Government of India
Ministry of Communications
Department of Telecommunications
Telecommunication Engineering Centre
Khurshid Lal Bhawan, Janpath, New Delhi 110001.

No: 13-1/2023-C&B/TEC

Dated 18-08-2023

Subject: Inviting the comments/inputs on the draft technical report on "Television Broadcasting to Mobile Handheld Devices - Direct to Mobile (D2M) Broadcasting" – reg.

With rapid technological advancements and an increasingly connected world, mobile devices have become an integral part of our daily lives. In present scenario, mobile users also desire to receive broadcasting services such as live television channels directly in their smartphones or similar terminal devices. The demand for personalized, on-demand content has led to the emergence of **Direct to Mobile (D2M)** as a game-changing content delivery approach. In addition, such broadcasting can deliver the content to a large audience simultaneously, without requiring an internet connection.

2. There are different emerging technologies that enable (or promise to enable) direct broadcasting to handheld devices. These include 3GPP (rel. 18) based 5G Multimedia Broadcast/Multicast Service (MBMS), ATSC 3.0, DTMB-A, DVB-T2, ISDB-T, etc. TEC has also released a "Standard on Converged Gateway Node for Delivering Broadcast Content to Portable Devices Through Wireless LAN" (TEC 57040:2023) which provides a solution to enable the dissemination of broadcast content to portable devices.

3. Telecommunication Engineering Centre (TEC), New Delhi is working on publishing a technical report on **"Television Broadcasting to Mobile Handheld Devices - Direct to Mobile (D2M) Broadcasting"** bringing out the features, deployment status, technology maturity, etc., of these technologies. The aim is to create general awareness amongst the stakeholders/ policymakers on this emerging technology landscape.

4. In this regard, TEC invites comments/suggestions from the stakeholders on the draft report (enclosed). All the stakeholders are requested to send their inputs/comments/ suggestions/information by 08.09.2023 at dircb2.tec-dot@gov.in with a copy to avinash.70@gov.in .

Encl. as above

Avinash 18/08/2023
(Avinash Agarwal)
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To,
All Stakeholders

Copy for kind information to:

1. Secretary(T), Department of Telecommunications, New Delhi
2. Secretary(I&B), Ministry of Information and Broadcasting, New Delhi
3. Member(T)/Member(S), DoT HQ, New Delhi
4. CEO, Prasar Bharti, New Delhi
5. Secretary, TRAI, New Delhi
6. Advisor/Sr. DDG TEC, Delhi

Technical Report

On

Television Broadcasting to Mobile Handheld Devices - Direct to Mobile (D2M) Broadcasting

ISO 9001:2015

दूरसंचार अभियांत्रिकी केंद्र

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Abstract

The emergence of various new technology has brought about new opportunities and challenges for terrestrial broadcasting. In this report, we analyse the opportunities for terrestrial broadcasting in the Direct to Mobile (D2M) including the ability to offer new services and enhance the viewing experience for consumers. Direct to Mobile (D2M) is a groundbreaking content delivery approach that leverages the power of the internet to deliver a wide array of multimedia content directly to mobile devices. In this report, we explore the key features, benefits, and implications of D2M in reshaping the landscape of mobile entertainment and connectivity. We discuss the underlying technologies and architecture that enable seamless content delivery to smartphones and tablets, and how D2M is poised to revolutionize the way we access and experience multimedia in the digital age. Additionally, we examine the potential challenges and future prospects for D2M, considering its impact on consumer behavior, media industries, and the overall digital ecosystem.

1. Introduction

In an era characterized by rapid technological advancements and an increasingly connected world, mobile devices have become an integral part of our daily lives. The demand for personalized, on-demand content has led to the emergence of Direct to Mobile (D2M) as a game-changing content delivery approach. D2M enables users to access a wide range of multimedia content directly on their smartphones and tablets, bypassing traditional broadcasting methods. This report aims to provide an in-depth exploration of D2M, examining its features, benefits, underlying technologies, challenges, and potential implications for the future of media consumption.

2. What is “Terrestrial Broadcasting "?

Terrestrial broadcasting is a traditional method of broadcasting, where signals are transmitted from a broadcasting station to terrestrial receivers, such as televisions and radios. To provide viewers with higher-quality content in the 5G/6G era, terrestrial broadcasting can benefit from the increased capacity and quicker data rates. By delivering personalised content and interactive features, D2M technology can improve the user experience. Terrestrial broadcasters will need to adapt their business models to take advantage of the new opportunities presented by D2M. This may require new partnerships and collaborations with other industry players, as well as new revenue streams, such as advertising and sponsorships.

Terrestrial broadcasting can also provide wider coverage, especially in remote areas where access to high-speed internet is limited. It can also be a more reliable means of delivering content, as it is not affected by issues such as internet congestion, bandwidth limitations, or buffering.

Terrestrial broadcasting refers to the distribution of audio and video content through radio waves, which are transmitted through the air to terrestrial receivers, such as televisions and radios. In the 5G era, terrestrial broadcasting continues to play an important role in the distribution of media content, despite the emergence of newer digital technologies. Here are some reasons why terrestrial broadcasting is still needed:

i. **Wide coverage:** Terrestrial broadcasting can provide wide coverage to a large audience, including those in remote areas, where access to high-speed internet is limited. This makes it an important tool for delivering content to a wide range of viewers, especially for live events such as sports, news, and entertainment programs.

ii. **Reliability:** Terrestrial broadcasting is a reliable means of delivering content, as it is not affected by issues such as internet congestion, bandwidth limitations, or buffering. It can also provide uninterrupted service during emergencies or natural disasters, making it an important tool for public safety and emergency communication.

iii. **Cost-effectiveness:** Terrestrial broadcasting can be more cost-effective than other distribution methods, as it does not require an internet connection or subscription free. This makes it accessible to a wider audience, regardless of their income level.

iv. **Localization:** Terrestrial broadcasting can be used to deliver localized content, such as regional news, weather updates, and advertisements. This allows broadcasters to target specific regions or demographics, providing relevant and timely content to their audience.

v. **Compatibility:** Terrestrial broadcasting can be received on a wide range of devices, including radios, TVs, and mobile phones. This compatibility makes it an accessible and convenient way to deliver content to a broad audience.

3. Basic features of D2M

D2M have the following features and functionalities:

i. **Mobile-Centric Content Delivery:**
D2M is designed with mobile devices as the primary target platform. It focuses on delivering content optimized for the screen sizes, resolutions, and capabilities of smartphones and tablets.

ii. **Seamless Content Delivery:**
D2M allows users to access multimedia content seamlessly and instantaneously, eliminating buffering or waiting times associated with traditional downloading or streaming methods.

iii. Support of shared network functions across multiple 5G network operators.

iv. **Personalization and User-Centric Approach:**
D2M enables personalized content recommendations and tailored user experiences based on individual preferences and viewing habits.

v. **Over-the-Air Transmission:**
D2M utilizes over-the-air (OTA) transmission to deliver content directly to mobile devices. This approach eliminates the need for continuous internet connectivity, making it ideal for on-the-go entertainment.

vi. **Hybrid Broadcast/Broadband Integration:**
D2M can combine OTA broadcast with broadband internet delivery, providing a hybrid approach that optimizes content delivery and ensures consistent user experiences.

vii. **Enhanced Multimedia:**
D2M supports high-quality audio, video, and interactive content, often including features like Ultra High Definition (UHD) video, High Dynamic Range (HDR), immersive audio, and interactive applications.

viii. **Real-Time and On-Demand Content:**
D2M allows users to access both live, real-time events and on-demand content, providing flexibility and variety in content consumption.

ix. **Interactive Services:**
D2M enables interactive features such as interactive advertisements, datacasting, interactive applications, and additional information alongside the main content.

x. **Energy Efficiency:**
D2M employs energy-saving technologies to optimize power consumption in both the broadcasting infrastructure and mobile devices.

xi. **Advanced Error Correction and Robustness:**
D2M uses advanced error correction techniques and robust transmission methods to ensure reliable reception, even in areas with weaker signals or high mobility scenarios.

xii. **Targeted Advertising:**
D2M can deliver targeted advertisements to specific user segments based on location, preferences, and demographics.

xiii. **Multilingual Support:**
D2M supports multiple audio tracks and subtitles, allowing for the delivery of content in different languages to cater to a diverse audience.

xiv. **Emergency Alert System (EAS):**
D2M can integrate with emergency alert systems to deliver critical information

and public safety alerts directly to mobile users.

xv. Scalability and Future-Readiness:
D2M is designed to be scalable and adaptable to future technological advancements, ensuring compatibility with evolving mobile devices and networks.

xvi. Content Protection and Security:
D2M includes measures for content protection and digital rights management to safeguard intellectual property and prevent unauthorized access.

