a well-known URI scheme name that has been previously registered per IETF BCP 35 [38]. When not present, it is assumed that the payload type can be determined through some component of the element value, possibly through registration in naming system.	Optional

Figure 10: DVB-I [7] extension to support additional networks such as 5G Broadcast

4.4.2. DVB-I Service Using 5G Media Streaming

The integration of 5G Multicast/Broadcast capabilities within the 5G Media Streaming (5GMS) architecture described earlier in this paper is essential to delivering linear content to large numbers of mobile consumers simultaneously, for instance during prime time or during major events. As an access-independent service layer, DVB-I is a strong candidate for providing a converging service layer for 5G in this context. In this case, a DVB-I application can be used to discover streaming services that are delivered over unicast with the assistance of a 5GMS System.

The potential optimizations identified for this scenario are minor and detailed in the Technical Report [17].

4.4.3. DVB-I Service Using both Broadcast and Unicast

This scenario is also referred to as hybrid service offerings and reflects the ability to receive DVB-I services over broadcast and unicast in parallel. Some potential use cases include:

- DVB-I via unicast and DVB-DASH via 5G Broadcast: DVB-I Service metadata is retrieved via unicast and DVB-DASH content is transmitted via 5G Broadcast.
- Hybrid broadcast-unicast services with **session continuity**: The same DVB-DASH service is made available via both unicast and 5G Broadcast networks, but only one Representation (i.e., typically bitrate) of each Adaptation Set (i.e., set of audio/video codec, language etc.) of the DVB-DASH service is provided via 5G Broadcast. When the receiver is in 5G Broadcast reception, it consumes the broadcast content, but when out of 5G Broadcast coverage, it uses unicast with DASH adaptive streaming.
- Hybrid broadcast-unicast services for **time-shifted viewing**: The service is made available via both unicast and 5G Broadcast delivery networks, but only one Representation of each Adaptation Set of the DVB-DASH service is provided via 5G Broadcast. The content is retained on unicast for a period of time to support time-shifted access.

