

Reimagining Broadcasting in India with ATSC3 B2X: Use cases, requirements and opportunities

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Executive Summary

This white paper has been prepared by IIT Bombay. This white paper examines how ATSC3 B2X—a broadcast–broadband convergence framework can strengthen India’s media delivery, public services, and digital inclusion. It consolidates India’s broadcasting context, the B2X technical approach, priority use cases, spectrum realities, and deployment opportunities across urban and rural regions. India’s broadcasting ecosystem spans public and private networks with deep terrestrial, satellite, and emerging digital capabilities. Against this backdrop, B2X leverages the one-to-many efficiency of broadcast and the personalization and interactivity of broadband, enabling resilient delivery of time-sensitive and high-volume content such as emergency alerts, education modules, software updates, vehicular data, IoT payloads, and AI models to edge devices.

The paper identifies seven opportunity pillars: upgrading existing broadcast infrastructure, harnessing India’s vast device base, aligning with National Frequency Allocation Plan (NFAP)-anchored spectrum, pursuing urban–rural dual strategies, realizing cost-effective nationwide coverage, integrating B2X with 5G, and leveraging Public–Private Partnership (PPP) pathways via smart-city programs and city command centers. Collectively, these form a practical blueprint to pilot, scale, and sustain B2X services in India.

Key takeaways:

- Broadcast–broadband synergy improves reach, resilience, and economics for mass delivery while unicast remains ideal for individualized sessions.
- Spectrum and policy under NFAP 2022 already recognize UHF 470–585 MHz for broadcasting with coordination windows for IMT, setting the baseline for NFAP 2025 deliberations.
- Deployment readiness benefits from 5G’s national footprint and D2M trials, alongside expanding fiber backbones (BharatNet) for timing and backhaul.
- Immediate use cases include emergency and disaster alerts, remote education, V2X data, agriculture advisories, IoT/edge payloads, and fleet software updates.

Editor’s Note: The content presented in this white paper is based on open references and ongoing national activities or reflects the author’s own interpretations and opinions. To ensure clarity and proper structuring of the content, assistance from AI-based tools was utilized during the preparation of this document.

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List of Abbreviations

AIR	All India Radio
AR	Augmented Reality
ATSC	Advanced Television Systems Committee
B2X	Broadcast-to-Everything
BIND	Broadcasting Infrastructure and Network Development
COAI	Cellular Operators Association of India
D2M	Direct-to-Mobile
DASH	Dynamic Adaptive Streaming over HTTP
DoS	Department of Space
DoT	Department of Telecommunications
DPIIT	Department for Promotion of Industry and Internal Trade
DTH	Direct-to-Home
DVB-T2	Digital Video Broadcasting – Second Generation Terrestrial
FID	Foreign Direct Investment
FOTA	Firmware Over-the-Air
HPT	High Power Transmitter
IBC	Indian Broadcasting Company
IAMAI	Internet and Mobile Association of India
ICCC	Integrated Command and Control Center
IMT	International Mobile Telecommunications
IoT	Internet of Things
ITU	International Telecommunication Union
LPT	Low Power Transmitter
MIB	Ministry of Information and Broadcasting
MNO	Mobile Network Operator
NBP	National Broadcasting Policy
NDMA	National Disaster Management Authority
NFAP	National Frequency Allocation Plan
NR	New Radio
OEM	Original Equipment Manufacturer
OTT	Over-The-Top
PNT	Positioning Navigation and Timing
PoC	Proof-of-Concept
PPP	Public–Private Partnership
ROUTE	Real-Time Object Delivery over Unidirectional Transport
SFN	Single Frequency Network
SLA	Service Level Agreement
SOTA	Software Over-the-Air
SVoD	Subscription Video on Demand
TDSAT	Telecom Disputes Settlement and Appellate Tribunal
TR	Technical Report
TRAI	Telecom Regulatory Authority of India
TS	Technical Specification
TSDSI	Telecommunications Standards Development Society, India
V2X	Vehicle-to-Everything
VR	Virtual Reality
WI	Work Item

1 Introduction

India's broadcasting journey—from the *Indian Broadcasting Company (1927)* to *All India Radio (1936)* and *Doordarshan (1959)*—has evolved into a multi-platform ecosystem that informs, educates, and entertains at national scale [1]. Liberalization in the 1990s catalyzed private participation, satellite growth, and today's OTT-led digital segment. The sector now operates within a multi-agency framework spanning the Ministry of Information and Broadcasting (MIB), Telecom Regulatory Authority of India (TRAI) / Telecom Disputes Settlement and Appellate Tribunal (TDSAT), Department of Telecommunications (DoT), Department of Space (DoS), and others, ensuring policy alignment, spectrum management, quality of service, and investment pathways [2]. Despite its reach, two structural challenges persist. First, **peak-hour mobile congestion** and rising video/AI payloads strain unicast networks in dense events and cities [3]. Second, **connectivity gaps** in rural and underserved regions limit equitable access to education, public information, and critical updates [4]. These dynamics motivate **broadcast–broadband convergence**: use broadcast for simultaneous delivery and broadband for personalized interaction.

ATSC3 B2X addresses this need with native IP transport, robust reception, and standards-based interoperability with 5G. It supports **low-latency datacasting**, **dynamic service reception**, and **scalable bootstrap signaling**—extending broadcast beyond TV to phones, vehicles, sensors, and city infrastructure. The use of a scalable bootstrap makes this technology energy efficient as there is no need to scan the whole bandwidth during the synchronization process. The one-to-many economics lower marginal cost per additional user; the hybrid model with mobile networks enables traffic sharing between networks.

Scope and structure of this paper: The white paper synthesizes India's broadcast landscape and regulation, introduces B2X, details priority use cases, surveys ongoing initiatives and device integration, outlines spectrum-related aspects, and highlights deployment opportunities and mobile convergence advantages. It culminates in a conclusion and way forward tailored to India's policy, market, and infrastructure realities.

2 Broadcasting in India

2.1 Significance of Broadcasting sector from the perspective of India

The journey of broadcasting in India began in 1927 with the establishment of the Indian Broadcasting Company (IBC) in Bombay and Calcutta [1]. This marked the country's first organized attempt to use radio as a medium for public communication. Though short-lived due to financial constraints, IBC laid the foundation for structured broadcasting in India and introduced the concept of mass media to the Indian public. Building on this early initiative, All India Radio (AIR) was formally established in 1936 as a national broadcaster [5]. AIR became a cornerstone of India's communication infrastructure, especially during the freedom movement and post-independence nation-building. It played a vital role in disseminating news, promoting education, and preserving cultural heritage across linguistic and regional boundaries. AIR's motto, "Bahujan Hitaya Bahujan Sukhaya" (for the benefit and happiness of the masses), reflected its commitment to public service broadcasting.

The next major milestone came in 1959 with the launch of Doordarshan, India's first television broadcasting service. Initially an experimental service in Delhi, Doordarshan evolved into a national broadcaster that brought visual storytelling into Indian homes [6]. It became a powerful tool for education, entertainment, and cultural integration, especially through iconic programs like *Krishna Darshan*, *Ramayana*, and *Bharat Ek Khoj*. The reach and influence of Doordarshan played a pivotal role in shaping the collective consciousness of the nation during its formative years. The economic liberalization of the 1990s paved the way for private sector participation, catalyzing rapid growth in satellite television and FM radio. This era ushered in a dynamic broadcasting landscape characterized by multiple channels and diverse platforms. The entry of private broadcasters introduced competition, innovation, and audience-centric programming, transforming broadcasting into a vibrant industry. Regional channels flourished, niche content emerged, and the democratization of media began to take shape.

From its humble beginnings in 1927 to the multi-platform ecosystem of today, India's broadcasting sector has evolved into a powerful force for socio-economic development, cultural preservation, and democratic engagement. Its historical trajectory reflects the nation's journey — from colonial constraints to global connectivity. Yet, despite these remarkable advancements, the sector continues to hold immense untapped potential. With a vast and diverse audience, growing digital infrastructure, and increasing demand for high-quality content, India

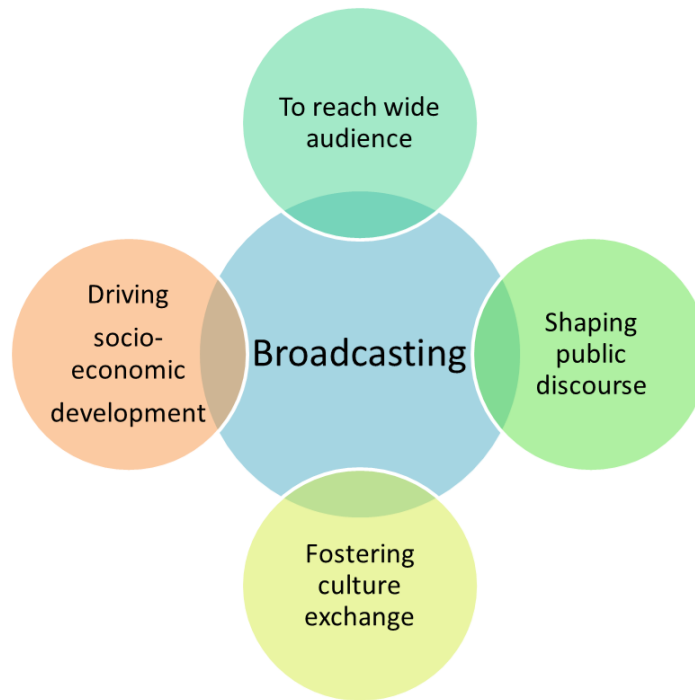


Figure 1: Significance of Broadcasting

presents a fertile ground for innovation in broadcasting. The time is ripe to introduce cutting-edge technologies, modern standards, and scalable solutions that can further enhance reach, efficiency, and impact.

“Broadcasting sector is the cultural ambassador of the country and has given a unique identity to India. Broadcasting services inform, educate and entertain the masses, empower the consumers and inspire the nation in its journey of progress and prosperity.” [7]

Figure 1 highlights the significance of broadcasting. In a diverse and multilingual country like India, the broadcasting sector plays a pivotal role in unifying the population through shared narratives and inclusive communication. Its ability to reach a wide audience — from urban centers to remote rural regions — makes it one of the most powerful tools for mass engagement. Whether through television, radio, or emerging digital broadcast platforms, it ensures that vital information, educational content, and cultural programs are accessible to all, regardless of geography or socio-economic status.

Beyond information dissemination, broadcasting actively shapes public discourse. It provides a platform for democratic dialogue, enabling citizens to engage with national issues, government policies, and social movements. News channels, talk shows, and public service broadcasts contribute to an informed citizenry, fostering transparency and accountability in governance.

Culturally, the broadcasting sector serves as a bridge across India’s rich tapestry of traditions, languages, and customs. It facilitates cultural exchange by showcasing regional art, music, literature, and festivals, thereby promoting mutual understanding and national integration. This cultural representation not only strengthens internal cohesion but also projects India’s soft power globally. Economically, broadcasting is a driver of growth and innovation. It supports a vast ecosystem of content creators, technicians, advertisers, and service providers. The sector contributes significantly to employment generation and GDP, while also enabling the growth of adjacent industries such as entertainment, education, and e-commerce. Moreover, broadcasting has proven to be a critical tool in socio-economic development — from promoting health awareness and financial literacy to supporting remote education and disaster response.