4. Technology options for D2M

4.1 3GPP

The 3rd Generation Partnership Project (3GPP) stands as a collaborative force in the realm of telecommunications standards, with a rich background dating back to its establishment in 1998. Conceived through the joint efforts of leading standardization bodies like ETSI, ARIB, TTC, ATIS, and CCSA, 3GPP was formed to unify the global landscape of mobile communication systems. Rooted in the principles of cooperation and harmonization, 3GPP has been instrumental in shaping the evolution of mobile technology, propelling it through successive generations – from the foundational 2G and transformative 3G to the high-speed 4G and cutting-edge 5G. Over the years, 3GPP's regular releases have introduced a tapestry of advancements, encompassing enhanced data rates, spectral efficiency, multimedia capabilities, and the broader horizon of the Internet of Things. Beyond the realm of mobile phones, 3GPP's standards ripple across industries, facilitating smart cities, connected vehicles, critical communications, and a diverse spectrum of applications that define the interconnected modern world. Through its global standardization efforts, 3GPP continues to foster innovation, compatibility, and a seamless mobile experience that transcends borders and empowers societies.

4.1.1 Architecture of Broadcasting over 5G:

3GPP has defined 5G Broadcast (LTE-based 5G Terrestrial Broadcast) as a new terrestrial broadcast system in order to address new use cases and application. The general architecture for a 5G Broadcast System is provided in figure 1. The principal actors in the system are as follows:

i. A 5G Broadcast TV/Radio Content Service Provider runs a head-end providing linear television and radio services.
ii. A 5G Broadcast TV/Radio Service Application runs on devices that include a 5G Broadcast Receiver.
iii. A 5G Broadcast System operator runs a 5G Broadcast System with 5G Broadcast Transmitters for use by devices including 5G Broadcast Receivers.
iv. A 5G Broadcast TV/Radio Content Service Provider makes services available using the 5G Broadcast System.
v. A 5G Broadcast TV/Radio Service Application is able to consume the service by communicating with the 5G Broadcast Receiver through a dedicated set

of 5G Broadcast Client APIs.

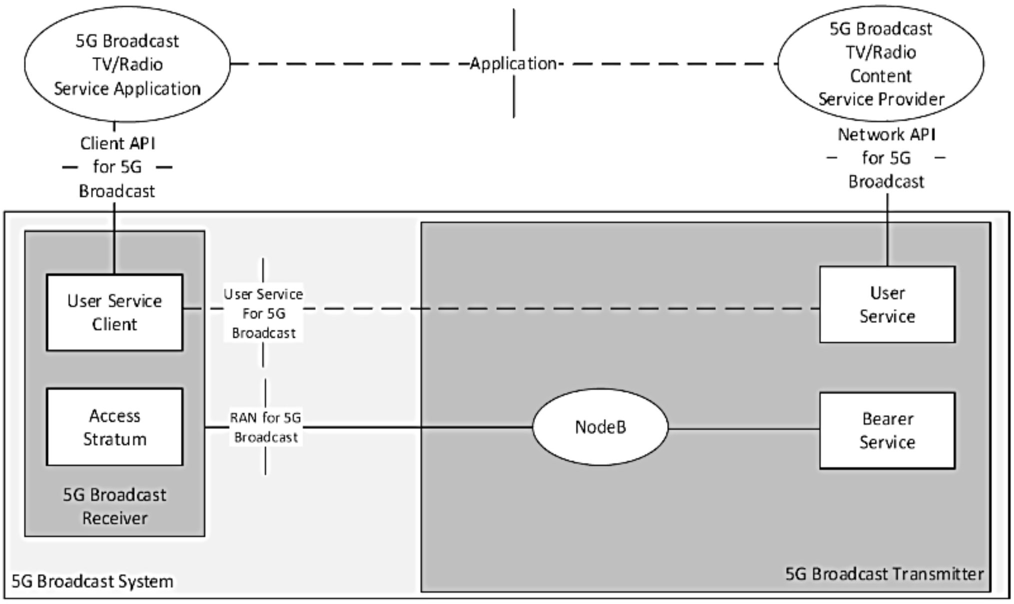

Figure 1 - Reference architecture for 5G Broadcast System

4.1.2 Specifications for Broadcasting over 5G:

Some of the key technical specifications of Terrestrial Broadcasting in 5 Era:

i. **Frequency Bands:** 5G broadcast services can be delivered over various frequency bands, including sub-6 GHz and millimeter-wave (mm Wave) bands. The choice of frequency band depends on the specific use case, network architecture, and local regulations.

ii. **Modulation Schemes:** 5G broadcast services can use various modulation schemes, such as 16-QAM, 64-QAM, and 256-QAM, to encode the multimedia content for transmission over the network.

iii. **Core Network Architecture:** The core network architecture for Terrestrial Broadcasting in 5G Era services includes a broadcast/multicast service centre (BM-SC), which is responsible for managing the delivery of broadcast/multicast content over the network.

iv. **Media Delivery Methods:** 5G broadcast services can use various media delivery methods, such as File Delivery over Unidirectional Transport (FLUTE), MPEG-2 Transport Stream (TS), and MPEG-DASH, to deliver multimedia content to end- users.

v. **Latency:** 5G broadcast services are designed to have low latency, typically between 10 and 100 milliseconds, to enable real-time multimedia experiences such as live streaming of sports events or concerts.

vi. **Quality of Service (QoS):** Terrestrial Broadcasting in 5G Era services support various QoS levels, including best-effort and guaranteed bit rate, to ensure that the multimedia content is delivered with the appropriate level of quality and reliability.

vii. **Security:** Terrestrial Broadcasting in 5G Era services are designed with various security features, such as encryption and authentication, to ensure the privacy and integrity of the multimedia content and the network.

4.1.3 Ways of data transmission

Unicast and multicast are two different methods of data transmission in 5G broadcasting.

- Unicast is a one-to-one communication method, where data is sent from one device to another. This is the most common method of data transmission in 5G, and is used for things like streaming video, downloading files, and making phone calls.
- Multicast is a one-to-many communication method, where data is sent from one device to a group of devices. This is used for things like broadcasting live TV, sending emergency alerts, and delivering updates to a fleet of devices.

In 5G, multicast is implemented using a technology called Multimedia Broadcast Multicast Service (MBMS). MBMS allows 5G networks to send the same data to a group of devices, which can save bandwidth and improve the efficiency of data transmission.

4.1.4 Deployment scenario in various countries

Country	Details
South Korea	South Korea has been at the forefront of 5G technology deployment and has conducted trials and demonstrations of 5G-based terrestrial broadcasting, showcasing the delivery of Ultra High Definition (UHD) content over 5G networks. In 2018, the Korean Broadcasting System (KBS) and major telecom operators like SK Telecom, KT, and LG Uplus collaborated on a 5G broadcast trial during the PyeongChang Winter Olympics. This trial demonstrated the efficient delivery of live UHD (Ultra High Definition) content to multiple devices using 5G broadcast technology. South Korea's 5G broadcast initiatives involve collaboration between broadcasters, telecom operators, equipment manufacturers, and other industry stakeholders.
USA	Multicast broadcast services in the USA have seen notable deployments and trials, primarily in the domain of mobile video delivery and public safety communications. One of the 5G broadcast demo examples was U. S. Open Championship in June 2018, to use mmWave 5G cellular technology to stream 4K video for potential