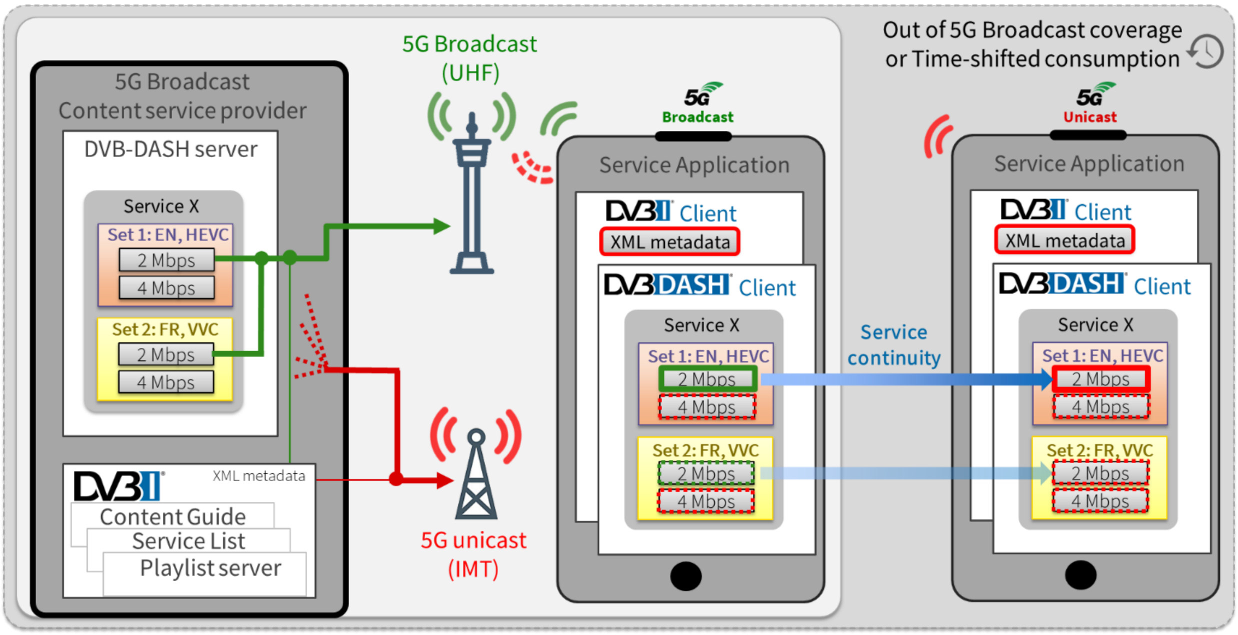


Figure 11: Hybrid broadcast-unicast services with session continuity or time-shifted viewing

- Hybrid broadcast-unicast services with **content or component replacement**: The service is made available via both unicast and 5G Broadcast networks, but only one Representation of selected Adaptation Sets is provided via 5G Broadcast. Some Adaptation Sets are only available via unicast. In another case, two or more content alternatives may exist for a period of time, but only one alternative is provided over 5G Broadcast. Based on the selection of the client, the receiver collects the content from broadcast, if available, otherwise from unicast.

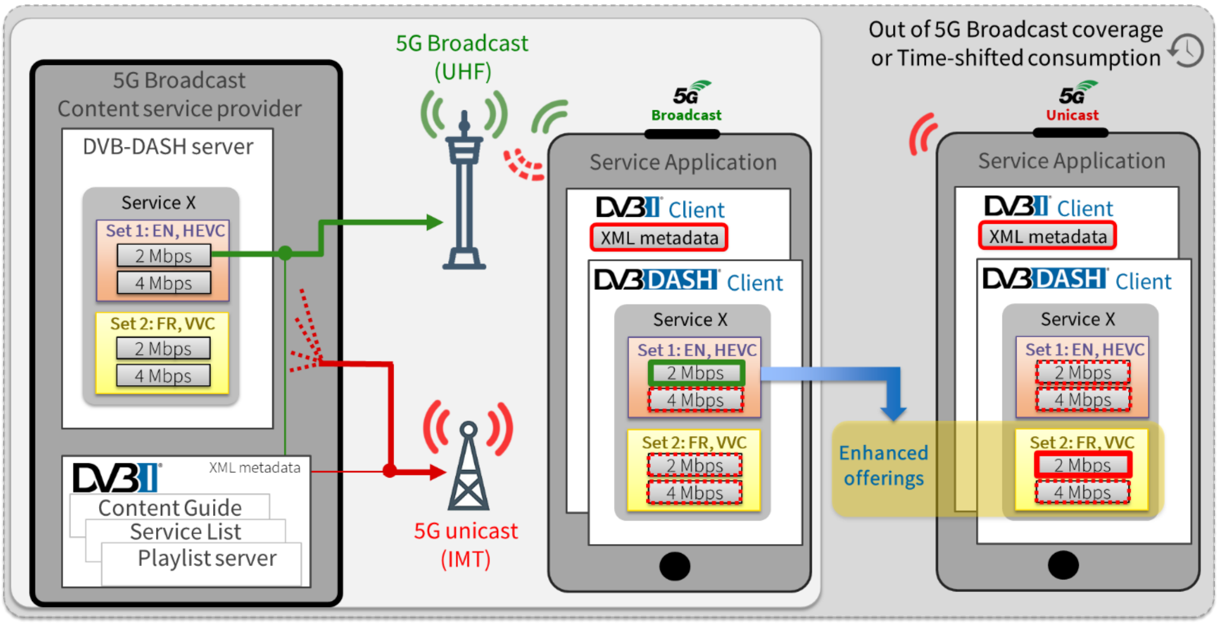


Figure 12: Hybrid broadcast-unicast services with content or component replacement

For the support of these use cases, either the 5G Broadcast client or the DVB-DASH client needs to define which network resources are selected at what time. The DVB-DASH client needs to be able to receive content from at least two different networks and needs to be actively steered towards selecting one or the other network. This may involve using additional signaling in the Media Presentation Description (MPD) document.

