THE DVB-T2 TECHNOLOGY AND THE DVB-X2 CLASS OF STANDARDS

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A B S T R A C T

The Digital Video Broadcasting – Second Generation Terrestrial (DVB-T2) technology represents a major advancement in terrestrial digital television, achieving up to 50% higher spectrum efficiency compared to DVB-T by employing Orthogonal Frequency Division Multiplexing (OFDM) with up to 32K FFT modes, 256-QAM modulation, and advanced error protection using LDPC/BCH codes. The standard supports multiple Physical Layer Pipes (PLPs), providing flexible service delivery and robustness against multipath fading. Laboratory and field trials have demonstrated net data rates exceeding 50 Mbps in an 8 MHz channel, enabling reliable delivery of HDTV and Ultra-HDTV services. The DVB-X2 class of standards extends this efficiency to other transmission environments. DVB-S2X, for example, achieves spectral efficiencies above 5 bits/s/Hz using up to 1024/16384-QAM and finer roll-off factors (0.05–0.35). DVB-C2 provides over 60% capacity gain in cable networks through channel bonding and higher-order constellations, while DVB-NGH (Next Generation Handheld) adapts DVB-T2 features for mobile broadcasting. Collectively, these standards support flexible deployment, reduced transmission costs per bit, and scalability for next-generation services such as UHDTV, interactive broadcasting, and hybrid broadcast-broadband convergence. This paper presents a comparative analysis of DVB-T2 and DVB-X2 technologies, emphasizing their technical innovations, spectral efficiency, and implementation performance. Results indicate that the DVB-X2 family enables sustainable growth of digital broadcasting by meeting increasing demands for bandwidth-intensive multimedia while maintaining backward compatibility and service reliability.

Introduction

The DVB organisation established three main standards for TV distribution via satellite, terrestrial, and cable channels by the middle of the 1990s: DVB-S, DVB-T, and DVB-C. The DVB association created its first "second-generation" DVB-S2 standard ten years later to capitalise on the significantly enhanced decoder-chip VLSI capabilities (“Radio Explorations,” 2024). The primary purpose of this new satellite standard, which offered a 30% increase in transmission capacity over DVB-S, was HDTV broadcasting. The improved Low-Density Parity Check Codes (LDPC) concatenated with BCH codes form the basis of DVB-S2's forward error correction, which brings the available performance very near to the Shannon limit. With the goal of creating international standards for the provision of digital television and data services, the Digital Video Broadcasting Project (DVB) is an industry-led group comprising broadcasters, manufacturers, network operators, software developers, regulatory agencies, content owners, and others. Market-driven solutions that satisfy the demands and financial situations of customers and stakeholders in the broadcast business are fostered by DVB. All facets of digital television are covered by DVB standards, including transmission, conditional access, interfaces, and interactive digital video, audio, and data. In 1993, the consortium was formed to provide future-proof definitions, interoperability, and worldwide standardisation .

It was widely acknowledged in the DVB community in 2006 that, by building on the advancements made in DVB-S2, comparable advancements might be made for terrestrial broadcasting, which could aid in the European terrestrial platform's transition to HDTV. As a result, DVB established a technical committee to create the DVB-T2 standard, which was ultimately released in June 2008 (Bell, 2010).

The UK was working hard to prepare for the digital switch-over (DSO), which was scheduled to be finished by the middle of 2012. It was agreed that one of the public service multiplexes will be converted to DVB-T2 in order to transmit terrestrial HD services as part of the DSO regional roll-out. This choice was made with the knowledge that, under the same coverage planning conditions, a DVB-T2-based multiplex could provide at least 30% more capacity than a traditional DVB-T multiplex. Furthermore, the launch date for these additional HD services was scheduled for December 2009, with a timeline based on the regional DSO plan for the UK.

The industry's interest in the new standard was sparked by these UK judgements, and the tight timelines accelerated the standardisation process. Over 40 businesses have actively engaged in a rigorous schedule of meetings, phone calls, and email correspondence to help design the T2 specification. This was followed by validation and verification exercises to make sure early implementations worked together.

As this procedure came to a close, DVB began defining a second-generation modulation scheme for cable systems, known as DVB-C2. Many of the sophisticated methods and data structures found in the DVB-S2 and DVB-T2 standards were expanded upon by the DVB-C2 standard, creating a logical "family" of second-generation "DVB-x2" standards. At the end of 2009, the DVB-C2 standard was released (Hailes et al., 2015).