In essence, the broadcasting sector is not just a medium of communication; it is a catalyst for empowerment, unity, and progress. As India continues its digital transformation, the sector’s role will only deepen, making it indispensable in shaping the nation’s future.

2.2 Structure, Regulation and Major Segments of Indian Broadcasting

The broadcasting sector in India operates under a multi-agency regulatory framework to ensure compliance, quality, and orderly growth. At the core are several government bodies and authorities, each with distinct responsibilities. The MIB oversees uplinking and downlinking permissions, distributor approvals, and content regulation, while also shaping policy for the sector. The TRAI formulates and enforces regulations related to service quality, interconnection, and tariffs, supported by the TDSAT for resolving carriage disputes. The Department of Telecommunications manages spectrum allocation and usage permissions, whereas the Department of Space grants satellite permissions critical for broadcasting infrastructure. Additionally, the Ministry of Home Affairs provides security clearances, and the DPIIT governs FDI policy and intellectual property rights. This collaborative structure ensures that broadcasting in India remains secure, competitive, and aligned with national priorities, while enabling technological innovation and investment opportunities [2]. Figure 2 shows the interconnection between different regulatory bodies.

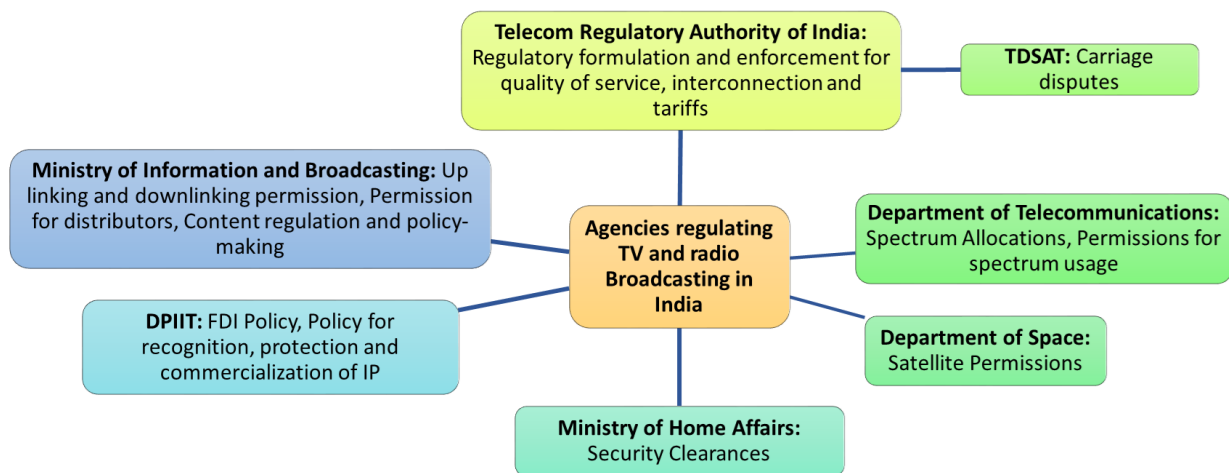


Figure 2: Structure and Regulation of Indian Broadcasting [2]

India's broadcasting ecosystem is vast and diverse, comprising three major segments: television broadcasting, radio broadcasting, and digital broadcasting. Each segment plays a unique role in reaching audiences across the country and reflects the evolution of media consumption patterns.

Television Broadcasting:

Television remains the dominant medium in India, encompassing terrestrial services like Doordarshan, cable networks, Direct-to-Home (DTH) platforms, and IPTV. The television landscape is multilingual and multicultural, catering to India's diverse population through 330 registered broadcasters and 859 Multiple System Operators (MSOs) [7]. This segment has been instrumental in delivering entertainment, news, and educational content to millions of households, bridging urban and rural divides.

Radio Broadcasting:


Radio continues to be a trusted and accessible medium, particularly in rural and remote areas. It includes AM, FM, and community radio services. AIR, the national public broadcaster, operates alongside 388 private FM stations, collectively covering approximately 98% of India's population and 92% of its geographical area [8]. Radio serves as an essential channel for information dissemination, cultural programs, and emergency communication, reinforcing its relevance even in the digital age.

Digital Broadcasting:

The digital revolution has ushered in a new era of broadcasting through Over-The-Top (OTT) platforms and internet radio. India now hosts over 50 OTT services, including leading platforms such as JioHotstar (Disney/Hotstar and JioCinema merger), Amazon Prime Video, Netflix, ZEE5, Sony LIV, and regional players like Hoichoi, Sun NXT, Aha, and Planet Marathi [9]. This segment reflects changing consumer preferences for on-demand, personalized content and represents the fastest-growing area in the broadcasting industry.

Together, these segments form a dynamic broadcasting landscape that continues to expand with technological advancements and evolving audience needs. While television and radio maintain their stronghold, digital broadcasting is redefining the future of media in India, creating opportunities for innovation and investment. The Media & Entertainment sector contributes 0.73% to India’s GDP. Digital media and Television are major contributors, as shown below in the table [10]


Key trends of 2024

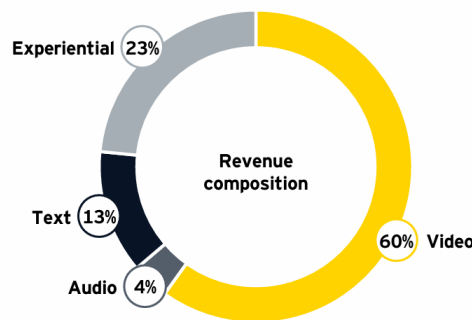
 Indian M&E sector grew 3.3% in 2024 to reach INR2.5 trillion

	2019	2022	2023	2024	2025E	2027E	CAGR 2024-2027
Digital media	308	571	686	802	903	1,104	11.2%
Television	788	726	711	679	676	667	(-)0.6%
Print	296	250	259	260	262	267	0.9%
Online gaming	64	222	236	232	260	316	10.8%
Filmed entertainment	191	172	197	187	196	213	4.3%
Animation and VFX	95	107	114	103	113	147	12.5%
Live events	83	73	88	101	119	167	18.2%
Out-of-home media	51	48	54	59	66	79	10.2%
Music	15	46	54	53	60	78	13.4%
Radio	31	21	23	25	27	30	6.6%
Total	1,922	2,237	2,422	2,502	2,682	3,067	7.0%
Growth		23.3%	8.3%	3.3%	7.2%		

All figures are gross of taxes (INR in billion) for calendar years | EY estimates

Courtesy [10]

 Video continued to command the lion’s share of revenues



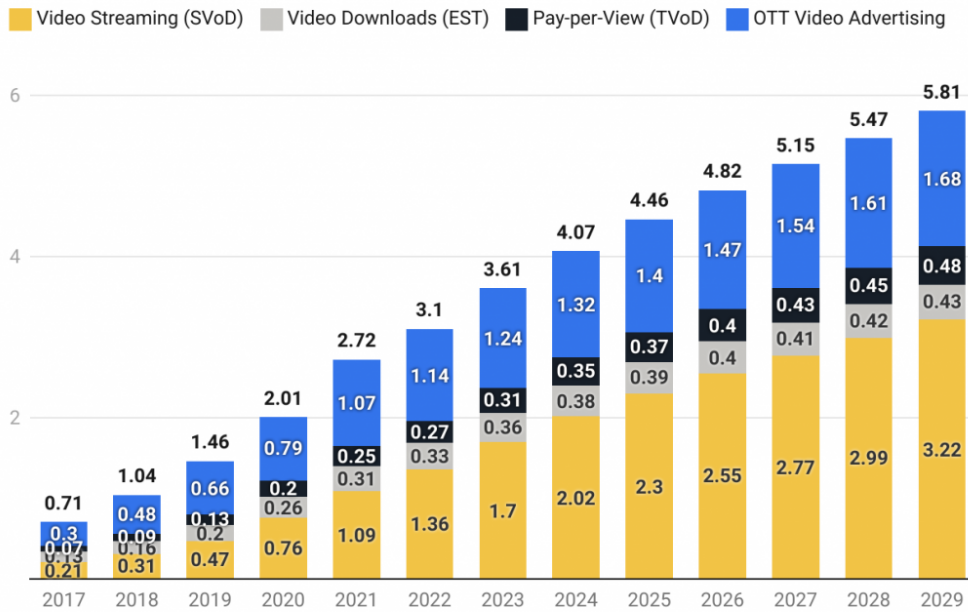
EY 2024 revenue estimates | Does not include data pack values and e-commerce advertising

Figure 3: Revenue composition from different types of content. Courtesy [10]

Video continues to dominate the digital content revenue landscape, commanding nearly 60% of total revenues, far surpassing other formats such as experiential (23%), text (13%), and audio (4%) as shown in Figure 3 [10]. This dominance is reinforced by long-term revenue projections, where subscription-based video streaming (SVoD) is expected to grow from \$0.71 billion in 2017 to over \$3.22 billion by 2029. Concurrently, OTT video advertising is forecasted to rise from \$0.3 billion to \$1.68 billion during the same period, while pay-per-view and video downloads maintain modest growth as shown in Figure 4 [9]. Collectively, these trends highlight video’s pivotal role as the primary driver of monetization in the evolving media ecosystem.

Revenue

(in billion USD)



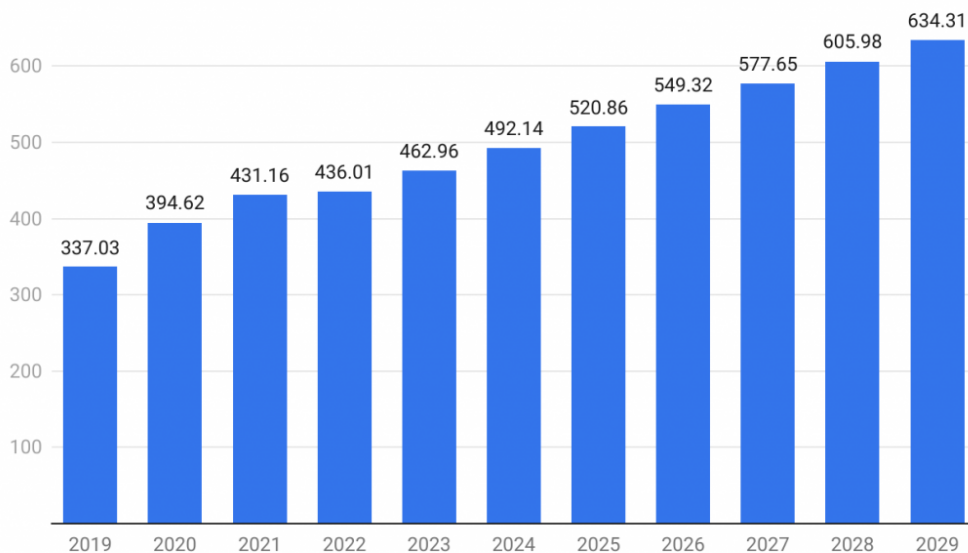
Source: Sci-Tech Today



Figure 4: Indian OTT Video By Revenue. *Courtesy* [9]

Number Of Users In The OTT Video Segment Of The Media Market India From 2019 To 2029

(in million individuals)



Source: Sci-Tech Today



Figure 5: Top 10 Indian OTT Platforms statistics by number of users in the OTT video segment. *Courtesy* [9]

India's OTT video market is not only expanding in terms of user base but also driving significant data consumption trends. The number of OTT video users in India is projected to grow from 337 million in 2019 to over 634

million by 2029, as shown in Figure 5, reflecting an 88% increase over the decade [9]. This surge aligns with evolving consumption patterns highlighted in the Ericsson Mobility Report June 2025, as shown in Figure 6, where video accounts for the largest share of mobile data traffic across all usage segments. By 2024, video dominates even in extreme usage categories (>100 GB per month), representing more than 60% of total data consumption, while other services such as social networking, web browsing, and gaming occupy comparatively smaller shares [11]. The trend highlights video’s dual role as both a revenue driver and a bandwidth-intensive application, necessitating robust network infrastructure and spectrum strategies to support high-quality streaming experiences. Together, these figures illustrate how the convergence of user growth and data-heavy video services is shaping India’s digital media ecosystem and influencing policy, investment, and technology priorities.