For cases where the same service is available over unicast and broadcast networks, two separate MPDs are provided, each one describing an instance of the same DVB-I service. New signaling is then required in the DVB-I Service List to indicate that the content distributed on these two service instances is both identical and time-aligned, and that the content can therefore be combined into a single hybrid presentation to the user. Also, it is likely that the operation of the DVB-DASH client would need to be modified to support switching between the two presentations described by the two MPD documents.

Potential extensions to DVB-DASH specifications [8] to fulfill those requirements are being considered within DVB technical groups, together potential optimizations to DVB-I specifications [7].

4.4.4. Promising Use Case: DVB-I Bridging Satellite and 5G Delivery

For transitional purposes, combined solutions involving both 5G and DVB networks for their own strengths could seamlessly coexist thanks to DVB-I and its extension to support 5G technologies. In low connectivity areas for instance, DVB-NIP over existing satellite links (DVB-S2) can be used to reach legacy devices – without any device adaptation – through Wi-Fi hotspots, especially indoors. Such a combination could alleviate the current spectral efficiency disadvantage of 5G by removing the need to take indoor coverage into account in the link budget, which also reduces the number of transmission towers needed to cover a given target reception area.

Such a 5G/DVB-NIP combination is totally seamless for end users thanks to the interworking between heterogeneous distribution networks that DVB-I enables at the service layer. In addition, this scenario's relevance is strengthened by the fact that DVB-NIP is also envisioned for feeding 5G base stations.