Standards for DVB-T2

The T2 projects were structured around a set of established commercial needs. Among these prerequisites were:

i. T2 transmissions must be able use existing domestic receive antenna installations and must be
ii. able to re-use existing transmitter infrastructures. (This requirement ruled out the consideration of MIMO techniques which would involve both new receive and transmit antennas.)
iii. A method for service-specific robustness should be included in T2, meaning that different services should be able to get varying degrees of robustness. Targeting certain services for roof-top reception and others for portable reception, for instance, should be feasible within a single 8MHz channel.
iv. T2 should allow for flexibility in frequency and bandwidth.
v. To lower transmission costs, a method should be established to lower the transmitted signal's peak-to-average-power ratio, if at all practicable.
vi. T2 should primarily target services to fixed and portable receivers
vii. T2 should provide a minimum of 30% capacity increase over DVB-T working within the same planning constraints and conditions as DVB-T
viii. T2 should provide for improved single-frequency-network (SFN) performance compared with DVB-T

Technical aspects of T2

When feasible, T2 incorporated two essential DVB-S2 technologies to offer a cohesive family of standards. They were:

i) DVB-S2's system-layer architecture, namely how data is packaged into "Baseband Frames" (see below)
ii) The application of the same error-correcting codes for Low Density Parity Check (LDPC) as those in S2.

The need to maximise the data carrying capacity guided the majority of T2's design choices. There are numerous variables in T2 that allow the modulation scheme's overheads to be minimised according to the demands of a certain transmission channel. For instance, as explained below, a number of choices have been added for guard-interval fractions, pilot carrier modes, and FFT sizes.

Forward Error Correcting (FEC) schemes and Baseband Frames

Figure 1 illustrates how the data to be sent is bundled into Baseband Frames, each of which has a header that contains specific information about the data it contains. The

The DVB-S2 LDPC FEC then adds the LDPC check bits at the end to safeguard the data. As seen in Figure 1, the data is additionally safeguarded by a brief BCH code to remove any remaining faults following the LDPC decoding.

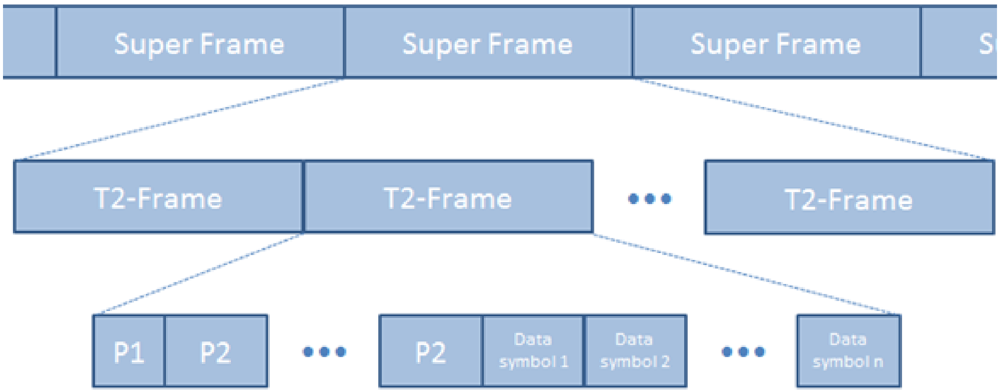

Figure 1: Baseband Frame Structure

An essential component of the T2 system, the FEC frame has a total length of 64,800 bits. The percentage of the frame that can be devoted to FEC parity bits in T2 falls between 15% and 50%. To reduce the potential delay that a T2 transmission system may present to low-data-rate services, a 16200-bit FEC frame is also offered as an option. Usually, a series of MPEG transport stream packets will be the data transmitted within the Baseband Frame. However, a new DVB standard known as "Generic Stream Encapsulation" makes the signalling fields in the Baseband Frame Header completely compatible with the transmission of native IP packets.

Comparing the performance of the LDPC error-correcting scheme in a T2 system to that of the DVB-T error-correcting scheme, which combines Reed-Solomon coding with convolutional coding, reveals a notable improvement. A typical residual error rate and a certain FEC overhead can result in a 3dB improvement in the C/N ratio, which can be translated into a 30% capacity gain (for example, by switching to a higher-order constellation mode).

Modulation

The performances of several multi-carrier and single-carrier modulation scheme variations were compared during the T2 development process. The typical guard-interval OFDM, which is currently employed in DVB-T, was chosen to be utilised in T2.