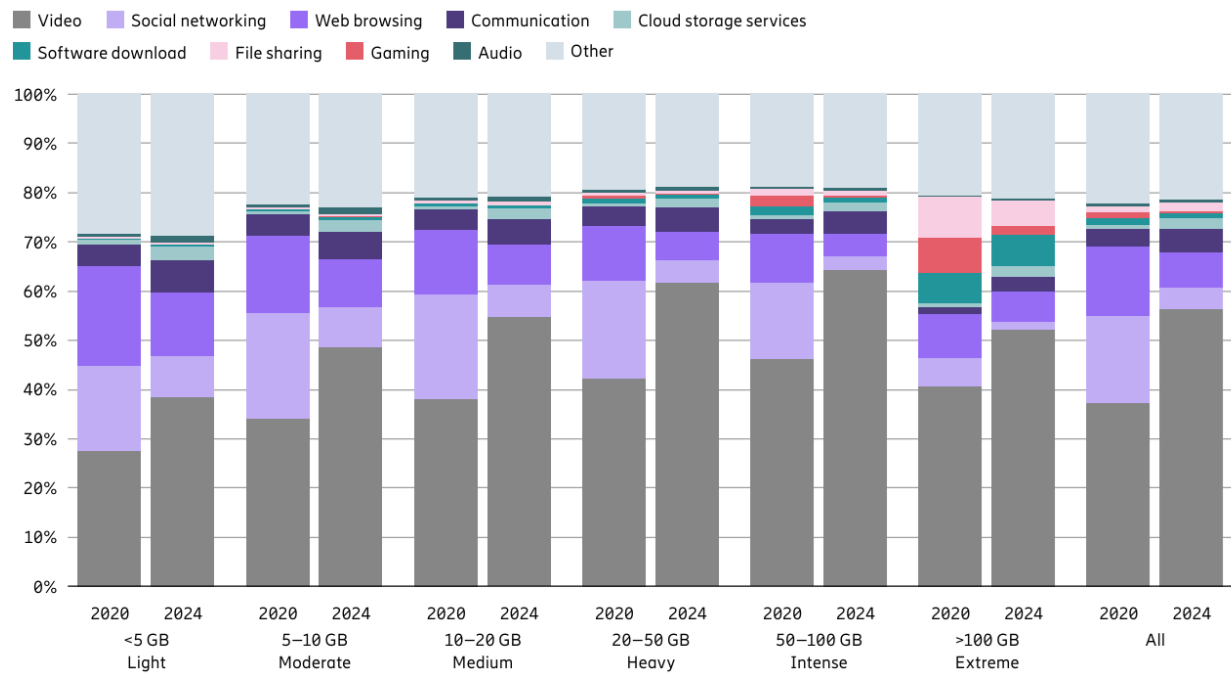


Figure 6: Global mobile traffic volume per application type. Courtesy [11]

2.3 Emerging Trends and Technologies in the Broadcasting Sector

Digital Radio as an Affordable Mass Communication Tool: Digital radio is rapidly emerging as a transformative medium in the broadcasting landscape, particularly in developing countries like India. Offering superior sound quality, increased spectrum efficiency, and the ability to transmit additional data services, digital radio presents a cost-effective solution for mass communication. Unlike traditional analog systems, digital radio can support multiple channels within the same bandwidth, enabling broadcasters to deliver diverse content to a wider audience. Its resilience to interference and ability to reach remote and underserved regions make it an ideal platform for educational programs, emergency alerts, and community engagement, thereby bridging the information divide [12].

Direct-to-Mobile (D2M) Broadcasting, A Game-Changer for Content Delivery: D2M broadcasting represents a paradigm shift in how content is delivered and consumed, especially in mobile-first markets like India. By enabling broadcasters to transmit content directly to smartphones without relying on cellular data or internet connectivity, D2M ensures uninterrupted access to news, entertainment, and emergency alerts. This technology is particularly valuable during network congestion or natural disasters, where traditional communication channels may fail. Moreover, D2M can support public service initiatives, educational outreach, and localized content delivery, making it a powerful tool for inclusive and resilient communication infrastructure [12].

Evolution of Broadcasting Standards in India, From DVB-T2 to ATSC3: India’s broadcasting standards have evolved from the deployment of DVB-T2 (Digital Video Broadcasting – Second Generation Terrestrial), which has been operational since 2016 and offers improved spectral efficiency, HD content delivery, and mobile reception, to exploring next-generation technologies like ATSC 3.0 [13]. ATSC 3.0 introduces IP-based broadcasting, enabling

hybrid broadcast-broadband services, interactive applications, and targeted content delivery. This progression reflects India's push toward convergence of telecom and broadcast networks, aiming to enhance accessibility, support innovative services, and meet growing consumer demand for high-quality, personalized content in a rapidly digitizing ecosystem.

Leveraging 5G and Immersive Technologies for Next-Gen Broadcasting: The convergence of 5G networks with immersive technologies like Augmented Reality (AR) and Virtual Reality (VR) is set to redefine the broadcasting experience. With ultra-low latency, high bandwidth, and massive device connectivity, 5G enables real-time, high-resolution content delivery, making interactive and immersive media experiences feasible [14]. Broadcasters can now offer viewers dynamic storytelling formats, such as 360-degree live sports coverage or virtual classroom environments, enhancing engagement and personalization. This synergy between 5G and immersive tech not only enriches content consumption but also opens new avenues for education, entertainment, and remote collaboration.

3 Broadcast-to-Everything (B2X)

3.1 Introduction to B2X

B2X represents a transformative leap in broadcasting technology, building upon the capabilities of the ATSC 3.0 standard [15] [16]. As a next-generation broadcasting framework, B2X is engineered to deliver rich content and critical data streams efficiently across a diverse ecosystem of devices and applications — ranging from smartphones and connected vehicles to smart infrastructure and remote learning platforms. At its core, B2X leverages the advanced features of ATSC 3.0 to enable robust, scalable, and low-latency datacasting. This evolution is particularly significant in the context of emerging digital ecosystems, where seamless integration with 5G networks and intelligent traffic systems is essential. B2X is poised to play a pivotal role in dynamic traffic management, emergency alerting, and real-time data delivery, thereby enhancing both public safety and user experience. One of the key advantages of B2X is its non-disruptive deployment. The introduction of B2X does not interfere with existing ATSC services or require changes to previously deployed ATSC infrastructure, allowing broadcasters to adopt B2X alongside legacy systems in a cost-effective and scalable manner.

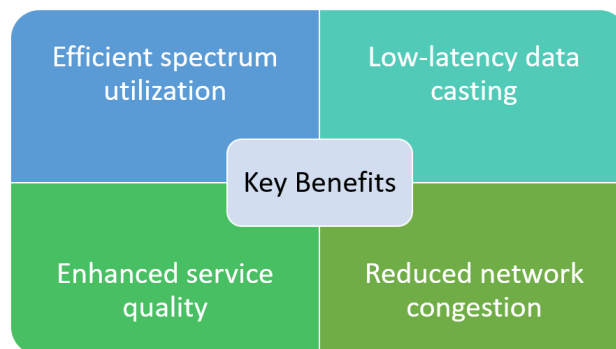


Figure 7: B2X Key Benefits

The key benefits of B2X as shown Figure 7 are as follows [17]:

- **Efficient Spectrum Utilization:** B2X technology is designed to make optimal use of available broadcast spectrum, which is a finite and valuable resource. By leveraging advanced modulation and coding techniques inherent in ATSC 3.0, B2X enables high-capacity data transmission without requiring additional spectrum allocation. This efficiency allows broadcasters to deliver multiple services — such as video, audio, emergency alerts, and IP-based data — within the same frequency band. In the Indian context, where spectrum is heavily contested among telecom, defense, and broadcasting sectors, B2X offers a strategic advantage by maximizing throughput while minimizing interference and regulatory overhead.
- **Low Latency Datacasting:** One of the standout features of B2X is its ability to deliver data with minimal delay. This low-latency capability is critical for time-sensitive applications such as vehicular communication

(V2X), real-time traffic updates, and emergency alert systems. Unlike traditional IP-based delivery over congested cellular networks, B2X uses a one-to-many broadcast model that ensures rapid and simultaneous data delivery to all receivers within coverage. This is particularly beneficial for smart transportation systems, where milliseconds can make a difference in decision-making and safety.

- **Enhanced Service Quality:** B2X ensures consistent and high-quality service delivery across a wide range of devices and network conditions. Its robust error correction mechanisms and adaptive bitrate streaming allow content to be received reliably even in challenging environments — such as rural areas, moving vehicles, or during adverse weather conditions. This makes B2X an ideal solution for bridging the digital divide, supporting remote education, and enabling uninterrupted infotainment services in public transport systems.
- **Reduced Network Congestion:** By offloading data delivery from traditional unicast cellular networks to a broadcast-based infrastructure, B2X significantly reduces the burden on mobile networks. This is especially important in high-density urban areas or during peak usage times, where cellular networks often struggle with congestion. B2X complements existing 4G/5G infrastructure by handling non-interactive, high-volume data distribution — such as software updates, multimedia content, and public service announcements — thereby freeing up bandwidth for interactive services and improving overall network performance.

3.2 Highlights of B2X with respect to ATSC 3.0

B2X builds upon the foundation of ATSC 3.0 while introducing key enhancements to address emerging connectivity needs. While ATSC 3.0 was primarily designed for standalone broadcast deployments, B2X extends this capability to support both standalone and converged deployments, enabling seamless integration with telecom networks. It offers broader RF band support compared to ATSC 3.0's limited bandwidth, ensuring greater flexibility for diverse spectrum environments. Furthermore, B2X is harmonized with 5G standards and aligned with O-RAN principles, making it future-ready for next-generation networks [15]. Unlike ATSC 3.0's limited use case scenarios, B2X supports a wide range of applications and incorporates features such as scalable bootstrap, which reduces power consumption during synchronization—making it highly suitable for low-power user devices and enabling efficient direct-to-mobile broadcasting. Table 1 shows a side-by-side comparison of ATSC 3.0 and B2X.