	broadcast nationwide. AT&T provided the required spectrum to optimize the 5G performance; Ericsson provided the 5G network equipment, including radios, baseband, simulated network core and 4K video encoder and decoder; Intel supplied the Intel® Mobile Trial Platform, working as the 5G modem or "phone. However, FCC has been considering the use of the ATSC 3.0 standard, which combines terrestrial broadcasting with IP-based delivery over 5G networks. Several broadcasters in the U.S. have started deploying ATSC 3.0-based NextGen TV services, which could potentially leverage 5G networks for content distribution.
China	China has been investing heavily in the development and deployment of 5G technology. While the primary focus has been on 5G mobile communications, there have been discussions and trials exploring the use of 5G for broadcasting and multimedia services. China Telecom's "Hello 5G" project, launched in 2018, aimed to build a comprehensive 5G ecosystem that fosters innovation and enables the implementation of advanced applications. In April 2018, a significant milestone was achieved when the first flight of 5G drones was successfully demonstrated in Shenzhen. This demonstration highlighted the real-time transmission of 360-degree panoramic 4K HD video over a 5G network. Furthermore, in 2019, China Telecom conducted a real-time 4K live broadcast of the Spring Festival Evening in Shenzhen using 5G networks.
Germany	Germany has been working on the development and deployment of 5G-based broadcasting through initiatives like the 5G Media Initiative. The goal is to explore the convergence of broadcasting and 5G technologies to enable broadcasters to leverage the benefits of 5G networks for content delivery. Germany has been leading the way, with the Bavarian Research Foundation funding the 5G TODAY project, which aims to test and demonstrate the feasibility of 5G broadcast for delivering live TV content in the Munich region.
Spain	In Spain, Spinner, a global provider of filters for broadcast and mobile infrastructures, has been participated in the proof of concept by providing a 5G Broadcast-based 5MHz filter for the transmitter. Cellnex, RTVE, Rohde & Schwarz and Spinner team up to bring a totally new live mobile experience to smartphones, tablets, and a range of SIM-free devices throughout central Barcelona. The content transmitted through the Broadcast/Multicast trial includes both live and delayed 4K transmissions. A whole new range of business models has now been possible to deliver content or data to a large number of consumers and without affecting the 5G mobile network.
Italy	The use of 5G Broadcast during the Eurovision Song Contest 2022 event showcased the potential of this technology for media distribution and audience engagement. By transmitting the signal live and in high quality from multiple sites in different European

	cities, it demonstrated the ability to reach a wide audience simultaneously. At the time, only a select group of users with 5G Broadcast-enabled smartphones in Paris, Stuttgart, Turin, and Vienna were able to receive these transmissions.
United Kingdom	The UK has been exploring the potential of 5G-based terrestrial broadcasting. The country has conducted trials and demonstrations to evaluate the use of 5G networks for delivering high-quality video and multimedia content. In UK, project "5G Rural First", both technologies were used, Rel-12 eMBMS and LTE unicast and Rel-14/15 FeMBMS. 5G Broadcast Radio trial comprised two parts; a public trial based on commercially available 4G equipment and the in-house development of a standalone '5G broadcast' modem that implements the latest mobile broadcast features that weren't available in commercial handsets.
Finland	Finland has been at the forefront of 5G technology adoption and has conducted trials to evaluate the use of 5G networks for broadcasting services. The country has been exploring the potential of leveraging 5G capabilities for delivering high-quality content to viewers. An other project was '5G eMBMS Demo" in Finland. Main goal promoting broadcast-like services in 5G network. Participants from media, press, ministerial, telco, EBU etc. Multiple mobile devices receiving broadcast quality DASH streams via 5G network in the 2.9 GHz band.
Czech Republic	The Czech national transmission company CRA has started the testing of 5G broadcast technology. CRA notes that in addition to the Czech Republic, broadcasting using 5G Broadcast technology is also being tested in other European countries including Germany, Austria or Italy.

4.2 ATSC 3.0

ATSC 3.0, also known as NextGen TV, ATSC3.0 is US based, is a cutting-edge digital television broadcasting standard that builds upon the foundation of its predecessor, ATSC 1.0. Developed by the Advanced Television Systems Committee (ATSC), ATSC 3.0 was created to address the evolving landscape of media consumption and technological advancements in the digital age. The transition from analog to digital broadcasting was facilitated by ATSC 1.0, revolutionizing television with improved picture and sound quality. However, the rapid progress of technology and changing viewer habits necessitated a more versatile and feature-rich standard, leading to the development of ATSC 3.0.

ATSC 3.0 introduces a host of transformative features. It enables broadcasters to deliver Ultra High Definition (UHD) and High Dynamic Range (HDR) content, offering viewers a captivating visual experience that was previously unattainable. The standard's enhanced audio capabilities further immerse audiences in rich and lifelike soundscapes.

One of ATSC 3.0's groundbreaking aspects is its interactivity. Viewers can now engage with content through interactive features, opening doors to personalized experiences, engaging advertisements, and more. Moreover, the standard embraces datacasting, allowing broadcasters to transmit non-broadcast data over the airwaves, enhancing emergency alerts, software updates, and targeted advertising.

ATSC 3.0 harmoniously merges traditional broadcasting with broadband internet, resulting in hybrid services that offer a seamless blend of linear television and internet-based content. This adaptability caters to various devices, from conventional TVs to mobile devices, ensuring a consistent and versatile viewer experience.

4.2.1 Features of ATSC 3.0

- **i.** Mobile Reception: ATSC 3.0 supports mobile reception, allowing users to receive multimedia content directly on their smartphones and tablets.
- **ii.** Ultra High Definition (UHD) Video: ATSC 3.0 enables the transmission of UHD video content, providing a superior visual experience on mobile devices.
- **iii.** High Dynamic Range (HDR): The standard supports HDR, enhancing color depth and contrast for a more immersive viewing experience on mobile screens.
- **iv.** Immersive Audio: ATSC 3.0 supports object-based audio, delivering immersive and personalized sound experiences on mobile devices.
- **v.** Interactive Content: ATSC 3.0 allows for the delivery of interactive content, including interactive advertisements and additional information alongside the main broadcast.
- **vi.** Robust Error Correction: The standard includes advanced error correction techniques, ensuring reliable reception even in challenging mobile environments.
- **vii.** Broadcast Internet Integration: ATSC 3.0 integrates broadcast and broadband networks, enabling hybrid services that combine OTA and internet-based content.
- **viii.** Scalability: The standard is designed to be scalable to various screen sizes and resolutions, ensuring a consistent user experience across different mobile devices.
- **ix.** Personalized Content Delivery: ATSC 3.0 enables personalized content recommendations based on user preferences, enhancing content discovery on mobile devices.
- **x.** Advanced Emergency Alerts: The standard enhances emergency alert systems with geo-targeted and multimedia alerts for public safety on mobile devices.
- **xi.** Energy Efficiency: ATSC 3.0 incorporates energy-saving technologies, optimizing power consumption in both broadcasting stations and mobile devices.
- **xii.** Adaptive Bitrate Streaming: The standard supports adaptive bitrate streaming, adjusting the video quality based on network conditions for smooth playback on mobile devices.
- **xiii.** Mobile App Integration: ATSC 3.0 allows integration with mobile apps,

enabling interactive features and complementary content on mobile devices.

xiv. Mobile Data Offloading: The standard supports mobile data offloading, reducing mobile network congestion by delivering content through broadcast channels.

xv. Real-time Broadcast: ATSC 3.0 ensures real-time delivery of live events and broadcasts, enabling users to watch sports, news, and other events on their mobile devices in real-time.

4.2.2 Architecture of ATSC 3.0

The architecture of ATSC 3.0 is structured in layers to ensure efficient and seamless content delivery to mobile devices, offering users an immersive multimedia experience on their smartphones and tablets. At its foundation is the Physical Layer (PHY), responsible for transmitting and receiving data through the airwaves using OFDM modulation. The Link Layer (LL) manages the connection between transmitting and receiving devices, overseeing link adaptation and resource allocation. Above this, the Protocol Layer (PL) handles data packets, error correction, and retransmission protocols to ensure dependable data delivery.

The Management and Protocols Layer (MPL) takes charge of service discovery, signaling, and the management of various protocols. The Presentation Layer (PLS) decodes and presents multimedia content, offering audio, video, and more. The Application Framework (AF) lays the groundwork for interactive applications and services, while the Application Layer (AL) manages interactive content delivery, personalized recommendations, and user interactions.

Enabling the integration of broadcast and internet-based services, the Broadcast Internet Protocol (BIP) facilitates the delivery of IP-based content over broadcast channels. Service Layer Multiplexing combines diverse services like audio, video, and data into a unified transport stream, and Service Protection and Security handle content encryption and digital rights management for secure delivery.

The Broadcast Internet Integration layer manages the harmonious integration of broadcast and broadband networks, facilitating hybrid services. The Emergency Alert System (EAS) ensures efficient delivery of emergency alerts to mobile devices, enhancing user safety. The Electronic Service Guide (ESG) provides interactive access to program schedules and information, enriching user engagement. The Interactive Application Execution Environment executes interactive applications on receiver devices, enhancing interactivity.