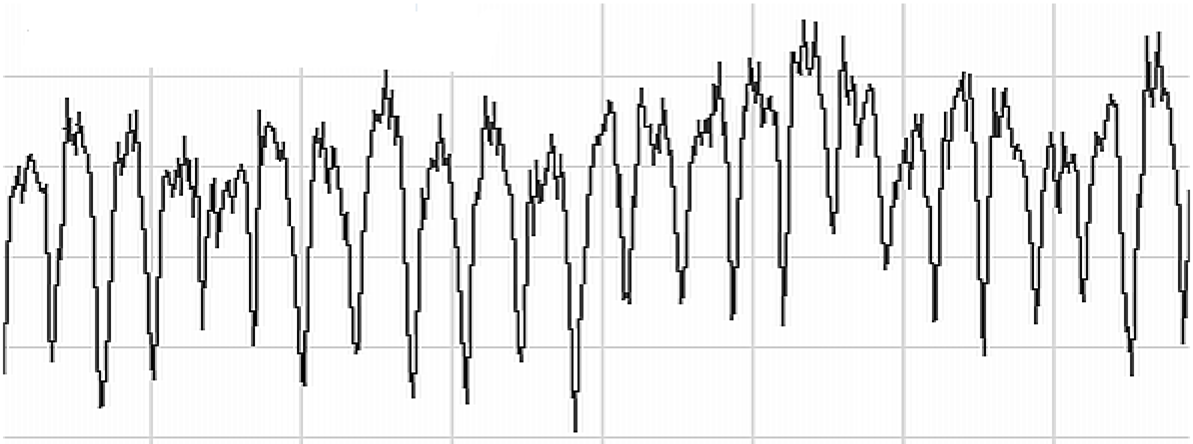

Figure 2: The use of guard intervals

Each symbol in GI-OFDM is made up of numerous independent carriers, each of which has its amplitude and phase modulated by data. DVB-T, for instance, provides "2K" and "8K" carrier modes. The FFT size that was utilised to generate the multi-carrier signal is indicated by these figures. These figures are a little lower than the real carriers that are utilised to transport data. Protection against data loss on each carrier within each symbol when the transmission has multipath components channel, as illustrated in Figure 2, is supplied by transferring each symbol's tail-end to the symbol's beginning. The transmission path and transmission network determine the necessary guard interval length. In single-frequency networks, where strong signal components can appear with a large delay compared to the main signal channel, longer guard intervals are necessary. The guard interval is an overhead that lowers the transmission channel's capacity to carry data. The maximum guard interval size in DVB-T is equal to ¼ of the signal's "data" part, as seen in Figure 2. T2 has introduced 16K and 32K carrier modes to extend the guard interval's maximum duration without raising the guard-interval overhead.

An OFDM system's symbol period increases as the number of carriers increases. Figure 3 shows how the guard-interval overhead can be decreased for a given absolute size of guard interval.

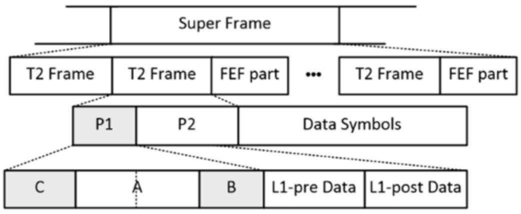

Figure 3: DVB-T2 uses longer symbols to reduce the overhead associated with the guard interval

With a fractional guard interval of 19/128, the 32K mode in T2 offers the highest absolute guard interval value that can be attained. A big national SFN can be implemented when the guard interval above 500 µs.
T2 provides a variety of guard interval choices and number-of-carrier modes (FFT sizes). They are:

i. FFT sizes: 1K, 2K, 4K, 8K, 16K, 32K
ii. Fractional guard intervals: 1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4

As previously stated, in GI-OFDM, data for each symbol period modulates the phase and amplitude of each carrier. With 64 QAM, the maximum modulation mode in DVB-T, 6-bits per carrier per symbol (per data cell) is possible. The maximum modulation mode in T2 is raised to 256 QAM, which has the capacity to transport 8 bits per data cell. The enhanced performance of the LDPC FEC allows for the maintenance of this approximately 30% improvement in data-carrying capacity over DVB-T under normal circumstances, despite the fact that this larger constellation is more susceptible to errors caused by noise.
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Compared to the 2K mode in DVB-T, the out-of-band spectrum disappears considerably faster for the new 16K and 32K carrier modes in T2. Figure 4 illustrates how T2 takes advantage of this by increasing the number of data-carrying carriers in 8MHz channels that are closer to the standard spectrum mask used for DVB-T broadcasts.