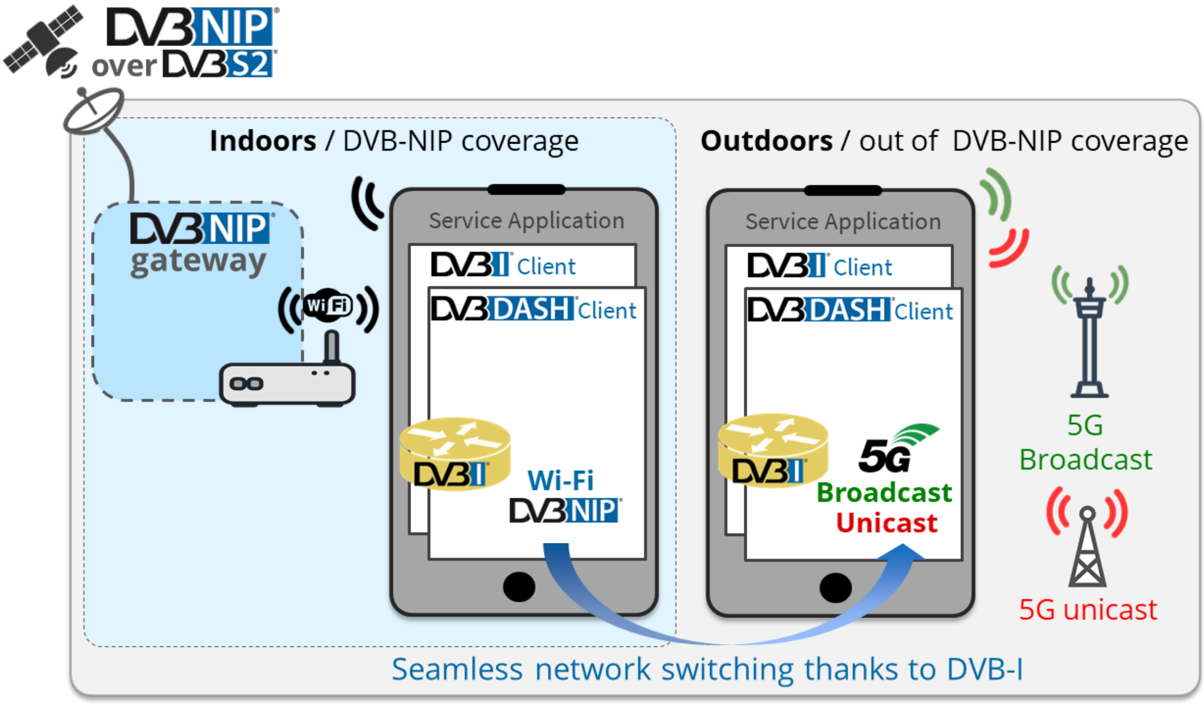


Figure 13: Possible use of DVB-I over 5G: bridging satellite and 5G delivery

5. Conclusion

Broadcast networks, when combined with unicast delivery in a hybrid scenario, offer the best opportunities for distributing the highest video qualities alongside unicast-delivered interactive and personalized services. While the collaboration of DTTB networks with broadband ones is already well established, initiatives towards mobile broadcasting have proven unconvincing so far. In the mobile industry, the appetite for broadcast technologies dates back a long time and their integration within the 5G System has seen important milestones reached, impacting the two different sectors. Indeed, the LTE-based 5G Broadcast standard is now a candidate for mobile broadcasting to be operated using broadcasters' infrastructures and spectrum; furthermore, MNOs will also benefit from the Multicast/Broadcast capabilities now enabled over 5G New Radio (NR) and soon integrated within the 5G Media Streaming system.

Even if both industries have achieved significant progress with the integration of new capabilities that address their – historically substantial – differences, collaboration between them is as important today as ever. Major steps were undertaken to facilitate interworking between DTTB and 3GPP networks. ATSC's project to specify a Broadcast Core Network that is agnostic to the DTT system will eventually allow converged operation within the available delivery networks. Furthermore, DVB's recent work on adapting DVB-I to support 5G technologies will ensure that LTE-based and NR-based 5G networks can carry services with an appropriate – standardized and 'TV-friendly' – service layer that is likely to facilitate commercial success. Thanks to DVB-I, promising scenarios involve the seamless use of either 5G NR or 5G Broadcast when available, or even DVB-NIP through hotspots when indoors, leveraging the existing infrastructure and well-proven DVB networks.

Undoubtedly, technological developments advance towards network and resource optimization, leading to a more resilient and sustainable media distribution landscape. Above all, they seem to be paving the way for mutually beneficial interworking, eventually offering opportunities for new services and revenue streams for both industries, while – key to success – allowing them to protect their independence and own assets.

6. References

[1]	ETSI TS 102 755 v1.1.1	DVB, Frame structure channel coding and modulation for a second generation digital terrestrial television broadcasting system (DVB-T2), February 2022
[2]	10.1109/BMSB.2013.6621781	Regueiro C., Berjon-Eriz G., Perez de Albeniz I., Eizmendi I., Prieto G., Velez M., “DVB-T2 field trials results for portable indoor reception using T2-Lite and multiple PLP”, *2013 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB)*, 07 October 2013
[3]	10.1109/TBC.2015.2505417	Fay L., Michael L., Gómez-Barquero D., Ammar N., Caldwell W., “An Overview of the ATSC 3.0 Physical Layer Specification”, *IEEE Transactions on Broadcasting,* Vol. 62, #1, March 2016
[4]	10.1109/TBC.2022.3222988	Seok-Ki A., et al., “Evaluation of ATSC 3.0 and 3GPP Rel-17 5G Broadcasting Systems for Mobile Handheld Applications”, *IEEE Transactions on Broadcasting,* Vol. 69, No. 2, 23 November 2022
[5]	A/322:2023-03	ATSC Standard A/322: “Physical Layer Protocol”, Doc. A/322:2023-03, March 2023
[6]	A/331:2023-12	ATSC Standard A/331: “Signaling, Delivery, Synchronization, and Error Protection”, Doc. A/331:2023-12, December 2023
[7]	BlueBook A177r6	DVB, “Service Discovery and Programme Metadata for DVB-I”, Doc. BlueBook A177r6 (Interim draft TS 103 770 v1.2.1), February 2024
[8]	ETSI TS 103 285 v1.4.1	DVB, “DVB MPEG-DASH Profile for Transport of ISO BMFF Based DVB Services over IP Based Networks”, Doc. ETSI TS 103 285 v1.4.1, September 2023
[9]	BlueBook A180r2	DVB, “Native IP Broadcasting”, Doc. BlueBook A180r2 (Draft TS 103 876 v1.1.1), February 2024
[10]	---	Nakolos, “High speed racing and low latency 5G Broadcast distribution at the MotoGP in Austria”, August 2024
[11]	TS 103 720 v1.2.1	ETSI, “5G Broadcast System for linear TV and radio services; LTE-based 5G terrestrial broadcast system”, Doc. TS 103 720 v1.2.1, June 2023
[12]	TS 126 501 v16.5.0	ETSI, “5G Media Streaming (5GMS); General description and architecture”, Doc. TS 126 501 v16.5.0, October 2020
[13]	BlueBook S100	DVB, “BlueBook S100: Study Mission Report on Energy Aware service Delivery and Consumption”, November 2023, pp. 19-23
[14]	PT6-200r11	ATSC, “ATSC Planning Team Report: ATSC 3.0 and Global Convergence”, Doc. PT6-200r11, December 2022