Serving as a communication hub, Middleware manages interactions between the different layers and components of the ATSC 3.0 system. Altogether, these layers create a comprehensive architecture that optimizes content delivery, interactivity, security, and integration, offering a robust platform for delivering multimedia content seamlessly to mobile devices.

4.2.3 Deployment scenario in various countries

Country	Details
United States	The United States of America is currently in the process of deploying ATSC 3.0 for D2M. A number of broadcasters have already launched ATSC 3.0 D2M services, including Sinclair Broadcast Group,

	Nexstar Media Group, and Tegna. As of 2023, ATSC 3.0 D2M is available in over 30 markets in the United States.
Canada	**Canada is Integrating 3.0 and 5G.** To support research into ATSC 3.0 multi-sectoral applications in Canada, the Natural Sciences and Engineering Research Council (NSERC) and Canada Foundation for Innovation (CFI) has awarded a C$4.5 million grant (US$3.34 million) to Humber College to created Canada's first Broadcast-Broadband Convergence B²C Lab in Toronto. It provides insights through ATSC 3.0 innovations in our lab that can inform and support new provisions in broadcast regulatory policy." As well, having been granted the first and only ATSC 3.0 experimental broadcasting license in Canada, the Humber B²C Lab has deployed a custom multiple transmitter/antenna ATSC. 3.0 over-the-air test bed covering the Toronto area.
South Korea	The Republic of Korea (aka South Korea) was the first to launch ATSC 3.0 in 2017 to deliver better video and audio quality to OTA viewers in its largest urban areas, using the 2018 Winter Games in PyeongChang to promote its 4K capabilities. Today, this country is extending ATSC 3.0 coverage to medium and small cities, according to Dr. Sung-Ik Park, the Republic of Korea's Project Leader of ATSC 3.0 Physical Layer, for the Electronics and Telecommunications Research Institute (ETRI), a government-funded research organization. As of 2023, ATSC 3.0 D2M is available in all major cities in South Korea.
India	The Department of Telecommunications (DoT) and India's public service broadcaster Prasar Bharati are exploring the feasibility of a technology that allows to broadcast video and other forms of multimedia content directly to mobile phones, without needing an active internet connection. India is exploring ATSC 3.0 for direct-to-mobile services and broadcast traffic overload.
Brazil	Brazil is planning to use select ATSC 3.0 technologies for its "TV 3.0" project. The project aims to improve the quality of television broadcasting in Brazil, and it includes plans for D2M services.
Mexico	Mexico is also planning to deploy ATSC 3.0 for D2M. The government has issued a tender for the deployment of ATSC 3.0 D2M services, and the first services are expected to launch in 2023. Mexico is focused on distance education use cases for ATSC 3.0 D2M. The government is working with universities to develop D2M services that can be used for distance learning.
Jamaica	Jamaica launched ATSC 3.0 D2M services in 2022. These services offer a variety of channels, including news, sports, and entertainment.

4.3 DTMB-A systems

The Digital Terrestrial Multimedia Broadcast - Audio (DTMB-A) system is a digital broadcasting technology developed by China to provide advanced audio services within its digital television framework. It is an extension of the Digital Terrestrial Multimedia Broadcast (DTMB) standard, which was adopted as the national digital television standard in China.

The DTMB-A system builds upon the foundation of DTMB, which itself is based on the European DVB-T (Digital Video Broadcasting - Terrestrial) standard. DTMB was chosen as China's digital television standard due to its ability to deliver efficient and robust terrestrial broadcasting in a diverse geographical and population landscape.

DTMB-A specifically focuses on enhancing audio services by delivering high-quality and immersive sound experiences to viewers. This system aims to improve audio quality, support multiple audio channels, and provide compatibility with various audio codecs. It complements the video capabilities of the DTMB standard with advanced audio features, catering to the evolving preferences of modern audiences.

4.3.1 Basic Features of DTMB-A

- **i.** High spectral efficiency: DTMB-A Direct to Mobile can achieve a spectral efficiency of up to 5 bits/Hz, which is much higher than traditional terrestrial TV broadcasting standards. This allows for more channels to be broadcast in the same bandwidth, or for existing channels to be broadcast with higher quality.
- **ii.** Low latency: DTMB-A Direct to Mobile has a latency of less than 100 milliseconds, which is comparable to cable and satellite TV. This makes it suitable for applications such as live streaming and gaming.
- **iii.** Robustness to interference: DTMB-A Direct to Mobile is robust to interference from other radio signals, such as WiFi and cellular networks. This makes it reliable even in crowded urban areas.
- **iv.** Support for mobile reception: DTMB-A Direct to Mobile can be received on mobile devices, such as smartphones and tablets. This allows users to watch TV anywhere they have a good signal.
- **v.** Low power consumption: DTMB-A Direct to Mobile receivers have a low power consumption, which makes them suitable for battery-powered devices.
- **vi.** Support for high definition (HD) and ultra high definition (UHD) video: DTMB-A Direct to Mobile can support HD and UHD video, with resolutions up to 4K. This provides a high-quality viewing experience.
- **vii.** Support for multiple audio languages: DTMB-A Direct to Mobile can support multiple audio languages, making it suitable for a global audience.
- **viii.** Support for closed captions: DTMB-A Direct to Mobile can support closed captions, which is helpful for people who are hard of hearing or deaf.
- **ix.** Support for interactive applications: DTMB-A Direct to Mobile can support interactive applications, such as voting, quizzes, and games. This makes it a more engaging viewing experience.
- **x.** Support for data broadcasting: DTMB-A Direct to Mobile can be used to broadcast data, such as news, weather, and traffic information. This can be

used to provide users with up-to-date information.

xi. Support for future technologies: DTMB-A Direct to Mobile is designed to be future-proof, and can support new technologies as they become available.

xii. Open standard: DTMB-A Direct to Mobile is an open standard, which means that it is not controlled by any one company. This makes it more affordable and accessible to broadcasters and consumers.

xiii. Support for global adoption: DTMB-A Direct to Mobile is being adopted by countries around the world, which makes it a more viable option for broadcasters and consumers.

xiv. Government support: DTMB-A Direct to Mobile is supported by governments in many countries, which helps to ensure its widespread adoption.

xv. Industry support: DTMB-A Direct to Mobile is supported by a number of industry organizations, which helps to promote its development and adoption.

4.3.2 Architecture of DTMB-A

The architecture of DTMB-A (Digital Terrestrial Multimedia Broadcast - Direct to Mobile) encompasses several key components to enable efficient and robust content delivery. At its core is the Physical Layer, which employs OFDM (Orthogonal Frequency Division Multiplexing) modulation, dividing the bandwidth into narrowband channels to enhance efficiency and resistance to interference. The Medium Access Control Layer manages resource access using TDMA (Time Division Multiple Access), ensuring fair allocation of radio resources among users. The Packet Layer encapsulates data into packets, integrating error correction coding to safeguard against transmission errors.

Facilitating multimedia content delivery, the Application Layer supports diverse services like television, radio, and data broadcasting. The Conditional Access Module (CAM) handles encryption and decryption to prevent unauthorized content access. Receivers equipped with OFDM demodulators, MAC decoders, packet decoders, and application layer decoders process the DTMB-A signal, while transmitters with modulators and encoders broadcast the signal. Signalling channels exchange system configuration, content, and user location details.

Networking capabilities include single-hop, multi-hop, and mesh networks, supporting various services. Security measures encompass encryption, authentication, and authorization to safeguard content. Engineered for performance, DTMB-A ensures reliability and quality of service even in challenging environments. Its cost-effectiveness stems from the use of affordable components and adaptability to different settings.

Scalability allows DTMB-A to accommodate numerous users and services through easy expansion. The system's future-proof design enables seamless integration of new technologies and services. With its international adoption by multiple countries, DTMB-A emerges as a practical option for broadcasters and consumers alike, fostering a globally recognized solution for multimedia content delivery.

4.3.3 DTMB-A deployment scenario

"Editor's note: Inputs solicited"

4.4 DVB-T2system

Digital Video Broadcasting - Terrestrial 2 (DVB-T2) is a European technology and is an advanced digital television broadcasting standard that represents a significant evolution from its predecessor, DVB-T. Developed by the Digital Video Broadcasting Project (DVB), DVB-T2 was designed to address the growing demand for higher-quality video, improved spectrum efficiency, and enhanced transmission robustness in terrestrial broadcasting.