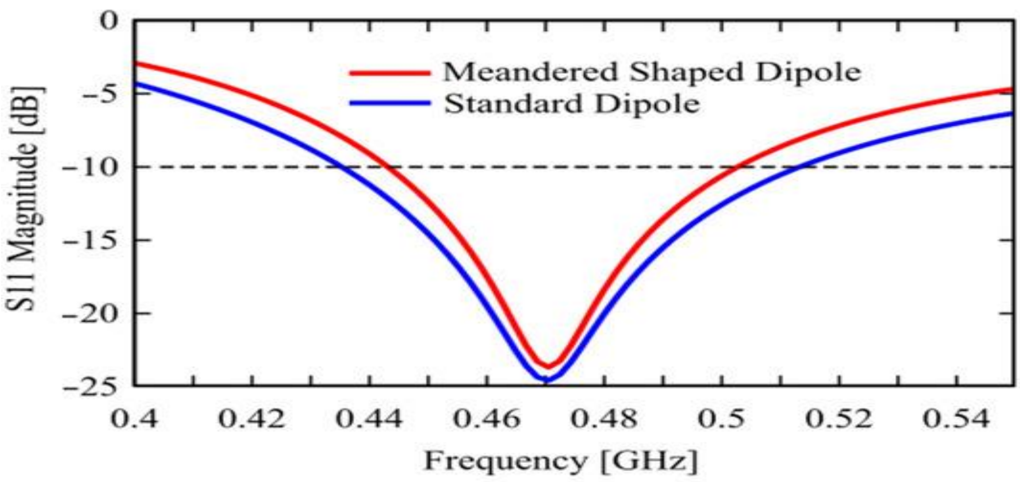

Figure 4 – Theoretical spectrum for DVB-T2 signals (8 MHz channels)

Scattered Pilot Patterns

OFDM (data) cells with known amplitude and phase are called scattered pilots in OFDM systems. The receiver uses these cells to equalise or compensate for channel impairments as the frequency and time of the channel vary. One out of every twelve OFDM cells in DVB-T are scattered pilots, representing an 8% overhead. Since DVB-T uses this scattered pilot pattern for all guard-interval possibilities, the pattern needs to be such that the demodulator can equalise channels that need a 1/4 fractional guard interval. This density of dispersed pilots, however, is higher than what is needed to allow for channel equalisation, which calls for a smaller fractional guard interval. Based on the time-varying nature of the target transmission channel, T2 provides eight different scattered pilot pattern options to minimise the overhead caused by scattered pilots. Two examples of T2 scattered-pilot patterns are shown in Figure 5. Each guard interval choice has a limited number of associated pilot patterns.

T2 frame structure and service-specific robustness

The ability to apply varying degrees of robustness, in terms of modulation mode and FEC coding mode, to various services was a commercial necessity for T2. As seen in Figure 6, this is accomplished in T2 by assembling OFDM symbols into frames and then allocating various services to various "slices" inside each frame.

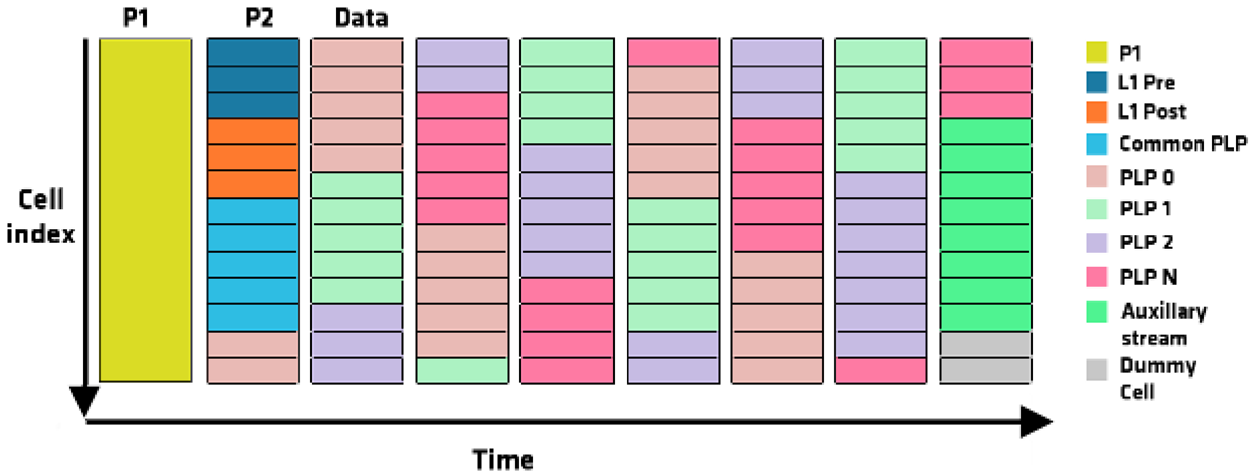

Figure 6 – Illustration of T2 frame structure different colours indicate different services

"Physical Layer Pipes" are the data channels that the slices in the above image supply (PLPs). Time interleaving, FEC protection, and a distinct modulation mode are features of every PLP.
A brief OFDM "P1" symbol, based on a 1K OFDM symbol with frequency-shifted repeats at the front and back, indicates the beginning of the T2 frame (Figure 7). While prohibiting any potential data imitation of P1 by any part of the signal within the main T2 frame, this arrangement makes it simple to detect the P1 symbol.