ATSC 3.0	B2X
Designed for standalone deployments	Extension of ATSC 3.0 and designed for standalone and converged deployments both
Limited RF bandwidth support	Extended support for many RF Bands
Interworking with 5G was not envisaged	Harmonization with 5G and aligned with O-RAN
Limited use case scenarios	Can support a wide range of use case scenarios and programmable APP-driven service reception optimized for low power UE devices (including scalable bootstrap)

Table 1: Comparison between ATSC 3.0 and B2X

3.3 ATSC3 B2X-Future evolution of DTT based Broadcasting

The global landscape of Digital Terrestrial Television (DTT) broadcasting reflects diverse technology adoption, with DVB-T dominating Europe, Africa, and parts of Asia, ATSC prevalent in North America, ISDB-T in Latin America and Japan, and DTMB in China [18]. This fragmentation underscores the need for flexible and interoperable standards as broadcasting evolves toward next-generation services. In India, the evolution of DTT-based broadcasting is progressing through three distinct phases as shown in Figure 8. The first phase, traditional over-the-air broadcasting using DVB-T2, enabled non-real-time content delivery with partial IP integration and limited interactivity. The second phase introduces D2M broadcasting, leveraging ATSC waveforms in proof-of-concept trials since 2021, supported by an emerging device ecosystem. The third phase represents a logical progression to ATSC3 B2X, which integrates OFDMA-based transmission, harmonizes with 5G, aligns with O-RAN principles,

and extends RF band support with features like scalable bootstrap for power-efficient synchronization. This evolution positions B2X as a future-ready framework capable of delivering real-time, interactive, and personalized services across multiple device categories, bridging the gap between broadcasting and broadband networks.

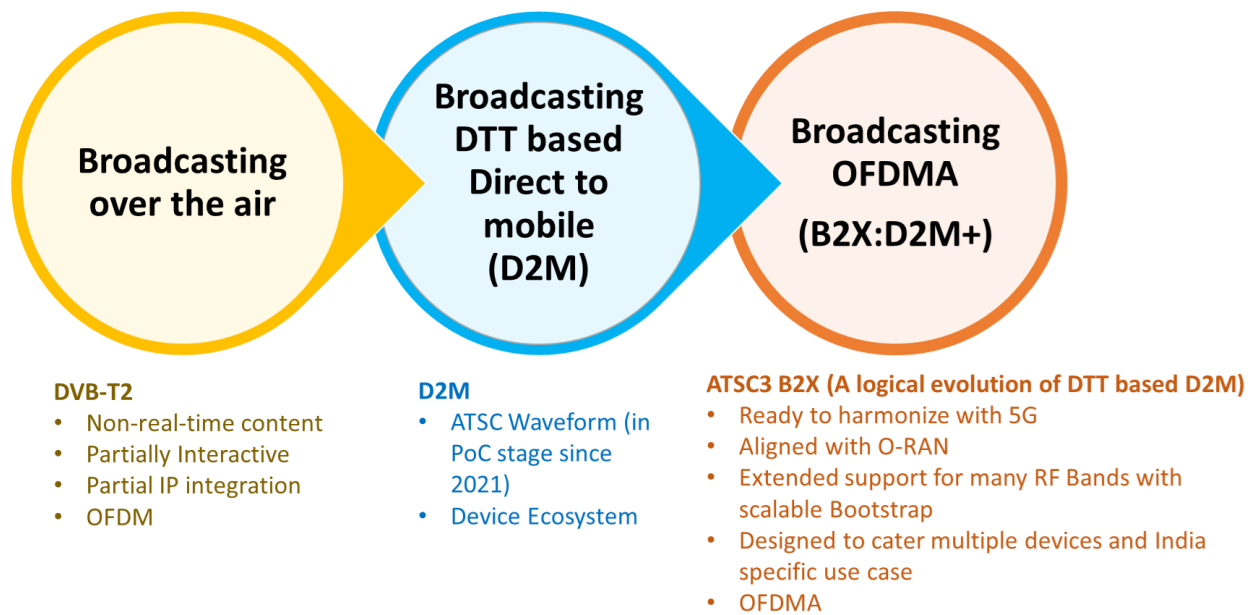


Figure 8: Future evolution of DTT based broadcasting (India)

3.4 Direct-to-Mobile Broadcasting via ATSC3 B2X from India perspective

D2M broadcasting is poised to revolutionize content delivery in India by enabling the transmission of live television, news, and entertainment directly to mobile devices—without relying on mobile data or internet connectivity. This is particularly impactful for rural and remote regions where cellular coverage is sparse or unreliable. By leveraging the UHF/VHF spectrum (470–582 MHz), D2M can deliver compressed digital signals efficiently, offering a scalable and cost-effective solution for reaching millions of users with high-quality content and public service information. ATSC 3.0-based B2X technology enhances this vision by aligning closely with the 5G ecosystem. Unlike 5G Broadcast, which is primarily designed for linear TV and lacks a clear upgrade path to 5G Multicast-Broadcast Services (5G-MBS), B2X system is inherently designed for bidirectional data services and seamless interworking with 5G and its future derivatives. This compatibility ensures that B2X can leverage common network infrastructure, chipsets, and user devices—both mobile and fixed—thereby reducing deployment costs and accelerating adoption.

In the Indian context, where ATSC 3.0 and 5G Broadcast are both being considered for D2M implementation, B2X offers a more future-ready and inclusive approach. While 5G Broadcast is constrained by its unidirectional nature and limited use cases, B2X supports a broader range of applications, including interactive services, emergency alerts, educational content, and localized information dissemination. Its ability to function independently of mobile networks while remaining interoperable with them makes it uniquely suited to India's diverse and mobile-centric population. Ultimately, DTT-based D2M powered by ATSC 3.0 B2X has the potential to become a cornerstone of India's digital infrastructure. By bridging the digital divide and enabling universal access to information, it can empower communities, enhance disaster resilience, and support the government's vision of Digital India.

4 Use Cases of ATSC3 B2X from India's Perspective

4.1 Emergency & Disaster Alerts

Cellular networks rely on a dense grid of base stations (cell towers), each needing power, backhaul connectivity, and coordination. In natural or man-made disasters, these towers can be physically damaged or lose power/backhaul, leading to network fragmentation. Even if towers survive, network congestion becomes a major issue. Everyone tries to call or use data at once, overwhelming the system. ATSC3 B2X is a broadcast system where one transmitter sends signals to many receivers simultaneously. This is inherently scalable and resilient to congestion — no matter how many people are tuned in, the load doesn't increase. Additionally, broadcast transmitters transmit with high power and are fewer in number, often located on elevated or protected sites. They are designed to cover large geographic areas, making them less vulnerable to localized damage.



Emergency & Disaster

Therefore, emergency and disaster alert broadcasting plays a vital role in delivering real-time warnings and safety instructions during critical events such as floods, earthquakes, cyclones, and other natural or man-made disasters. Using ATSC3 B2X wireless communication, alerts can be transmitted instantly to a wide range of devices including mobile phones, televisions, and connected infrastructure, without relying on the internet or cellular networks. In the Indian context, this capability is especially crucial for disaster-prone regions such as Uttarakhand, Assam, and coastal states like Odisha and Tamil Nadu, where timely alerts can save lives and aid in coordinated emergency response.

“Integrating B2X broadcasting with national disaster management systems can significantly enhance preparedness and resilience across vulnerable communities”

4.2 Remote Education

The COVID-19 pandemic has highlighted the critical importance of reliable tele-education infrastructure to ensure educational continuity in all regions. In India, where a significant portion of the population resides in rural and remote areas, the challenges of limited broadband penetration, high data costs, and inconsistent connectivity have exposed systemic inequalities in access to digital learning. These challenges highlighted the need for an alternative content delivery framework that is both scalable and resilient. The ATSC3 B2X technology can provide an innovative pathway to address these limitations. By utilizing IP-based broadcast transmission, ATSC3 B2X enables efficient and high-quality delivery of educational content to a wide range of connected devices, including televisions, smartphones, tablets, and personal computers, without dependence on continuous broadband connectivity.



Remote Education

Tele-Education leveraging ATSC3 B2X technology may allow the following services:

- Access to different courses and topics beyond what may only be available in an individual region
- Flexibility in attending schools based on an individual's circumstances
- Learning from other resources across the world
- Live streaming of sessions from other institutions

- Online help to do the homework and assignments
- Can help in saving money to be spent on lodging and travel

“Remote education broadcasting through ATSC3 B2X wireless communication can enable the delivery of high-quality educational content to low-cost devices in geographically remote and underserved areas”

4.3 Vehicular communication broadcasting

In the evolving landscape of autonomous and connected vehicles, uninterrupted network connectivity is fundamental to the operation of central control systems as shown in Figure 9. These systems rely heavily on real-time data exchange to support intelligent transport functions such as traffic management, navigation, and safety coordination. V2X communication plays a pivotal role in this ecosystem by enabling vehicles to interact with infrastructure, other vehicles, pedestrians, and cloud-based services. This interaction facilitates smart mobility solutions, including 3D HD mapping, real-time traffic updates, and enhanced driver awareness, all of which contribute to safer and more efficient transportation networks [19].

ATSC3 B2X broadcasting offers a robust alternative to traditional cellular-based V2X systems. By leveraging high-capacity wireless broadcast channels, it can deliver critical data directly to vehicles without relying on two-way internet connectivity. This includes real-time traffic information, Positioning Navigation and Timing (PNT) augmentation for improved GPS accuracy, safety alerts for hazard avoidance, and infotainment content for passenger engagement. The broadcast model ensures scalability and resilience, making it particularly suitable for high-density urban environments and remote areas where cellular coverage may be limited or unreliable. This use case highlights the potential of ATSC3 B2X technology to enhance vehicular communication infrastructure and support the future of autonomous mobility in India.

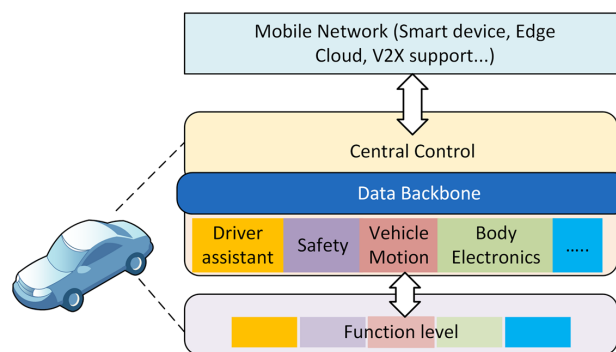


Figure 9: Vehicular Communication [20]

“Vehicular communication broadcasting is a way forward for future applications such as autonomous driving and connected vehicle ecosystems, aligning with India’s push toward smart cities and sustainable urban development”

4.4 Agriculture support

Agriculture remains a cornerstone of India’s economy, contributing approximately 17.94% to the national GDP in FY 2024–25, according to Statistics Times. Despite its significance, farmers across the country continue to face substantial challenges, particularly due to the lack of timely and reliable information. One of the most critical issues is the absence of real-time weather updates, which often leads to crop damage and financial losses. Additionally, limited access to market intelligence prevents farmers from securing fair prices for their produce, further exacerbating rural economic distress. The integration of ATSC3 B2X broadcast technology offers a promising solution to these challenges. Through its one-to-many transmission model, B2X can deliver real-time weather alerts and agricultural advisories directly to farmers, even in regions with poor or no internet connectivity. Information related to crop care, pest control, and market trends can be broadcast efficiently, empowering farmers to make informed decisions. This not only helps reduce crop losses but also improves access to fair market

opportunities. By ensuring that critical agricultural data reaches even the most remote farming communities, B2X communication contributes meaningfully to rural development, economic resilience, and national food security.