DVB-T2 builds upon the success of DVB-T, which played a crucial role in the global transition from analog to digital television broadcasting. DVB-T revolutionized television by providing better image quality, more channels, and interactive features. However, as technology continued to progress, the need for even more efficient and advanced broadcasting capabilities became evident.

DVB-T2 has been adopted by numerous countries as their preferred digital television broadcasting standard. Its enhanced capabilities and improved efficiency make it well-suited to the demands of modern broadcasting, offering viewers an enriched and immersive television experience while allowing broadcasters to deliver a broader range of content and services.

4.4.1 Basic Features of DVB-T2

- **i.** Efficient Spectrum Usage: DVB-T2 uses advanced modulation and coding techniques, including COFDM (Coded Orthogonal Frequency Division Multiplexing), to maximize the utilization of available spectrum.
- **ii.** High Definition (HD) Video: Supports the transmission of high-quality HD video content.
- **iii.** Robust Reception: DVB-T2 employs sophisticated error correction and diversity techniques to improve reception in challenging signal conditions.
- **iv.** Adaptive Bitrate Streaming: Enables adaptive bitrate streaming to adjust video quality based on network conditions for smoother playback.
- **v.** Interactive Services: Provides support for interactive services like electronic program guides (EPG) and datacasting.
- **vi.** Multimedia Subtitling and Audio: Supports multiple audio tracks and subtitles for multimedia content.
- **vii.** Hybrid Broadcast/Broadband Integration: Can be integrated with broadband networks for hybrid services.
- **viii.** Low Power Consumption: Enables energy-efficient transmission for reduced power consumption.
- **ix.** Multiple PLPs (Physical Layer Pipes): Allows multiple services to be multiplexed and transmitted in parallel.
- **x.** Time Slicing and MISO: Supports time slicing and multiple-input, single-output (MISO) techniques for improved reception.
- **xi.** Enhanced Guard Interval: Provides better resistance to multipath interference.
- **xii.** Hierarchical Modulation: Allows for different data rates for different reception environments.
- **xiii.** Dynamic Single Frequency Network (SFN) Configuration: Supports adaptive SFN configurations for optimized coverage.
- **xiv.** Regionalization and Local Services: Facilitates regional content delivery and localized services.

xv. Encryption and Conditional Access: Enables content protection and conditional access systems for secure broadcasting.

4.4.2 Conceptual Architecture of DVB-T2

The conceptual architecture of DVB-T2 for potential direct-to-mobile delivery is a creative adaptation that envisions a specialized approach beyond standard implementation. At its core, the architecture comprises distinct layers to facilitate seamless data transmission and reception. The Physical Layer (PHY) forms the foundation, utilizing DVB-T2 modulation (COFDM) for transmitting and receiving data over the airwaves. The Link Layer (LL) manages the connection between transmitting and receiving devices, incorporating error correction and diversity techniques to enhance reliability. The Protocol Layer (PL) oversees data packet management, error correction, and retransmission protocols, ensuring dependable data delivery.

An essential component is the Adaptation Layer, serving as an interface where content intended for mobile devices is extracted or transcoded from the DVB-T2 stream. This allows for efficient delivery of content tailored for mobile consumption. Additionally, the architecture includes Mobile Data Offloading, enabling mobile network operators to directly provide popular content to mobile devices, thereby alleviating traffic from cellular networks.

The Interactive Application Framework establishes the groundwork for interactive applications and services, while Mobile App Integration offers the potential for mobile apps to access supplementary interactive content and services. Middleware plays a pivotal role in managing communication between the various layers and system components. Content Protection and Security handle critical tasks, including content encryption and digital rights management, ensuring secure and protected content delivery.

The architecture also features Service Layer Multiplexing, consolidating diverse services like audio, video, and data into a unified transport stream. The Electronic Program Guide (EPG) offers users interactive access to program schedules and information. The Interactive Application Execution Environment executes interactive applications on receiving devices, enriching the user experience. Broadcast Internet Integration manages the harmonious integration of broadcast and broadband networks, enabling hybrid services that combine both mediums. The Emergency Alert System (EAS) ensures the efficient distribution of emergency alerts to mobile devices. Finally, Mobile Reception empowers DVB-T2-equipped mobile devices to capture and decode transmitted signals, bringing the envisioned direct-to-mobile content delivery to fruition.

4.4.3 DVB-T2 deployment scenario

"Editor's note: Inputs solicited"

4.5 ISDB-T systems family

Integrated Services Digital Broadcasting - Terrestrial (ISDB-T) is a digital television broadcasting standard that originated in Japan and has since been adopted by several countries in Latin America and other regions. Developed by the Japanese government and industry, ISDB-T represents a significant advancement over analog broadcasting, offering improved image and sound quality.

ISDB-T has played a vital role in the digitalization of television broadcasting, particularly in the countries where it has been adopted. Its capabilities have contributed to improved broadcasting quality, expanded services, and greater access to information and entertainment for viewers.

ISDB-T is designed to provide high-quality digital broadcasting signals with better resistance to interference compared to analog TV signals. It uses advanced modulation techniques and error correction to ensure that the transmitted signal is received accurately by the receiver.

4.5.1 Basic Features of ISDB-T

- **i.** Mobile Reception: ISDB-T supports mobile reception through its Terrestrial Mobile Multimedia Broadcasting (ISDB-Tmm) mode, enabling users to receive multimedia content directly on their handheld devices.
- **ii.** High-Quality Video and Audio: ISDB-T delivers high-quality video and audio content to mobile devices, using video codecs like MPEG-2 and MPEG-4 AVC (H.264), and audio codecs such as MPEG-2 AAC or MPEG-4 HE-AAC.
- **iii.** Interactive Services: ISDB-T allows for interactive services, enabling the delivery of additional data and applications alongside the main broadcast. This includes interactive applications, datacasting, and other interactive content.
- **iv.** Robust Error Correction: ISDB-T employs robust error correction techniques to ensure reliable reception, especially in areas with weaker signals or high mobility scenarios.
- **v.** Data Rate Adaptation: The standard supports adaptive data rate based on available bandwidth and content requirements, optimizing the transmission for different network conditions.
- **vi.** Modulation: Orthogonal Frequency Division Multiplexing (OFDM): ISDB-T uses OFDM modulation, which efficiently utilizes the available spectrum and provides resistance against multipath propagation.
- **vii.** Service Layer Multiplexing: ISDB-T allows multiple services, including audio, video, and data, to be combined into a single transport stream, giving users the option to select the desired service.
- **viii.** Hybrid Broadcast/Broadband Integration: ISDB-T can integrate terrestrial broadcast and broadband networks, enabling hybrid services that combine OTA and internet-based content.
- **ix.** Emergency Alert System: ISDB-T includes an emergency alert system to deliver critical information to mobile users during emergencies.
- **x.** Interactive Electronic Program Guide (EPG): Users can access an interactive EPG to browse program schedules and access additional information about the content being broadcasted.
- **xi.** Multilingual Audio and Subtitles: ISDB-T supports multilingual audio and subtitles, allowing users to choose their preferred language for audio and text.

xii. Personalized Content Delivery: ISDB-T enables personalized content delivery, tailoring content recommendations based on user preferences.
xiii. Energy Efficiency: The standard incorporates energy-saving technologies, optimizing power consumption in both broadcasting stations and mobile devices.
xiv. Parental Control: ISDB-T includes parental control features to restrict access to certain content based on age or content ratings.
xv. Real-time Broadcast: ISDB-T ensures real-time delivery of live events and broadcasts, enabling users to watch sports, news, and other events as they happen.

4.5.2 Architecture of ISDB-T

The ISDB-T architecture is composed of multiple interconnected layers, each with specific functions to ensure seamless digital broadcast operations. At its foundation, the Physical Layer (PHY) employs OFDM modulation to transmit and receive data over airwaves. Above this, the Data Link Layer handles link establishment and management to facilitate efficient data transfer. The Transport Layer comes into play, responsible for packetization and error correction to ensure dependable data transmission. The Service Layer Multiplexing combines audio, video, and data services into a unified transport stream, while the Presentation Layer decodes and presents audio and video content. The Application Layer manages interactive services, datacasting, and applications, supported by the Interactive Application Framework that provides the basis for interactive applications. These applications are executed by the Interactive Application (IA) Execution Environment on receiver devices, and their data is combined with audio and video through the IA Composition Engine. Ensuring synchronization of audio and video streams is the role of Media Synchronization. Middleware manages communication between different system layers and components, while Content Protection and Security handle encryption and digital rights management. The Network Layer oversees hybrid broadcast/broadband integration, and the Emergency Alert System (EAS) is in place for delivering crucial alerts to mobile devices. Finally, the Electronic Program Guide (EPG) offers users interactive access to program schedules and information. Together, these elements form the comprehensive ISDB-T architecture, enabling a rich and secure digital broadcast experience.