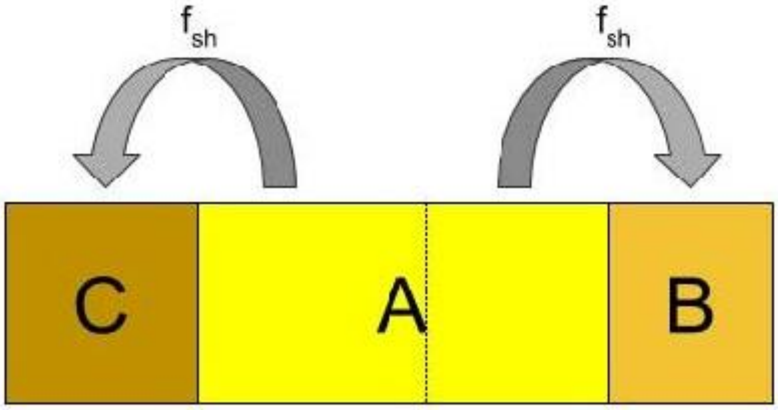

Figure 7 – llustration of DVB-T2's P1 symbol

Only a small percentage of the 1K carriers are in use, and those that are carry one of a few carefully selected data patterns that offer some signalling power. When a receiver scans over the proper spectrum range, this P1 symbol structure offers a) a straightforward and reliable method for quickly detecting T2 signals, and b) a quick frequency lock mechanism for the receiver and 6-bit signalling (e.g. for the FFT size used for symbols in the T2 frame).
The overhead needed to indicate the frame's structure is usually less than 1%, and a typical T2 frame lasts 200 ms. At the start of every frame, this frame structure information is transmitted in a robust manner using unique "P2" symbols.

Interleaving

The four interleaving phases used by T2 are "bit," "cell," "time," and "frequency." In order to prevent long sequences of the original data stream from being lost due to either frequency-selective fading (disturbance over a limited frequency span) or impulsive noise (disturbance of the OFDM signal over a short time period), the interleaving stages aim to distribute the content in the time/frequency plane. Additionally, the behaviour of the error-control coding, which does not uniformly safeguard all data, is matched by the interleaving.Finally, the architecture of the interleaving ensures that the bits carried by a particular transmitted constellation point do not match a series of consecutive bits in the original stream.
The most important change from DVB-T to DVB-T2 is the addition of time interleaving, usually over 70 ms, to guard against brief time-selective fading and impulsive noise.

Rotated constellations

The new method of "rotated constellations" is employed by T2. The robustness of the signal can be significantly improved with rotated constellations, especially when dealing with difficult terrestrial channels. Figure 8 illustrates how each constellation point, denoted by u1 and u2, can have a distinct mapping onto each axis by rotating the constellation to a precisely selected angle.