[15]	A/321:2023-03	ATSC Standard A/321: “System Discovery and Signaling”, Doc. A/321:2023-03, March 2023
[16]	Bluebook C100	DVB, “Commercial Requirements for DVB-I over 5G”, Doc. Bluebook C100, July 2021
[17]	TR 103 972 v1.1.1	DVB and 5G-MAG, “DVB-I service delivery over 5G Systems; Deployment Guidelines”, Doc. TR 103 972 v1.1.1, July 2023

7. Abbreviations

For the purposes of the present document, the following abbreviations apply:

ABR	Adaptive Bit Rate
API	Application Programming Interface
AVC (DVB-AVC)	Audio/video coding
BCN	Broadcast Core Network
CA	Carrier Aggregation
CAS	Cell Acquisition Subframe
CMAS	Commercial Mobile Alert System
COFDM	Coded Orthogonal Frequency Division Multiplexing
D2M	Direct-to-Mobile
DASH	Dynamic Adaptive Streaming over HTTP
DASH (DVB-DASH)	Dynamic Adaptive Streaming over HTTP
DTH	Direct to Home
DTT	Digital Terrestrial Television
DTTB	Digital Terrestrial Television Broadcasting
eMBMS	evolved MBMS
enTV	enhanced TV
EPG	Electronic Programme Guide
FEC	Forward Error Correction
FEFs	Future Extension Frames
FeMBMS	Further evolved MBMS
GI	Guard Interval
GSE (DVB-GSE)	Generic Stream Encapsulation
HbbTV	Hybrid Broadcast Broadband Television

HPHT	High-Power High-Tower
IBB	Interactive Broadcast-Broadband
LDPC	Low-Density Parity Check
LTE	Long-Term Evolution
MABR (DVB-MABR)	Multicast ABR
MBMS	Multimedia Broadcast/Multicast Service
MIMO	Multiple-Input and Multiple-Output
MMTP	MPEG Media Transport Protocol
MNO	Mobile Network Operator
MPD	Media Presentation Description
MPE (DVB-MPE)	Multiprotocol Encapsulation
MPEG-2 TS	MPEG-2 Transport Stream
MPMT	Medium-Power Medium-Tower
MPU	Media Processing Units
NIP (DVB-NIP)	Native IP broadcasting
NR (5G NR)	New Radio
OFDM	Orthogonal Frequency Division Multiplexing
PLP	Physical Layer Pipes
PSI	Programme-Specific Information
RAN	Radio Access Network
ROUTE	Real-Time Object Delivery over Unidirectional Transport
SFN	Single Frequency Network
SNR	Signal-to-Noise Ratio
TDM	Time Division Multiplexing
UMTS	Universal Mobile Telecommunications Service
V2X	Vehicle to everything

8. History

Version	**Date**	**Milestone**
1.0	16-04-2024	First DVB publication