4.5.3 ISDB-T deployment Scenario

"Editor's note: Inputs solicited"

5. TEC's Standard on Converged Gateway Node

Telecommunication Engineering Centre (TEC) has released a standard i.e. Generic Requirement (GR) on "Converged Gateway Node For Delivering Broadcast Content To Portable Devices Through Wireless LAN" (TEC 57040:2023). This standard provides a readily solution to enable the dissemination of broadcast content to portable devices. In this solution, there is a converged access node which receives the linear television and other signals through the conventional modes such as satellite, cable, or terrestrial and then distributes them using Wi-Fi or other WLAN. The end users can view the television or other audiovisual content on their portable devices without consuming mobile data and without requiring any additional hardware or plugin, etc.

5.1 A conceptual diagram of the Converged Gateway Node for delivering broadcast content is as below;

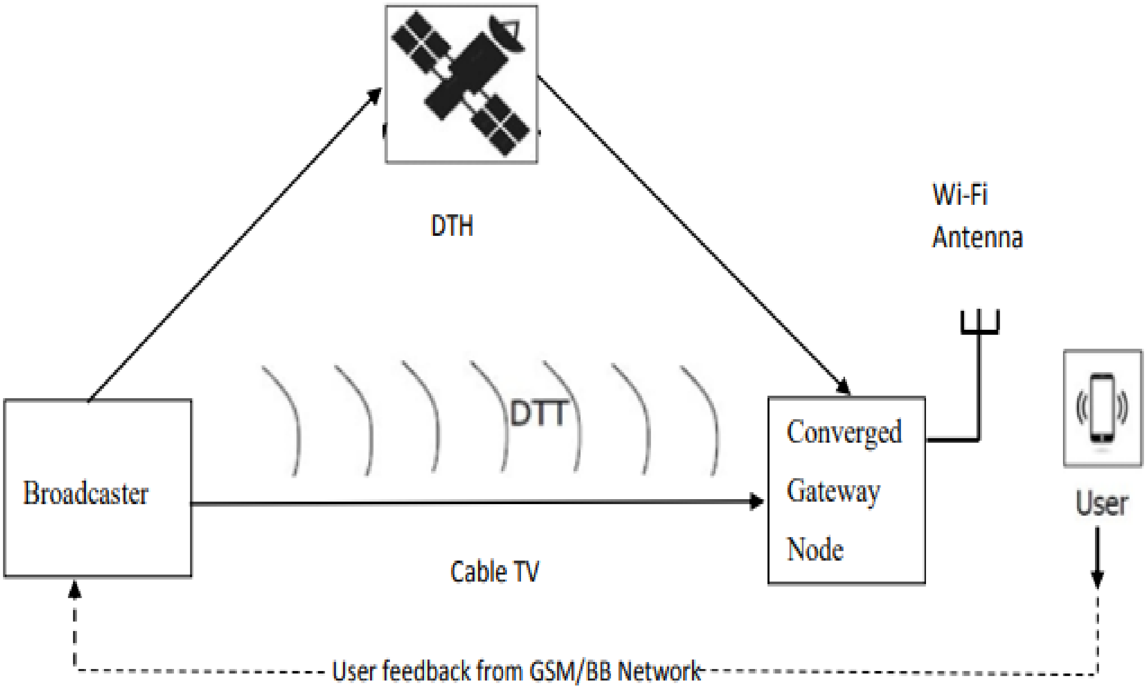

Figure 2 - Conceptual diagram

In the Converged Gateway Node, Digital Terrestrial/Satellite/Cable content is received, demodulated, decoded, and finally selectively streamed in appropriate formats over the WLAN/Wi-Fi. A local content server can also be hosted for various offline services. The content is consumed by end-users using browsers on smartphones and laptops by accessing a web portal through the WLAN/Wi-Fi. Additionally, the end-user can switch to regular OTT services if the access point has been connected to the internet backhaul.

5.2 A functional block diagram of the Converged Gateway Node is as below;

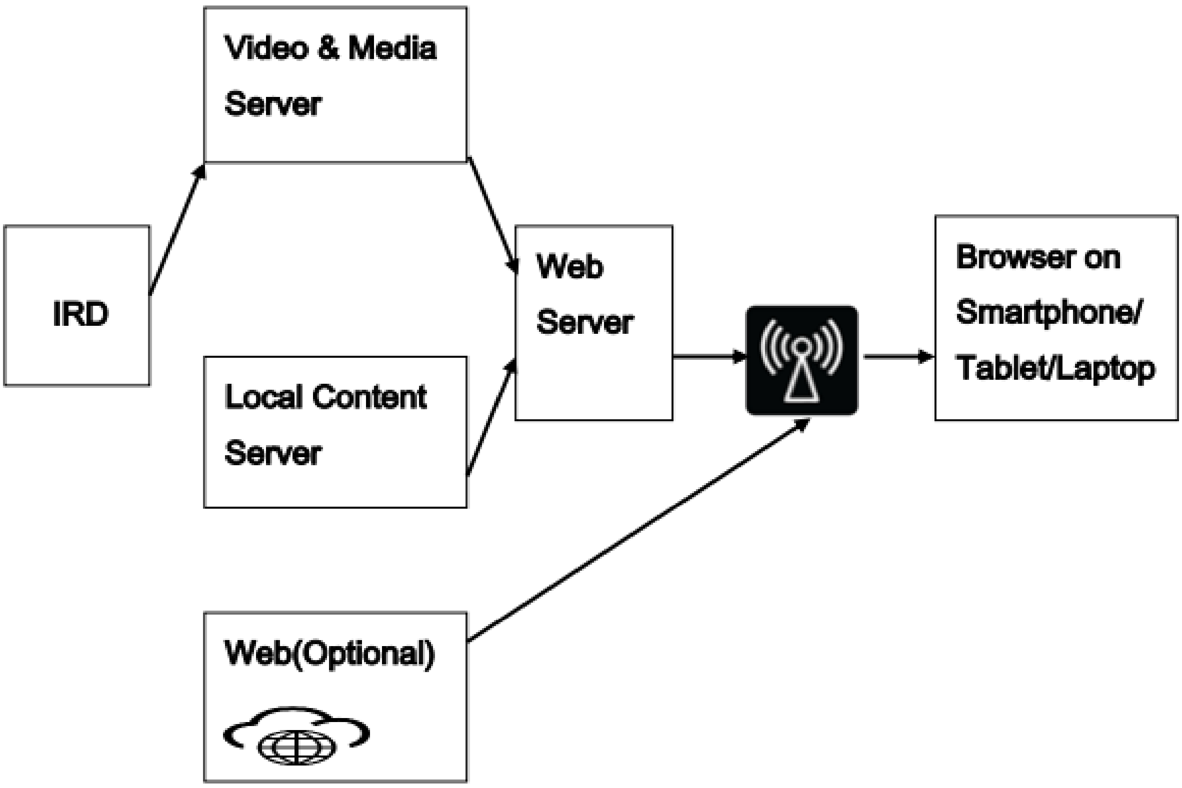

Figure 3 - Functional block diagram

The blocks are briefly explained below:

i. **IRD (Integrated Receiver Decoder)**
A dish antenna on the ground at the gateway location receives the down linked signals from the satellite. Terrestrial signals are similarly received via a smaller antenna. A device at the antenna amplifies these signals and converts them to a suitable band for consumption by demodulation devices. A demodulation device is tuned only for a particular frequency and can only receive a certain number of channels. So ideally one would need a great number of these devices to cater to all satellite and terrestrial channels. This device further converts the signals to baseband signals containing multiple DTV or Radio channels and are streamed out.

ii. **Video and Media Server**
To ensure that the audio/video content is consumed by the end user without having to rely on any kind of specialized software or plugin. Having to install third party plugins or players is not only an inconvenience but also a risk factor for the user. Streams generated in the previous step are not playable by any industry standard browser. This requirement is addressed by the Video & Media Server which transcodes the UDP stream into a stream that can be made HTML compatible to the browser. Also, it ingests a stream and breaks it down to files that can be hosted over HTML using a webserver.