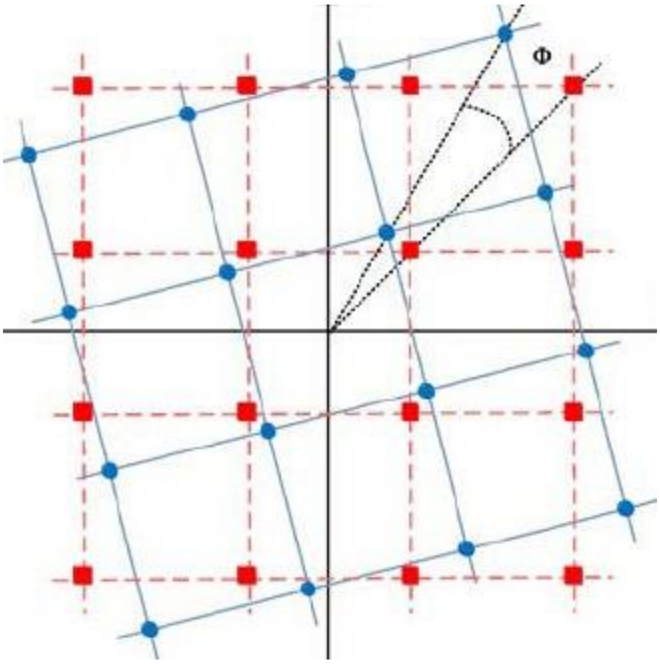

Figure 8 – A rotated 16-QAM constellation

Along with u2 and u1 data from a separate data cell, the modulator separates the data from each of the two axes, u1 and u2, and arranges them to travel independently through the OFDM signal (i.e. the values of the constellation points on each of u1 and u2 travel on different OFDM carriers and in different OFDM symbols). The original rotated constellation is obtained at the receiver by recombining the u1 and u2 data. In this manner, even with a lower signal-to-noise ratio, some information can still be gleaned from the remaining axis value in the event that one carrier or symbol is lost due to interference based on preliminary simulation results, this strategy may result in a large performance gain (more than 5dB) in challenging channels.

Transmit Diversity

Due to the possibility of deep "notches" in the resulting channel, DVB-T's support for Single-Frequency Networks (SFNs) is negligible when two transmitters in a network send signals of comparable power.

DVB-T2 offers the option of using the Alamouti technique with two transmitters. Alamouti is an example of a Multiple Input, Single Output (MISO) system, where each transmitter transmits a slightly modified version of each pair of constellations, but in the opposite order in frequency. The coding and doubling of the pilot pattern allow the two reception paths to be combined and decoded in an optimal manner. According to preliminary planning studies, using this technique may result in a 30% increase in coverage from some basic SFNs.Reducing the Peak to Average Power Ratio

The efficiency of the RF power amplifier may be lowered by OFDM systems' high peak-to-average power ratio. T2 uses two methods that can lower the PAPR and provide a 20% drop in the peak amplifier power rating. The cost of electricity could be significantly reduced as a result.The two T2 approaches are as follows:

i. "Tone reservation," in which 1% of the carriers are set aside and do not carry any data; instead, the transmitter may utilise them to add values that will offset the signal's peaks.

ii. "Active constellation extension," which involves shifting some of the edge constellation points' values "outwards" so that the signal peaks are reduced. The ability of the receiver to decipher the data is not significantly affected because edge constellation points are only ever shifted outward.

Extension Frames for the Future

The T2-frame structure has provisions for signalling some unused frames that can be used to carry as-yet-undefined signals; the contents of these "Future Extension Frames" (FEF) have not been specified; however, by including appropriate signalling within the T2 specification, first generation receivers will know to ignore the FEF parts, which can therefore provide a backwards compatible upgrade path for the inclusion of new technologies in the future. These two additional features found in the T2 specification may offer room for future expansion plans.

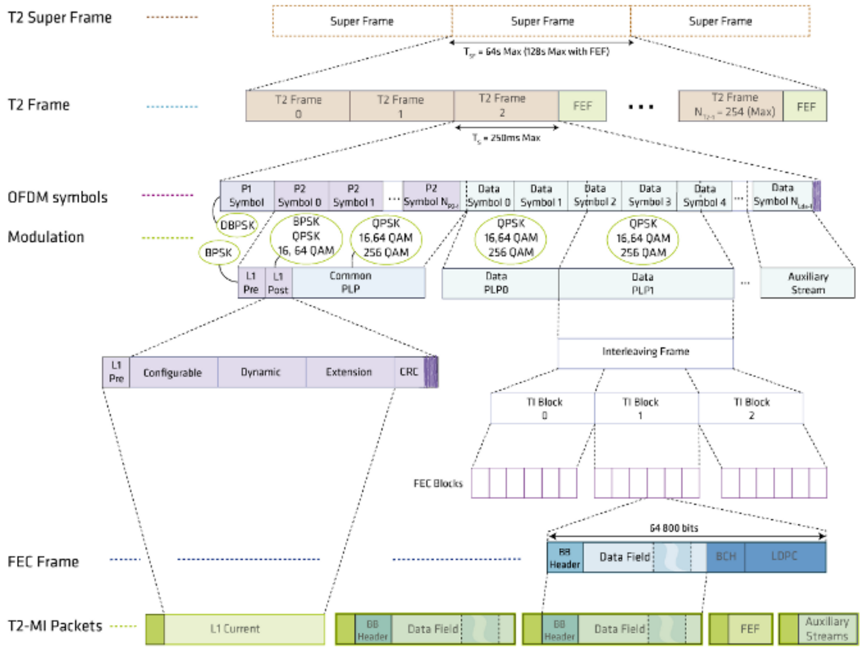

Figure 9 – The insertion of FEF parts in between T2-frames (*DVB T2 Tutorial*, n.d.)