“ATSC3 B2X can enable the timely and efficient delivery of critical information such as weather forecasts, crop advisories, pest alerts, and market prices directly to farmers via broadcasting”

4.5 Sustainable broadcasting for IoT Devices

ATSC3 B2X broadcasting presents a transformative approach to delivering data to Internet of Things (IoT) devices in a battery-efficient and scalable manner. Unlike traditional cellular or Wi-Fi networks that require constant connectivity and high energy consumption, B2X leverages one-to-many broadcast capabilities to transmit data simultaneously to a wide array of devices—such as wearables, sensors, and low-power IoT devices—without the need for individual connections. This method significantly reduces the power burden on devices, making it ideal for low-power applications and extending the operational life of battery-dependent systems. This broadcasting paradigm is particularly advantageous in remote or resource-constrained environments, where infrastructure is limited and energy conservation is most important. For instance, agricultural sensors deployed across vast rural landscapes or health-monitoring wearables in underserved regions can receive periodic updates or alerts without relying on costly and power-hungry cellular networks. By decoupling data delivery from traditional internet connectivity, ATSC3 B2X enables a sustainable and inclusive model for IoT communication, aligning with global goals for energy efficiency and digital equity.

“By supporting low power devices as part of design, ATSC3 B2X can enhance the sustainability and scalability of IoT deployments across both urban and rural India”

4.6 Smart Datacasting

AI-driven datacasting over ATSC3 B2X networks introduces a powerful mechanism for delivering personalized digital content efficiently and intelligently. By leveraging artificial intelligence, broadcasters can tailor content based on dynamic parameters such as geographic location, user occupation, and local relevance. This enables targeted delivery of educational material, emergency alerts, agricultural advisories, or entertainment content, ensuring that users receive information most pertinent to their context without requiring active internet connectivity. Beyond personalization, AI enhances the overall broadcasting ecosystem through real-time content optimization, intelligent spectrum management, and automated distribution workflows [21, 22]. Dual-mode content delivery—where broadcast and broadband channels are used in tandem—can be managed by AI to balance load, reduce latency, and improve user experience. These capabilities make datacasting not only more efficient but also more adaptive to changing network conditions and user needs, paving the way for scalable, context-aware broadcasting solutions in both urban and rural areas.

“ATSC3 B2X with AI integration can offer smart broadcasting capabilities to fulfil the goals specific to India with varied linguistic, cultural, and educational needs”

4.7 Broadcasting AI models and data to edge devices

In smart cities, a practical scenario involves a citywide network of edge devices performing localized tasks using lightweight AI models. These tasks include real-time traffic flow analysis to optimize signal timing, air quality monitoring for public health alerts, crowd density estimation for event management, and emergency alert detection for rapid response coordination. By broadcasting AI models and relevant datasets periodically, municipalities can maintain synchronized and up-to-date intelligence across all nodes without relying on centralized cloud infrastructure. ATSC3 B2X broadcasting offers a scalable and efficient method for deploying AI models and datasets to edge devices across smart city infrastructures. In contrast to traditional cloud-based distribution, which often requires persistent internet connectivity and high bandwidth, B2X enables one-to-many transmission of AI payloads directly to devices such as traffic cameras, environmental sensors, and public kiosks. This approach significantly reduces network congestion and latency, while ensuring timely updates to edge intelligence systems.

This method also supports dynamic model updates, allowing cities to adapt to changing conditions—such as seasonal pollution patterns or evolving traffic behaviors—by pushing new models or retraining data via broadcast. Moreover, it enhances resilience in areas with intermittent connectivity, ensuring that critical edge functions

continue uninterrupted. The integration of B2X broadcasting with AI deployment aligns with the broader vision of decentralized, energy-efficient smart cities.

“The next generation networks are supposed to support network for AI use cases, which involves timely delivery of AI models to UEs. Delivery of AI models is data intensive and is expected to severely increase the load on traditional network. Broadcast networks like ATSC3 B2X can solve this issue. Instead of relying on cellular or fiber backhaul infrastructure, ATSC3 B2X can be used to broadcast AI models and updates to all devices simultaneously.”

4.8 Software Updates

In today’s AI/ML-driven digital ecosystem, software updates play a critical role in maintaining device security, ensuring compatibility with evolving technologies, and optimizing performance. These updates are often data-intensive, requiring the transmission of large files across networks. As the number of connected devices continues to grow, especially in consumer electronics, automotive systems, and industrial IoT, the demand for efficient and scalable update mechanisms has become more important.

Traditional mobile networks, while widely used for software updates, face significant challenges in high-density environments. Events such as live concerts, sports matches, or festivals often result in network congestion, leading to delayed or failed updates. In such scenarios, ATSC 3 B2X broadcasting offers a compelling alternative. By leveraging one-to-many transmission, broadcasters can push updates simultaneously to thousands of devices without overloading the network, ensuring timely and reliable delivery.



Software Update

This broadcast-based approach is particularly beneficial for devices that require periodic firmware or security patch updates but are not continuously connected to the internet. Examples include public kiosks, smart meters, infotainment systems in vehicles, and even mobile phones in low-connectivity regions. The ability to deliver updates over a robust and scalable broadcast infrastructure enhances operational continuity and reduces dependency on cellular bandwidth.

“ATSC3 B2X can be useful for software updates due to its capabilities of using broadcast spectrum to deliver software updates to billions of devices simultaneously and supporting robust data rate while ensuring security and reliability”

4.9 Drone communication support for Defense applications

ATSC3 B2X broadcasting offers a robust and scalable solution for supporting drone-based operations in defense applications. With the increasing reliance on unmanned aerial systems (UAS) for surveillance, reconnaissance, and tactical missions, the need for efficient communication and data dissemination has become critical. B2X enables the transmission of IP-based data—including video feeds, telemetry, and mission updates—over terrestrial broadcast infrastructure to multiple receivers simultaneously, ensuring real-time situational awareness for ground teams and command centers. One of the key advantages of this approach is its support for PNT systems, particularly through ATSC-based Real-Time Kinematic (RTK) positioning. Validated results [23] demonstrate that ATSC RTK can achieve centimeter-level accuracy, which is essential for precision navigation in defense scenarios. Unlike cellular RTK, which often incurs costs and suffers from limited coverage in remote or contested areas, ATSC RTK is free-to-air and benefits from the wide reach of broadcast networks, making it a more feasible and resilient option for military-grade deployments.

Additionally, B2X broadcasting facilitates Firmware Over-the-Air (FOTA) and Software Over-the-Air (SOTA) updates for drones, ensuring that mission-critical systems remain secure and up-to-date without relying on conventional internet connectivity. This capability is particularly valuable in dynamic operational environments where connectivity may be intermittent or compromised. Updates can be pushed simultaneously to entire drone fleets, reducing downtime and enhancing operational readiness. The B2X Bootstrap signaling feature further enhances

defense utility by enabling event-triggered communication. Drones equipped with B2X receivers can respond to broadcast-triggered alerts—such as emergency warnings or mission reconfiguration commands—without requiring additional data transmission. This lightweight signaling mechanism ensures rapid responsiveness while conserving bandwidth and energy, making it ideal for time-sensitive defense operations.

“ATSC3 B2X can support defense drone operations by enabling secure, long-range, one-to-many IP-based datacasting, ideal for real-time video, telemetry, and coordination in contested or infrastructure-poor environments.”

5 Ongoing Activities Related to Broadcasting in India

5.1 Government Initiatives

The Government of India is actively driving initiatives to strengthen the broadcasting and media ecosystem, ensuring inclusivity and technological advancement. A landmark event in this direction was the World Audio Visual & Entertainment Summit (WAVES) 2025, held from May 1 to May 4 at the Jio World Convention Centre in Mumbai, with the aim of positioning India as a global hub for media and entertainment. The summit featured prominent industry leaders, global delegates, and celebrities, showcasing India’s creative economy and emerging technologies such as AI-driven content creation and immersive media. During the summit, the Union Ministry of Information & Broadcasting launched WAVEX 2025, an initiative aimed at funding and providing national exposure to startups in the media and entertainment sector. Organized in collaboration with the Internet and Mobile Association of India (IAMAI), WAVEX attracted over 1,000 applications, with 30 shortlisted startups pitching to investors and celebrity angel investors, and the event facilitated over Rs. 10,000 crore in investment commitments, reinforcing India’s commitment to fostering innovation and entrepreneurship [24, 25].

Adding to these efforts, the India Mobile Congress (IMC) 2025, held from October 8 to 11 at Yashobhoomi Convention Centre, New Delhi, emerged as Asia’s largest telecom, media, and technology forum. Organized by the Department of Telecommunications (DoT) and the Cellular Operators Association of India (COAI), IMC 2025 was themed “Innovate to Transform” and showcased over 1,000 cutting-edge use cases in 5G, 6G, AI, IoT, and green technologies. The event attracted 1.5 lakh visitors from 150+ countries, featured 400 exhibitors, and hosted 7,000 global delegates. IMC also introduced aspirational programs such as ASPIRE, connecting 500+ startups with 300 investors, and featured India’s first Satcom Summit to explore satellite-based connectivity for bridging the digital divide [26, 27].

A major boost to public service broadcasting came with the approval of the Broadcasting Infrastructure and Network Development (BIND) Scheme by the Cabinet Committee on Economic Affairs (CCEA). With an outlay of Rs. 2,539.61 crore up to 2025–26, BIND aims to modernize broadcasting infrastructure and expand coverage to underserved regions. Under this scheme, FM coverage of AIR will increase to cover more than 80% of India’s population, ensuring that vital information and entertainment reach even remote areas [28]. This expansion strengthens disaster communication, educational outreach, and public service delivery. Additionally, BIND includes the distribution of 8 lakh DD Free Dish DTH Set-Top Boxes to households in remote, tribal, Left Wing Extremism (LWE)-affected, border areas, and aspirational districts. By providing free access to television services, this initiative bridges the digital divide and reduces dependency on costly internet or mobile data. Together with WAVES, IMC, and WAVEX, the BIND scheme reflects the government’s commitment to creating a robust, future-ready broadcasting infrastructure. These efforts pave the way for next-generation technologies like D2M and ATSC3 B2X, ensuring affordable, high-quality content delivery across India’s diverse geography.