iii. **Self-Learning Web Server**

The function of a web server is two-fold: a. To act as an HTML/Web server for serving the audio/video content to the end user's browser & b. To learn from the user viewership statistics and come up with a list of "n" number of channels as the most watched/desired channels. The channels are thus selectively streamed initially for a period followed by a self-learning algorithm that determines the most desired/watched channels at a given location. After the algorithm converges to a decisive list over time, the channels are finalized. This brings down the cost in terms of reliance on the number of demodulating devices. As mentioned in the "IRD" section, the number of such devices can ideally be a lot but the same is not desired and that purpose is solved by the algorithm inside the web server business logic layer.

iv. **Local Content Server**

A local content server can be hosted for various offline services. The content is consumed by end-users using browsers on smartphones and laptops by accessing a web portal through the WLAN/Wi-Fi.

v. **End-User Browser**

The end-user experience is at the heart of any solution or product. The smart phone/laptop/tab user who wants to consume content doesn't have to install any special app or plugin which is both unsafe and inconvenient. After connecting to the Wi-Fi, the user would access the web portal using an appropriate link. In the browsers, the user shall be able to find the list of channels decided by the algorithm in the previous step. The user shall be able to play the content of these channels directly in the browser by pressing the channel name.

5.3 This solution is technology agnostic and support DVB-S/S2)/ DVB-C)/DVB-T/T2 RF input stream. It can also support other technologies as mentioned above like ATSC 3.0, 5G Broadcast or any other emergent technology. The Converged Gateway Node can be used in various scenarios such as Bharat Net in rural areas. Wi-Fi access points through PM-WANI can also deploy Converged Gateway Node so that the broadcast channels are also available to users without using internet data. It can be deployed for inflight sin moving vehicles (like State Road Transport Buses / City Buses/ Trains/ Taxis/Cars, etc.)

6. Comparison between Technical Features of Technologies available for D2M

A comparison between different technologies mentioned above is as below;

Characteristics	**ATSC3.0**	**DVB-T/T2**	**DTMB-A**	**ISDB-T**
Net data rates in Mbps (depending on BW and MCS)	0.93 – 77.2	7.5 – 50.5	4.81 – 32.48	3.65 – 23.23
SFN/MFN	Supported	Supported	Supported	Supported
Spectrum	UHF	UHF	UHF	UHF

Transmission parameter signaling		Bootstrap, Preamble symbol, L1 signaling	Preamble symbol P1	Service Channel signaling is Carried by control channel in the super frame	TMCC Pilot carriers
Technology status		Deployed	Deployed	Not Deployed	In development
Targeted regions/countries		US, KR, Jamaica	EMEA, Columbia, Australia, Malaysia, Indonesia	China	Japan, Latin America (exl. Columbia), Philippines
Ecosystem readiness (Infrastructure/ End user devices)	Fixed	*R/*R	*R/*R	*R/*R	*R/*R
	Mobile	*R/**NR	*R/**NR	*R/**NR	*R/**NR

*R → Ready. Readiness is assessed based on the available market offerings and accessibility.
**NR → Not Ready. Non-readiness is defined by the ecosystem willingness or readiness to support in relation to support of the standard based on the expected Bill of Materials (BoM) for the stakeholders.

7. Receiver Requirements for D2M

i. **Frequency bands:** D2M terrestrial broadcasting may likely use specific frequency bands allocated for broadcasting services. Receivers must be capable of tuning into these frequencies to receive the broadcasting signals.

ii. **Antenna compatibility:** Receivers should have antennas designed to receive signals in the frequency bands used for D2M. These antennas may be integrated into the device or be external, depending on the application.

iii. **Decoding capabilities:** D2M terrestrial broadcasting might use different codecs and compression techniques. Receivers need to support the relevant codecs to decode the audio and video content accurately.

iv. **Error correction and resilience:** Broadcasting systems require robust error correction and resilience mechanisms to handle transmission errors. Receivers should be equipped to handle and correct errors in the received signals to ensure a seamless viewing or listening experience.

v. **Low latency:** To support real-time or near-real-time services like live broadcasting, receivers should have low latency to minimize delays between the transmission and reception of the content.

vi. **Data throughput:** D2M terrestrial broadcasting could deliver high-quality audio and video content, requiring receivers capable of handling high data throughput to avoid buffering or interruptions.

vii. **Security features:** Broadcasting services may require content protection mechanisms to prevent unauthorized access or content piracy. Receivers should support these security features to ensure content is only accessible by authorized users.

viii. **Interoperability:** To ensure compatibility with various broadcasting networks and services, receivers should adhere to industry standards and specifications.

ix. **Software update capability:** As technology evolves, it's essential for receivers to have the ability to receive software updates to stay current with the latest features, bug fixes, and security patches.

8. Transmitter requirements for D2M

Some general considerations and potential transmitter requirements for 5G-based terrestrial broadcasting.

i. **Frequency bands:** D2M terrestrial broadcasting may likely use specific frequency bands allocated for broadcasting services. Transmitters must be capable of operating in these frequency bands to transmit the broadcasting signals.

ii. **Modulation and Coding Scheme (MCS):** advanced modulation and coding techniques to improve spectral efficiency and data rates. Transmitters must support the specific MCS used for broadcasting to encode the signals effectively.

iii. **Transmit power and coverage:** Broadcasting systems need to deliver signals over a wide area to reach a large number of users. Transmitters must have sufficient power output and coverage capabilities to reach the intended audience.

iv. **Antenna design:** Transmitters require well-designed antennas to efficiently radiate the broadcasting signals. Antenna systems should be optimized for the frequency bands used and the desired coverage area.

v. **Content encoding and compression:** Broadcasting systems often use codecs and compression techniques to efficiently deliver audio and video content. Transmitters should be equipped to encode content using the relevant codecs.

vi. **Error correction and resilience:** Broadcasting systems require robust error correction and resilience mechanisms to handle transmission errors and ensure reliable reception. Transmitters should implement error correction coding techniques to improve the signal's robustness.

vii. **Low latency:** Broadcasting real-time or near-real-time services like live events requires low latency. Transmitters should have low latency capabilities to minimize delays between content generation and transmission.

viii. **Data throughput:** Terrestrial broadcasting may deliver high-quality audio and video content, requiring transmitters capable of handling high data throughput to support the required bit rates.

ix. **Security features:** Broadcasting services may require content protection mechanisms to prevent unauthorized access or content piracy. Transmitters should support these security features to ensure content is only accessible by authorized users.

x. **Interoperability:** To ensure compatibility with various receiving devices and broadcasting standards, transmitters should adhere to industry standards and specifications.

xi. **Network synchronization:** In a broadcasting network, transmitters need to be synchronized to ensure seamless handover and consistent coverage across different cells.

xii. **Energy efficiency:** Transmitters should be designed with energy efficiency in mind, considering the environmental impact and operational costs.

9. Benefits of D2M

There are several advantages of terrestrial broadcasting in the D2M as below;

i. **Wide coverage:** Terrestrial broadcasting has the ability to provide wide coverageacross large geographic areas, reaching people in both urban and rural areas. This is particularly important in regions where internet connectivity is limited or unreliable.

ii. **Reliability:** Terrestrial broadcasting is less susceptible to disruptions caused by weather, natural disasters or other factors that can affect internet connectivity. It provides a stable and reliable platform for broadcasting critical information, such as emergency alerts.

iii. **Cost-effective:** Terrestrial broadcasting infrastructure is already in place in manyareas, and upgrading it to support 5G technology is often less costly than building new infrastructure for wireless networks.

iv. **Low latency:** 5G terrestrial broadcasting can offer low latency, which means that there is minimal delay between when a signal is sent and when it is received. This is especially important for real-time applications such as live sports broadcasts.

v. **High-quality video:** Terrestrial broadcasting can deliver high-quality video content with better picture and sound quality than many streaming services. This is because broadcasting networks have more bandwidth and are not affected by internet traffic congestion.

vi. **Energy-efficient:** Terrestrial broadcasting networks are designed to be energy- efficient and can operate using low power consumption, making them a more sustainable option than some wireless network

vii. **Emergency Alerts** are delivered directly, reliably and without dependence on internet/cellular networks.

viii. **Disaster Management** audio content is delivered directly and authentically in a targeted manner.

ix. **A terrestrial fallback** is available for broadcast of public content of strategic or national importance in the event of catastrophic satellite failures.

x. Valuable spectrum, land, manpower and other public resources are conserved by converging Radio services to a common shared broadcast infrastructure where both audio and video broadcasts can be received through a single interface on smartphones or smart devices.

xi. The D2M technology could be considered an extension of content delivery networks (CDNs), allowing seamless integration into the OTT ecosystem and architecture. This enables D2M providers to leverage the existing CDN ecosystem and edge computing capabilities to deliver a TV viewing experience on mobile. Once a Direct-To-Mobile network is rolled out, a broadcaster can use such a network as a data pipe and deliver various applications apart from traditional TV, traditional Radio such as educational content, emergency alert system, disaster management updates, Video on demand and FOTA (firmware upgrade over the air for automobiles).