The sections of Time Frequency

Additionally, T2 contains the signalling needed for Time Frequency Slicing (TFS) deployment in the future. Hooks have been added to the signalling so that a future receiver with two tuners can use TFS, which enables a signal to be distributed across several (non-adjacent) RF channels, even though the basic specification is meant to be received with a single tuner and without the usage of TFS. To get the data it needs for its service, the receiver will switch between channels. This makes it feasible to efficiently combine many channels, resulting in a significantly bigger total multiplex than would be achievable with only one channel. This can yield a major frequency planning benefit in addition to a statistical multiplexing gain.

The capacity of the system

The precise selection of the several system parameters will determine the T2 system's capacity. These have been purposefully kept open-ended, with the T2 system signalling the parameter choices. The precise performance optimisations needed, such as the trade-off between capacity and ruggedness or overhead and zapping time, will be reflected in the parameter selection.

Direct comparisons with other systems will always be challenging because the balance of parameter selections will vary. For instance, a T2 configuration offering comparable Gaussian channel performance may be selected as compared to DVB-T, even though it would be anticipated that the T2 system would be noticeably more resilient in challenging terrestrial channels in this situation. When compared to DVB-T, this would result in a notable boost in capacity. On the other hand, a system that performs somewhat better in challenging channels but has somewhat lower Gaussian performance may provide an even larger capacity boost.

Table 1 compares T2 (Option A) with the existing UK DVB-T system, demonstrating a capacity increase of around 50% with the goal of achieving equal Gaussian performance. Although it is a little less reliable, the real mode selected for use in the UK has a 40.1 Mbit/s data capacity. In a statistical multiplex, this capability can support four or possibly five HD services when combined with H264 video compression coding.

Table 1 – Transmission capacity comparison between DVB-T and DVB-T2 for initial UK mode and predicted equal Gaussian channel performance

	DVB-T (UK mode)	DVB-T2 (Option A)	DVB-T2 (UK mode)
Modulation	64QAM	256QAM	256QAM
FFT size	2K	32K	32K
Guard Interval	1/32	1/128	1/128
FEC	2/3 CC + RS (8%)	3/5LDPC + BCH (0.3%)	2/3LDPC + BCH (0.3%)
Scattered Pilots	8%	1%	1%
Continual Pilots	2.6%	0.53%	0.53%
Frame structure overhead	1%	0.53%	0.53%
Bandwidth	Normal	Extended	Extended
Data Capacity	24.1 Mbit/s	36.1 Mbit/s	40.1 Mbit/s

Specifications for the Modulator Interface

Every transmitter in a single frequency network (SFN) must broadcast the same signal, and the timing of the transmissions must be precisely regulated. Due to the T2 multiplex's more complex framing than DVB-T, a new distribution interface (DVB "Blue Book" A136 and ETSI standard TS102 733) has been established, where the T2 frames are

built at a central "T2 gateway," and these frames are subsequently sent to all modulators and transmitters in the SFN (either via ASI or IP).

Additional advancements in relation to T2

The development of a next-generation standard for broadcasting to handheld and mobile devices, known as DVB-NGH, has begun inside DVB. Expanding the DVB-T2 system with new features and methods to enhance reception in the increasingly challenging mobile reception settings is one of NGH's choices. Adding MIMO possibilities is one example of an additional way to boost capacity or coverage.

DVB-C2

In 2007, efforts began to examine a second-generation DVB-C2 standard to expand the capacity and flexibility of cable systems. The standard was formally developed in 2008 and 2009, with the aim of building, where feasible and appropriate, on the successful features of the DVB-S2 and DVB-T2 standards. Considering that cable systems have historically relied on single-carrier QAM modulation, the rather unexpected choice to base DVB-C2 on the use of COFDM was made for the following reasons:

i. Broadband or narrowband notches are easily implemented;
ii. sub-band signal level modifications are readily possible;
iii. cable-specific interference setups are handled more easily;
iv. the channel bandwidth is flexible, ranging from 6 MHz to 64 MHz;and
Intolerance for echoes up to a specific echo delay

Additional characteristics of C2 that align with DVB-S2 and/or DVB-T2 include:

i. Generic stream encapsulated (IP) streams and transport streams are supported.
ii. LDPC + BCH FEC encoding using FEC frames of length 64800 / 16200
iii. A systems layer that makes use of baseband frames and physical layer pipes
iv. A number of COFDM characteristics were customised for cable networks, including: 4K FFT-based reception with an 8MHz or 6MHz system-appropriate number of active carriers
v. Two choices for the Guard Interval (1/64 and 1/128);
vi. two distinct scattered pilot alternatives and a new continuous pilot pattern;
vii. a fixed frame length of 448 symbols; and
viii. 1024-QAM and 4096-QAM constellation options

Among the new features in DVB-C2 are:

i. The idea that a receiver's "Receiving Window," such as 8 MHz, can move anywhere in the transmitted C2 signal's bandwidth, such as 24 MHz. Several PLPs are multiplexed into a "Data Slice," which only takes up a certain portion of the decoder receiving window.
ii. A new frame-start symbol called "Preamble" that includes frame structure signals and a header.