5.2 TRAI Consultations

The Telecom Regulatory Authority of India (TRAI) initiated a major consultation process for the formulation of the National Broadcasting Policy (NBP) 2024. On April 2, 2024, TRAI released a Consultation Paper on Inputs for Formulation of National Broadcasting Policy-2024, inviting stakeholders to provide their views on framing the Preamble, Vision, Mission, and Broad Objectives of the policy [29]. The paper highlighted that the policy should “stipulate the vision, mission, goals and strategies that could set the tone for a planned development and growth of the broadcasting sector in the era of new and emerging technologies.” It also emphasized objectives such as

universal reach, fostering innovation, and creating a framework for modernization of broadcasting services in line with technological advancements.

Following this, TRAI published its Recommendations [30] on Inputs for Formulation of National Broadcasting Policy-2024 on June 20, 2024. These recommendations reiterated that the policy should aim to provide a clear roadmap for sectoral growth, encourage quick adoption of emerging technologies, and ensure cost-effective and immersive consumer experiences. The recommendations also stressed the importance of collaboration among stakeholders, including broadcasters, OTT platforms, telecom operators, and equipment manufacturers, to enable a robust and future-ready broadcasting ecosystem. The National Broadcasting Policy 2024 is expected to serve as a guiding document for India's broadcasting roadmap over the next decade, aligning with national priorities such as Digital India and Atmanirbhar Bharat. By addressing challenges like infrastructure development, affordability, and innovation, the policy seeks to create an environment that supports modernization of broadcasting services, encourages collaboration among stakeholders, and promotes the adoption of emerging technologies to deliver high-quality and inclusive content to all regions of the country.

5.3 Standardization and Collaborations

India has been actively pursuing standardization efforts and strategic collaborations to enable next-generation broadcasting technologies and their integration with telecom networks. The Telecommunications Standards Development Society, India (TSDSI) has played a pivotal role in developing technical specifications for multicast-broadcast services. In 2019, TSDSI published Technical Report TR 6002 [31], titled "Broadcast Offload", which addressed the growing need to offload OTT content from cellular networks to reduce congestion and improve efficiency. Building on this, TSDSI released TR 6026 V1.0.0, "5G Extensions for Broadcast Offload", defining an integrated mobile broadband broadcast solution that enables data offload between 3GPP cellular networks and non-3GPP broadcast networks [32]. Furthermore, in SGN TP#37, a new work item (NIP386) [33] from Reliance Jio was approved as a WI to propose a TS on "Extensions to broadcast offload" and TSDSI-SGSS-NIP298 [34] introduced adoption of ATSC 3.0 standards for advanced broadcast capabilities. These initiatives reflect India's commitment to harmonizing global standards with local requirements for efficient spectrum utilization and service delivery.

Collaborative efforts have accelerated the development and validation of D2M broadcasting in India. A key milestone was the "Direct to Mobile and 5G Broadband – Convergence Roadmap for India" conclave organized by IIT Kanpur in June 2022, in partnership with TSDSI and Prasar Bharati, which outlined India-specific needs for D2M networks and announced a Proof-of-Concept (PoC) for NextGen D2M broadcasting integrated with emerging 5G standards [35]. Building on this, IIT Kanpur recently conducted a comprehensive technical study to address concerns about interference and device safety during D2M operations. The tests, carried out at a TEC-designated NABL-accredited lab, confirmed that D2M broadcasting in the 470–582 MHz band does not cause harmful interference to 4G/5G mobile networks and does not lead to abnormal heating of smartphones. Measurements showed zero desensitization on LTE and 5G NR bands and spurious emissions well below 3GPP limits, proving that D2M can coexist with existing mobile networks without performance degradation [36].

These findings strengthen the case for commercial rollout, which is expected to begin in phases by mid-2026. Meanwhile, Prasar Bharati, in collaboration with IIT Kanpur and Saankhya Labs, continues to test D2M technology in multiple cities to deliver multimedia content directly to mobile devices without internet connectivity, leveraging terrestrial broadcast infrastructure. Industry players such as Tejas Networks and Saankhya Labs have developed solutions like the SL3000 chip, enabling mobile phones to receive television and video content without a SIM or data connection [37]. This technology promises to lower data costs, reduce network congestion, and improve access to content in media-dark regions, particularly in Tier-II and Tier-III cities.

In addition to domestic initiatives, India is fostering global partnerships to advance broadcasting standards. IIT Bombay signed a Memorandum of Understanding (MoU) with Sinclair Inc., a major U.S.-based broadcaster, to collaborate on next-generation telecom and broadcast networks [38]. This partnership focuses on research and development around ATSC 3.0, an advanced wireless broadcast standard that supports mobile and fixed applications. Such collaborations aim to bring global best practices to India while contributing to international standardization efforts.

5.4 Showcase Events & Pilot Projects

India's broadcasting sector witnessed a major technology showcase at the WAVES Summit 2025, held from May 1 to May 4 at the Jio World Convention Centre in Mumbai [25]. The event featured groundbreaking demonstrations of D2M technology, which enables delivery of OTT content, live TV, video, audio, and emergency alerts directly to mobile devices without requiring Wi-Fi or internet connectivity. This innovation, based on ATSC 3.0 standards, was presented as a transformative solution for bridging the digital divide and reducing network congestion in India.

A highlight of WAVES 2025 was the unveiling of D2M-enabled laptops and mobile devices by leading technology players. Intel and Tejas Networks showcased laptops integrated with the indigenously developed SL-3000 SDR chipset, enabling broadcast reception through embedded UHF antennas [39]. These laptops can deliver educational content offline, supporting NEP 2020 goals and Digital India's vision for universal access to learning. Intel India President Gokul Subramaniam emphasized that this innovation opens new possibilities for inclusive education, allowing students in rural and underserved areas to access multimedia content without connectivity barriers. Similarly, HMD Global and Lava International announced plans to launch India's first D2M-enabled feature phones and smartphones, designed to receive live TV and public alerts without mobile data. These devices, priced affordably, aim to democratize access to entertainment and critical information across Tier-II and Tier-III cities.

The demonstrations at WAVES 2025 were backed by extensive Proof-of-Concept (PoC) trials conducted in cities like Bengaluru and Delhi by Prasar Bharati, in collaboration with IIT Kanpur, Tejas Networks, and FreeStream Technologies. These trials validated the feasibility of D2M broadcasting over terrestrial TV spectrum and its potential to deliver high-quality content without internet dependency. Industry leaders highlighted that the multicast capabilities of ATSC 3.0 allow simultaneous transmission of content in multiple languages and formats, making it ideal for educational and public service applications. The successful showcase at WAVES marks a critical step toward large-scale field trials and commercial rollout of D2M services in India, expected to begin in phases by 2026.

5.5 Devices availability and their Integration

India's device ecosystem for D2M is moving from pilots to early productization across feature phones, smartphones/tablets, and laptops, driven by partnerships among device OEMs, chipset vendors, and broadcasters.

Feature phones and smartphones/tablets: Ahead of WAVES 2025, HMD Global and Lava International announced D2M-enabled feature phones that can receive live TV/video/audio and public alerts over terrestrial broadcast airwaves without Wi-Fi or mobile data [40]. Lava's model integrates MediaTek MT6261 with Saankhya Labs' SL3000 tuner, a UHF antenna, 2.8" QVGA display, and 2,200 mAh battery; HMD confirmed SL3000-based devices with D2M reception to be showcased at the summit and prepared for field trials in India. Mainstream tech outlets (GSMArena, Digit, Indian Express) corroborated these device announcements and configurations, highlighting that D2M will be demonstrated at WAVES 2025 and positioned for low-cost, mass-market adoption across India's 230M+ feature-phone user base.

Laptops (education-first integration): On April 29–30, 2025, Tejas Networks (Tata Group) and Intel announced successful integration of D2M capability into Intel-powered laptops, using an embedded antenna and the Tejas–Saankhya SL-3000 SDR chipset to enable broadcast delivery of educational content offline. The joint release and multiple reports emphasize multicast delivery (ATSC3.0) tailored by grade/board/language, and alignment with NEP2020 and Digital/Design in India objectives for equitable access in low-connectivity regions. These laptops were showcased at WAVES 2025 and are supported by Tejas' end-to-end D2M infrastructure hardware/software for deployment [39].

New OEM entrants & rural-first device programs: In July 2025, KhushTech Korea, in collaboration with Tejas Networks and FreeStream Technologies (IIT Kanpur–incubated), unveiled what it calls the world's first D2M feature phone under the FreeStream brand, designed for 470–608 MHz UHF operation and positioned for rural education and emergency communications; the company also signaled BIS certification and potential manufacturing in Andhra Pradesh to scale production locally [41].

6 Spectrum-Related Aspects

6.1 Spectrum Bands Allocated for Broadcasting

The National Frequency Allocation Plan (NFAP) 2025 [42] is the latest official document outlining spectrum-related guidelines for broadcasting services in India. According to NFAP-2025, the *UHF band continues to be allocated for terrestrial broadcasting*, supporting services such as DTT and D2M. Prasar Bharati (Doordarshan) remains the primary incumbent operating within this band. NFAP-2025 emphasizes harmonization between broadcasting and emerging mobile broadband requirements. While terrestrial broadcasting retains its presence in UHF, the policy framework signals a gradual shift toward coexistence with IMT services. Notably, NFAP-2025 identifies 6425–7125 MHz as an IMT band for mid-band 5G/6G deployments, marking a significant step toward spectrum diversification for next-generation networks. This evolution aligns with India's roadmap for D2M broadcasting and mobile broadband convergence, while ensuring protection for incumbent services and scientific applications [42].

6.2 Spectrum related challenges

Although NFAP-2025 [42] does not allocate IMT services in the UHF band, significant challenges remain for broadcasting stakeholders. These challenges arise from the policy direction toward *harmonization and coexistence* between broadcasting and mobile broadband, as highlighted in NFAP-2025. While terrestrial broadcasting retains its incumbent status in UHF, future revisions or spectrum-sharing frameworks could introduce IMT access under coordination agreements, creating uncertainty for broadcasters. Broadcasters, particularly Prasar Bharati, have expressed concerns about potential re-farming of UHF spectrum and the risk of interference if shared use is implemented [43]. Global trends further amplify these concerns, as several countries have reallocated portions of the 600 MHz band for IMT deployments. Industry discussions in India now focus on how DTT and D2M services will coexist with emerging 5G/IMT requirements, whether exclusive broadcasting rights will continue, and how new licensing frameworks will integrate satellite-based systems and AI-driven content delivery. In this context, spectrum management becomes a critical regulatory challenge for 2025 and beyond. Ensuring equitable access, protecting incumbent broadcasting services, and defining clear coexistence mechanisms will be essential to maintain service continuity while enabling next-generation connectivity.

6.3 ATSC3 B2X spectrum specs

The ATSC3 B2X framework remains optimized for delivering APP services across both broadcast and IMT bands, enabling seamless integration of broadcast and broadband capabilities for advanced use cases such as vehicular communication, emergency alerts, and direct-to-mobile content delivery. According to ITU guidelines [44], the following IMT bands are identified across all three ITU regions and are applicable to India:

- 450–470 MHz
- 790–960 MHz
- 1710–2025 MHz
- 2110–2200 MHz
- 2300–2400 MHz
- 2500–2690 MHz

Additionally, on a national basis, NFAP-2025 [42] has identified 6425–7125 MHz as an IMT band for mid-band 5G/6G deployments.