10. Potential Challenges of D2M

i. **Limited interactivity:** Terrestrial broadcasting is a one-way communication channel, which means that it does not support interactivity or two-way communication. This limits the ability to offer personalized content or to receive feedback from viewers.

ii. **Limited capacity:** Terrestrial broadcasting networks have limited capacity, which can make it difficult to deliver large amounts of data, such as high-quality video content. This can result in lower picture and sound quality or longer buffering times.

iii. **Fixed infrastructure:** Terrestrial broadcasting networks are based on fixed infrastructure, which means that they cannot be easily adapted to changing needs or user demands. This can make it difficult to keep up with evolving technologies and consumer preferences. To launch the technology on a large scale, it is required to overcome infrastructural challenges as well as making technology available in every corner of the country is not going to be easy.

iv. **Regional differences:** Terrestrial broadcasting networks may vary in terms of coverage and availability depending on geographic location. This can result in unequal access to information and entertainment for people in different regions.

v. **Spectrum allocation:** The allocation of spectrum for terrestrial broadcasting networks can be a complex and politically charged issue, with limited spectrum available for broadcasting in some regions. This can limit the expansion of terrestrial broadcasting services and lead to increased competition for available spectrum.

vi. **Vulnerability to interference:** Terrestrial broadcasting signals can be vulnerable to interference from other sources, such as other broadcast signals, electrical equipment, or weather conditions. This can result in signal disruptions or reduced coverage in certain areas.

vii. **Telecom operators fear D2M revenue loss**: D2M technology could significantly benefit consumers by allowing them to access live TV on their mobile phones without using data and on the lines of direct-to-home (DTH). This would also help content providers reach a broader audience. Despite these advantages, telecom operators are concerned about losing revenue from video consumption. Besides that, they also fear the potential harm to their 5G strategies or 5G beyond.

11. Future of D2M

The future of terrestrial broadcasting in the emergent technology is promising, as this traditional method of broadcasting continues to evolve and adapt to new technologies and changing consumer behaviors. Here are some potential developments in the future of terrestrial broadcasting:

i. **Enhanced interactivity:** With the higher bandwidth and faster data speeds, terrestrial broadcasting can provide enhanced interactive features and personalized content delivery, such as on-demand services and real-time interactivity.

ii. **Augmented Reality and Virtual Reality:** New technology can provide the necessary bandwidth for transmitting high-quality augmented reality and virtual reality content over terrestrial broadcasting, leading to new possibilities for immersive media experiences.

iii. **Mobile broadcasting:** Terrestrial broadcasting can take advantage of the mobility to deliver content to mobile devices, such as smart phones and tablets. This allows viewers to access content on-the- go, without relying on a stable internet connection.

iv. **Improved efficiency:** The use of new technology in terrestrial broadcasting can also improve efficiency, such as reducing the power consumption of broadcasting equipment and increasing the capacity of transmission.

v. **Hybrid broadcasting:** In the future, terrestrial broadcasting may also integrate with other broadcasting technologies, such as satellite broadcasting and IP-based streaming, to provide a more flexible and versatile distribution system.

12. Importance of D2M in Future of Content Distribution

Terrestrial broadcasting still plays an essential role in the distribution of content, even in the new technologies or 5G era. While 5G technology offers high-speed internet access to users, it is not without limitations such as coverage, signal strength, and data caps. Terrestrial broadcasting, on the other hand, offers wider coverage, free-to-air content, and high- quality broadcast reception. Here are some reasons why terrestrial broadcasting remains important for content distribution in the 5G era:

i. **Broad Coverage:** Terrestrial broadcasting has a broad coverage area that can reach remote and rural areas, where 5G network coverage might not be available. This makes it possible for people to access content regardless of their location.

ii. **Free-to-air Content:** Terrestrial broadcasting provides free-to-air content, making it accessible to everyone regardless of their financial status. This is particularly important in developing countries where access to paid content is limited.

iii. **High-quality Reception:** Terrestrial broadcasting provides high-quality reception of content without buffering or interruptions. This is crucial for live events such as news, sports, and concerts where uninterrupted transmission is necessary.

iv. **Emergency Services:** Terrestrial broadcasting is a vital communication tool during emergencies, such as natural disasters or terrorist attacks. It provides critical information to the public when other communication channels might be unavailable.

v. **Efficient Use of Spectrum:** Terrestrial broadcasting uses spectrum more efficiently than 5G networks, making it possible to broadcast content to millions of people simultaneously. While 5G technology offers many benefits for content distribution, terrestrial broadcasting remains important in providing broad coverage, free-to-air content, high-quality reception, emergency services, and efficient use of spectrum.

13. Conclusion

With rapid technological advancements and an increasingly connected world, mobile devices have become an integral part of our daily lives. In present scenario, mobile users also desire to receive broadcasting services directly in their smartphones or similar terminal devices. The demand for personalized, on-demand content has led to the emergence of Direct to Mobile (D2M) as a game-changing content delivery approach. In addition, such broadcasting can deliver the content to a large audience simultaneously, without requiring an internet connection. It can also ensure emergency communication and public safety. It can be used to deliver localized content, such as news, weather updates, and advertisements.

This report tries to cover all possible technologies which can be used for the implementation of D2M. The selection of appropriate technology for D2M with keeping Indian specific interests is the aim of this report. This report covers the details about ATSC 3.0, 5G Multimedia Broadcast/Multicast Service (MBMS) based on 3GPP Rel. 18, DTMB-A, DVB-T2 system, ISDB-T etc. Appropriate D2M standard will help in offloading broadcasting traffic and it envisaged to promote the design and manufacturing of smartphones and similar terminal devices that can directly receive broadcast signals through integrated broadband cable networks or digital wireless transmission.

This report also tries to figure out several challenges to be faced by the industry with adaption of any new technology like spectrum, higher costs for terrestrial broadcasters. Further, the need for investment infrastructure, to invest in new equipment which can be very costly, especially for smaller broadcasters. As D2M continues to evolve, it is essential to address challenges such as content quality, security, and regulatory considerations.

"Editor's note: Inputs solicited"

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15. Abbreviations

1. 3GPP: Third Generation Partnership Project
2. ABR: Auditory Brainstem Response
3. ABMNC: Broadcast and Multicast Communication Service
4. AC-4: Audio Codec 4
5. API: Application Programming Interface
6. ATSC: Advanced Television Systems Committee
7. BMNC: Broadcast and Multicast Communication Service
8. CMAF: Common Media Application Format
9. CDNs: Content Delivery Networks
10. DASH: Dynamic Adaptive Streaming over HTTP (MPEG-DASH)
11. DRM: Digital Rights Management
12. DRMBMCS: Modulation and Coding Scheme
13. DTMB-A: Digital Terrestrial Multimedia Broadcast – Audio
14. DVB-T2: Digital Video Broadcasting - Second Generation Terrestrial
15. Es: Unified Energy Systems
16. FCC: Federal Communications Commission
17. HEVC: High Efficiency Video Coding
18. HLS: HTTP Live Streaming
19. HTTP: Hyper Text Transfer Protocol
20. IPTV: Internet Protocol TELEVISION
21. ISD: International Subscriber Network
22. ISDB-T: Integrated Services Digital Broadcasting – Terrestrial
23. MNO: Mobile Network Operator
24. MPEG-DASH: Moving Picture Experts Group Dynamic Adaptive Streaming over HTTP
25. MBMS: Multimedia Broadcast Multicast Service
26. OFDM: Orthogonal Frequency Division Multiplexing
27. QAM: Quadrature Amplitude Modulation
28. QoS: Quality of Service
29. RAN: Random Access Memory
30. ROM: Read Only Memory
31. SFN: Single Frequency Network
32. TS: Transport Stream
33. UHD: Ultra High Definition