Figure 10 displays the theoretical performance of the C2 system options in relation to the DVB-C system.

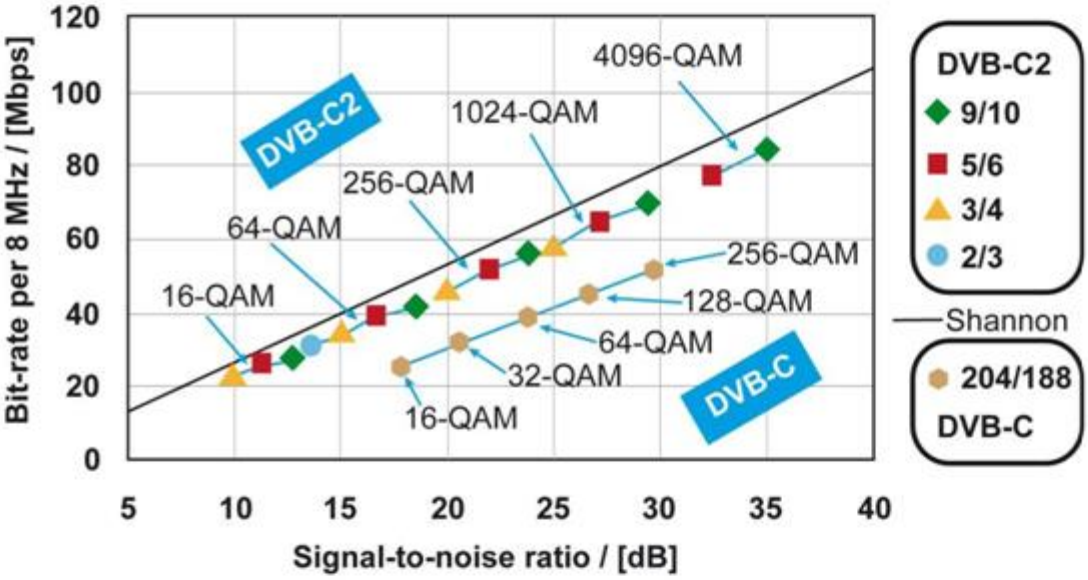

Figure 10: Performance of DVB-C2 versus DVB-C for various constellations and FEC coding rates.

The maximum overall capacity increase for DVB-C2 is more than 60% greater than that of DVB-C when the gain from the superior FEC scheme (30%), the gain from the broader channels (5%), and the gain of 4096-QAM relative to 1024-QAM (20%) are taken into consideration.

Conclusion

The DVB-T2 technology and the DVB-X2 class of standards collectively represent a milestone in the evolution of digital broadcasting. DVB-T2 has demonstrated its capacity to deliver up to 50% higher spectrum efficiency compared to DVB-T, through the integration of advanced modulation (up to 256-QAM), large FFT modes (up to 32K), and powerful error correction (LDPC/BCH). These features enable higher data throughput, improved robustness in multipath and mobile environments, and flexible service delivery using Physical Layer Pipes. The successful global adoption of DVB-T2 highlights its suitability for HDTV, UHDTV, and mobile services within limited spectrum resources.

The DVB-X2 family extends these advancements across satellite, cable, and handheld platforms. DVB-S2X provides spectral efficiencies beyond 5 bits/s/Hz with higher-order constellations and smaller roll-off factors, making it ideal for UHDTV broadcasting and broadband-over-satellite applications. DVB-C2 delivers up to 60% capacity gains in cable networks, while DVB-NGH adapts terrestrial broadcasting techniques for mobile devices, ensuring robust reception under dynamic channel conditions. Together, these standards offer a comprehensive and future-proof broadcasting ecosystem.

In summary, DVB-T2 and the DVB-X2 class of standards address the critical challenges of modern broadcasting spectrum scarcity, growing bandwidth demands, and service convergence. By enabling high-quality, scalable, and cost-efficient transmission, they form the technological foundation for next-generation broadcasting infrastructures. Their continued evolution will play a vital role in the integration of broadcast and broadband services, supporting emerging applications such as interactive TV, UHD content distribution, and hybrid communication systems.

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