ATSC3 B2X is highly flexible in terms of RF carrier bandwidths [45], supporting multiple configurations such as: 5, 6, 7, 8, 10, 12, 14, 15, 16, 18, 20, 21, 24, 30, 40, and 50 MHz. This flexibility ensures compatibility with diverse spectrum allocations, enabling efficient utilization for both broadcast and IMT services, and aligns with NFAP-2025's roadmap for converged networks and hybrid delivery models.

7 Opportunities for ATSC3 B2X in India

India presents a uniquely favorable environment for ATSC3 B2X (broadcast–broadband convergence) thanks to its nationwide broadcast footprint, rapidly scaling 5G networks, and policy initiatives aimed at digital inclusion. The opportunity spans urban and rural deployments, offers strong economics for one-to-many delivery, and can be accelerated via PPP and city-scale programs.

Leveraging Existing Broadcast Infrastructure: India already operates one of the world’s largest public broadcasting networks (Doordarshan/Prasar Bharati) with terrestrial DTT deployments and an extensive legacy of HPT/LPT sites [46]. DTT (DVB-T2) services are active in major metros with plans historically articulated for hundreds of transmitter locations—demonstrating coverage know-how, tower assets, and operational experience that can be software-upgraded or selectively repurposed for ATSC3 services and B2X use cases (data casting, public warning, edu-content). Satellite distribution and terrestrial backhaul also complement this footprint, giving Prasar Bharati and private broadcasters multiple origination paths to seed ATSC3 SFNs or distributed transmission systems as demand grows.

Device Ecosystem Readiness: India’s mobile market exceeds 1.16–1.18 billion wireless subscribers (2025), and broadband users are 980–1,000 million, reflecting both scale and sustained device churn toward 5G handsets [47]. This sheer base supports affordable ATSC3-capable devices (chipset integration or dongle-based add-ons) and makes B2X a practical path to reach hundreds of millions of screens with broadcast IP services (alerts, software updates, education, entertainment) without incremental data charges. Recent D2M trials—often framed around ATSC3 physical layer and ROUTE/DASH transports—signal growing feasibility of broadcast delivery to phones, including lab results showing coexistence with LTE/5G and manageable device thermals under tested conditions [48].

Spectrum Availability and Policy Support: The NFAP-2022 reserves UHF 470–585 MHz for broadcasting (DTT/D2M), with provisions for coordination with IMT in parts of 526–582 MHz—opening avenues for carefully designed coexistence and future refarming negotiations as deployments mature. NFAP sets the regulatory baseline and frames discussions under the upcoming NFAP 2025 cycle, where broadcasting and mobile broadband interests are being weighed with national objectives. Parallel national initiatives (Digital India, BharatNet) are expanding fiber and IP core capacity to towers and Gram Panchayats—resources that can anchor ATSC3 SFN timing, backhaul, and edge integration, even as BharatNet’s last-mile remains work-in-progress.

Urban–Rural Dual Deployment Strategy: Urban markets offer immediate B2X opportunities such as V2X signage, public safety feeds, stadium and venue multicasts, smart city data offload, and edge content distribution. These deployments can leverage dense 5G nodes and city command centers. 5G is now available in all states and approximately 99.6% of districts, with more than 469,000 5G base stations and around 250 million users reported by the Ministry of Communications [49]. This creates fertile ground for hybrid ATSC3 and 5G convergence. Rural regions benefit from broadcast efficiency for one-to-many services including education, agriculture advisories, telehealth content, and emergency alerts that do not rely on continuous unicast connectivity. While BharatNet continues to scale with over 693,000 km of optical fiber laid and approximately 214,000 Gram Panchayats connected, broadcast can bridge service gaps and reduce delivery costs for simultaneous content.

Cost-Effective Nationwide Coverage: Broadcast’s one-to-many economics are structurally advantaged when the same content must reach large populations. A single RF stream can serve thousands or millions, compared to duplicative unicast sessions that amplify backhaul and RAN load. This makes ATSC3 B2X attractive for data offload (e.g., software updates, live events, emergency alerts), with savings across core, RAN, and CDN layers. In practical terms, B2X can deliver wide-area coverage at lower marginal cost per additional user, while unicast remains ideal for individualized sessions—suggesting a hybrid architecture that aligns with India’s cost-sensitive market.

Integration with 5G (Hybrid Convergence): ATSC3 is natively IP and has well-documented pathways to converge with 3GPP Release-16+ systems via non-3GPP access. It also uses shared service layers such as ROUTE and DASH. This enables traffic steering where broadcast is used for concurrent demand and unicast is used for personalization and interactivity. Standards work including A/300 system specification [13] updates and industry research detail multi-radio user equipment, shared cores, and orchestration that India’s operators can leverage for scale. Industry debate increasingly converges on a hybrid model combining ATSC3 and 5G Broadcast or NR multicast. This positions broadcasters and mobile network operators as complementary partners rather than competitors, an approach that fits India’s network heterogeneity and diverse device ecosystem.

Public–Private Partnership (PPP) Models: India’s Smart Cities Mission and broader PPP frameworks have mobilized Rs.1.64 lakh crore across multi-sector urban projects with city-level ICCCs (Integrated Command and Control Centers), creating governance and financing templates [50] that B2X services can plug into (alerts, education channels, traffic messaging, disaster response). PPP roadshows and investment grids already showcase telecom-adjacent opportunities that could include city-wide broadcast data services. Academic and policy literature on PPPs for smart cities emphasizes fit-for-purpose procurement and risk sharing—useful for structuring B2X pilots where broadcasters, MNOs, OEMs, and civic agencies co-invest and co-operate to deliver measurable public outcomes.

8 Advantages of convergence of ATSC3 B2X and Mobile networks

The convergence of ATSC3 B2X with mobile networks represents a significant leap forward in the evolution of broadcast and broadband integration. Designed with interoperability in mind, ATSC3 B2X aligns closely with the user plane specifications of 5G systems, enabling flexible deployment models that support both standalone and converged network architectures. This alignment allows for seamless integration with existing mobile infrastructure, chipsets, and user devices, fostering a unified ecosystem for content delivery across mobile and fixed platforms. One of the most compelling advantages of this convergence is the introduction of a purpose-built multicast and broadcast layer within ATSC3 B2X. This layer enables efficient delivery of high-volume content—such as live video, software updates, and public alerts—across large geographic areas. By offloading such data-intensive services from mobile unicast channels, B2X can significantly reduce spectral and backhaul load on mobile networks. In fact, during peak demand scenarios, this offload capability has the potential to alleviate up to 95% of unicast congestion, ensuring a consistent and high-quality user experience even under network stress.

Furthermore, ATSC3 B2X introduces innovations like a scalable bootstrap mechanism, which is particularly beneficial for low-power and resource-constrained devices. This feature ensures that even basic or energy-efficient devices can reliably receive essential broadcast signals, making the technology more inclusive and adaptable to a wide range of use cases [17]. From a broader perspective, the convergence of 3GPP mobile networks with non-3GPP technologies like ATSC3 B2X offers a transformative model for delivering high-volume, low-latency data services. It addresses critical bottlenecks in current mobile infrastructure, especially in bandwidth-intensive applications such as video streaming, emergency communication, and real-time public service broadcasting. For a country like India—with its vast mobile user base, spectrum constraints, and infrastructure diversity—this convergence presents a scalable, cost-effective, and future-ready solution to meet the growing demand for ubiquitous, high-quality digital services.

9 Conclusion and Way Forward

Conclusion: ATSC3 B2X offers India a practical, standards-aligned pathway to deliver high-impact services at national scale. It complements mobile broadband by offloading simultaneous content, increases resilience for public warning and education, and enables smart-city and vehicular applications that need consistent coverage and predictable latency. With NFAP-recognized UHF spectrum, an expanding device ecosystem, and maturing D2M trials, India is well-positioned to move from pilots to phased rollouts.

Way Forward: A staged plan can accelerate deployment while balancing policy, industry, and technical factors:

1. **City and state pilots:** Launch multi-city pilots that pair broadcast SFNs with 5G cores, focusing on emergency alerts, school content packs, stadium/venue multicasts, and software/firmware updates. Measure coverage, device reception, latency, and offload gains.
2. **Spectrum roadmap:** Engage NFAP 2025 working groups to formalize broadcast protection in sub-600 MHz, define coexistence models in 526–582 MHz, and establish coordination procedures between broadcasters and MNOs for shared deployments.
3. **Device enablement:** Convene OEMs and chipset vendors to integrate B2X reception paths (embedded tuners or accessory modules) across feature phones, smartphones, laptops, IVI systems, and IoT sensors, with security, battery, and thermal guidelines validated through trials.

4. **Hybrid architecture with MNOs:** Implement traffic policies and ROUTE/DASH service layers to steer concurrent payloads to broadcast while reserving unicast for interactivity. Establish shared core and orchestration interfaces and publish reference configurations for Indian networks.
5. **Public service portfolios:** Institutionalize broadcast-first delivery for National Disaster Management Authority (NDMA) alerts, education curricula, agriculture advisories, and tele-health messages, aligned with city ICCCs and district administrations for operations, governance, and multilingual data casting.
6. **Smart-city PPPs:** Use proven PPP templates to fund and operate B2X services for traffic messaging, environmental sensing updates, and civic information, ensuring open procurement, performance Service Level Agreements (SLAs), and public oversight.
7. **KPIs and assurance:** Track broadcast reach, time-to-alert, packet success rate, device attach rate, mobile offload percentage, and cost-per-user. Publish quarterly dashboards to guide scale-up decisions.
8. **Capacity building:** Train state broadcasters, city engineers, and operator teams on ATSC 3.0 planning, SFN timing, service protection, and operational playbooks for joint broadcast–mobile operations.

By following this plan, India can deliver **reliable, affordable, and inclusive** services using broadcast–broadband convergence—improving emergency readiness, learning outcomes, and digital equity while easing pressure on mobile networks.

References

- [1] IMS, "History of Radio in India," <https://indianmediastudies.com/history-of-radio-in-india/>, accessed: Dec 2025.
- [2] V. R. Shivangi Mittal, "INDIAN TV BROADCASTING AT A CROSSROADS," <https://www.koanadvisory.com/wp-content/uploads/2020/08/Indian-TV-Broadcasting-at-a-Crossroads-2.pdf>, 2020, accessed: Dec 2025.
- [3] A. Jain, "AI Traffic Routing and Load Balancing: Transforming Mobile Networks," <https://blog.kairospulse.com/ai-traffic-routing-and-load-balancing-transforming-mobile-networks/>, 2025, accessed: Dec 2025.
- [4] C. Davis and J. Krupa, "Access, Education, and Connectivity: Closing the Fourth Industrial Revolution Gap in Rural Regions," *Science Journal of Education*, vol. 13, no. 2, pp. 62–68, 2025.
- [5] P. Bharati, "Growth & Development – Broadcasting in India," <https://prasarbharati.gov.in/growth-development/>, 2025, accessed: Dec 2025.
- [6] Prasar Bharati, "About Doordarshan – A Modest Experiment Becomes National Service," <https://prasarbharati.gov.in/about-doordarshan/>, 2025, accessed: Dec 2025.
- [7] TRAI, "Recommendations on Inputs for formulation of National Broadcasting Policy-2024," https://www.traai.gov.in/sites/default/files/2024-09/Recommendations_20062024.pdf, 2024, accessed: Dec 2025.
- [8] MIB, "Press Release MIB to release Statistical Handbook on Media an Entertainment Sector 2024-25," <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2126105>, 2025, accessed: Dec 2025.
- [9] Maitrayee Dey, SciTech Today, "Top 10 Indian OTT Platforms Statistics By Revenue, Demographics And Facts," <https://www.sci-tech-today.com/stats/top-10-indian-ott-platforms-statistics-updated/>, 2025, accessed: Dec 2025.
- [10] EY, "Shape the future," <https://www.ey.com/content/dam/ey-unified-site/ey-com/en-in/insights/media-entertainment/images/ey-shape-the-future-indian-media-and-entertainment-is-scripting-a-new-story.pdf>, 2025, accessed: Dec 2025.
- [11] Ericsson, "Ericsson Mobility Report June 2025," <https://www.ericsson.com/49e9b6/assets/local/reports-papers/mobility-report/documents/2025/ericsson-mobility-report-june-2025.pdf>, 2025, accessed: Dec 2025.
- [12] News24, "Emerging Trends And Technologies In The Broadcasting Sector': Key Highlights From TRAI's Half-Day Symposium," <https://news24online.com/india/emerging-trends-and-technologies-in-the-broadcasting-sector-key-highlights-from-trais-half-day-symposium/361552/>, 2024, accessed: Dec 2025.
- [13] ATSC, "ATSC 3.0 System," <https://www.atsc.org/wp-content/uploads/2025/08/A300-2025-07-ATSC-3-System-Standard.pdf>, 2025, accessed: Dec 2025.
- [14] ON-SIDE Partners, "Immersive Event Broadcasting Powered by 5G," <https://www.onside5g.org/blog/immersive-event-broadcasting-powered-by-5g/>, 2025, accessed: Dec 2025.
- [15] Michael Simon, Sangsu Kim, James Kelso and Joe Fabiano, "ATSC (B2X) Multicast Broadcast Neutral-Host O-RAN System Architecture," IBC 2025.
- [16] TV Tech , "Sinclair's Chris Ripley Lays Out ATSC 3.0 Challenges, Opportunities," <https://www.tvtechnology.com/news/sinclairs-chris-ripley-lays-out-atsc-3-0-challenges-opportunities>, 2024, accessed: Dec 2025.
- [17] Rashmi Kamran et al, "Convergence of 6G and ATSC 3 Networks via Broadcast to Everything (B2X): Use cases, Solutions and Collaborations," in *IEEE Future Networks World Forum*, India, Nov 2025.
- [18] Wikipedia, "Digital Video Broadcasting," https://simple.wikipedia.org/wiki/Digital_Video_Broadcasting, 2021, accessed: Dec 2025.
- [19] Reliance Jio, "Leveraging 5G to enable V2X," <https://www.jio.com/platforms/industries/v2x/>, 2025, accessed: Dec 2025.
- [20] IEEE Spectrum, "6 Key Connectivity Requirements of Autonomous Driving," <https://spectrum.ieee.org/6-key-connectivity-requirements-of-autonomous-driving#toggle-gdpr>, 2018, accessed: Dec 2025.

- [21] TV Tech, “Smartcasting: New Broadcast Media in the Digital Era,” <https://www.tvtechnology.com/opinion/smartcasting-new-public-media-in-the-digital-era>, 2025, accessed: Dec 2025.
- [22] GAO Tek, “Smart Broadcasting – Entertainment and Media IoT,” <https://gaotek.com/smart-broadcasting-entertainment-and-media-iot/>, 2025, accessed: Dec 2025.
- [23] H.-G. Shin, D.-K. Lee, S.-H. Lee, and S.-I. Park, “RTK Correction Data Transmission Service for Autonomous-Driving via ATSC 3.0 in South Korea,” in *2021 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB)*, 2021, pp. 1–3.
- [24] BestMediaInfo Bureau, “WAVES 2025 catalyses over Rs 10,000 crore in M&E deals: Official Outcome report,” <https://bestmediainfo.com/mediainfo/television/waves-2025-catalyses-over-rs-10000-crore-in-m-e-deals-official-outcome-report-9517198>, 2025, accessed: Dec 2025.
- [25] PIB Mumbai, “WAVEX 2025: A Game-Changer for Media & Entertainment Startups,” <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2112412>, 2025, accessed: Dec 2025.
- [26] PIB Delhi, “Union Minister Sh Jyotiraditya M. Scindia Unveils the Theme for 9th Edition of India Mobile Congress 2025 : ‘Innovate to Transform’,” <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2131498>, 2025, accessed: Dec 2025.
- [27] ADDA 24/7, “PM Modi Inaugurates 9th India Mobile Congress 2025,” <https://currentaffairs.adda247.com/pm-modi-inaugurates-9th-india-mobile-congress-2025/>, 2025, accessed: Dec 2025.
- [28] PIB Delhi, “Major Boost for Public Service Broadcasting: Cabinet Committee on Economic Affairs approves Central Sector ‘Broadcasting Infrastructure and Network Development (BIND)’ Scheme with an outlay of Rs.2,539.61 crore up to 2025-26,” <https://www.pib.gov.in/PressReleaselframePage.aspx?PRID=1888540>, 2023, accessed: Dec 2025.
- [29] TRAI, “Consultation Paper on Inputs for formulation of National Broadcasting Policy-2024,” https://www.traigov.in/sites/default/files/2024-09/CP_02042024.pdf, 2024, accessed: Dec 2025.
- [30] TRAI, “Recommendations on Inputs for formulation of National Broadcasting Policy-2024,” https://www.traigov.in/sites/default/files/2024-09/Recommendations_20062024.pdf, 2024, accessed: Dec 2025.
- [31] TSDSI, “TSDSI TR 6002 V1.0.0 Broadcast Offload,” 2019.
- [32] TSDSI, “TSDSI TR 6026 V1.0.0 5G Extensions for Broadcast Offload,” 2024.
- [33] TSDSI, “TSDSI-SGN-NIP386-V1.0.0 18122024 5G extensions for Broadcast offload,” (Initiated).
- [34] TSDSI, “TSDSI-SGSS-NIP298-V1.0.0-20221207 Adoption of specifications from ATSC 3.0 standards,” (Reserved).
- [35] PIB Delhi, “Direct-to-Mobile Broadcasting Conclave calls for action in national interest,” <https://www.pib.gov.in/PressReleasePage.aspx?PRID=1830487>, 2022, accessed: Dec 2025.
- [36] Storyboard18, “IIT Kanpur clears D2M Broadcasting; says no harmful interference or device overheating,” <https://www.storyboard18.com/digital/breaking-iit-kanpur-clears-d2m-broadcasting-says-no-harmful-interference-or-device-overheating-84631.htm>, 2025, accessed: Dec 2025.
- [37] The Economic Times, “D2M broadcast moving closer to launch in India,” <https://economictimes.indiatimes.com/industry/media/entertainment/media/d2m-broadcast-moving-closer-to-launch-in-india/printarticle/120941584.cms>, 2025, accessed: Dec 2025.
- [38] IIT Bombay, “IIT Bombay and Sinclair Inc. Forge Strategic Partnership to Revolutionize Broadcast and Telecom Networks,” <https://acr.iitbombay.org/iit-bombay-and-sinclair-inc-forge-strategic-partnership-to-revolutionize-broadcast-and-telecom-networks/>, 2024, accessed: Dec 2025.
- [39] Tejas Networks, “Tejas Networks and Intel team up to bring Direct-to-Mobile (D2M) capability to Laptops ushering in new possibilities for Universal Education,” <https://www.tejasnetworks.com/wp-content/uploads/2025/04/Tejas-Networks-PR-29Apr25.pdf>, April 2025, accessed: Dec 2025.
- [40] Gadgets 360, “HMD, Lava to Launch Direct-to-Mobile Phones in Partnership With Tejas Networks, FreeStream,” <https://www.gadgets360.com/mobiles/news/hmd-lava-direct-to-mobile-phones-india-launch-field-trials-8279153>, April 2025, accessed: Dec 2025.

- [41] businesswire, “KhushTech Korea to Launch India’s First D2M Feature Phone Under FreeStream Brand,” <https://www.businesswire.com/news/home/20250807699866/en/KhushTech-Korea-to-Launch-Indias-First-D2M-Feature-Phone-Under-FreeStream-Brand>, August 2025, accessed: Dec 2025.
- [42] Department of Telecommunications, “National Frequency Allocation Plan - 2025,” <https://dot.gov.in/whatsnew/national-frequency-allocation-plan-2025>, Dec 2025, accessed: Dec 2025.
- [43] financialexpress, “Prasar Bharati opposes allotment of broadcasting band to telcos,” <https://www.financialexpress.com/business/brandwagon-prasar-bharati-opposes-allotment-of-broadcasting-band-to-telcos-3621160/>, Dec 2025, accessed: Dec 2025.
- [44] ITU, “Spectrum for IMT,” <https://www.itu.int/ITU-D/tech/MobileCommunications/Spectrum-IMT.pdf>, Dec 2025, accessed: Dec 2025.
- [45] ATSC, “ATSC A/421: 2025-26, “B2X System Discovery and Signaling”,” June 2025.
- [46] Prasar Bharati R&D TR RD/2016/915, “Reception survey for assessment of coverage area for satisfactory reception of DVB-T2 Transmitter Located at Pitampura New Delhi,” <https://www.prasarbharati.gov.in/wp-content/uploads/2024/04/p1-5-915-DTT-DELH-CH34-SD.pdf>, 2024, accessed: Dec 2025.
- [47] The Economic Times, “India adds 2.46 mn wireless subscribers in June 2025, led by urban growth,” <https://economictimes.indiatimes.com/industry/telecom/telecom-news/india-adds-2-46-mn-wireless-subscribers-in-june-2025-led-by-urban-growth/articleshow/122980706.cms>, July 2025, accessed: Dec 2025.
- [48] BestMediaInfo Bureau, “Prasar Bharati tests say D2M broadcast won’t heat phones or hurt 4G, 5G networks,” <https://bestmediainfo.com/mediainfo/mediainfo-radio/prasar-bharati-tests-say-d2m-broadcast-won-t-heat-phones-or-hurt-4g-5g-networks-10806466>, Nov 2025, accessed: Dec 2025.
- [49] ET Telecom, “25 crore mobile subscribers using 5G in India as telcos expand networks,” <https://economictimes.indiatimes.com/news/industry/25-crore-mobile-subscribers-using-5g-in-india-as-telcos-expand-networks-ministry-of-communications/119327846>, Mar 2025, accessed: Dec 2025.
- [50] PIB, “10 Years of Smart Cities Mission,” <https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=154736&ModuleId=3®=3&lang=1>, June 2025, accessed: Dec 2025.