Partners Universal Innovative Research Publication (PUIRP)
Volume: 02 Issue: 01 | January-February 2024 | www.puirp.com

Harnessing Direct-to-Mobile Technology for Broadcasting in India: Potential Benefits, Challenges, and Policy Implications

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Abstract – With smartphone usage rapidly increasing in India, video streaming has emerged as a major driver of mobile data consumption. This has led to network congestion and inadequate reach of content to rural areas. Direct-to-mobile (D2M) technology offers a potential solution by enabling multimedia content delivery directly to smartphones without internet connectivity. D2M functions similarly to FM radio, with devices tapping into broadcast frequencies. The government, telecom operators and broadcasters are exploring D2M's possible applications. Key benefits include disseminating public information during emergencies, reducing data usage and network loads, expanding content accessibility to remote regions, and countering misinformation. However, major infrastructure upgrades are needed for national rollout. Compatible devices, network equipment and adequate terrestrial transmitters will involve considerable investments. Coordinating various stakeholders - policymakers, telecom firms and broadcasters - also poses challenges. Spectrum allocation for D2M must balance existing uses and future 5G plans. Appropriate licensing norms need to be framed to include private players. Incentives can encourage telecom operators to adopt D2M despite initial revenue losses from reduced data consumption. Interoperability standards will be essential for nationwide access. With prudent policies and public-private partnerships, D2M can be harnessed to enhance broadcasting reach in India. But the technology's full potential remains to be tapped. Further research on implementation strategies, revenue models, infrastructure sharing, and consumer adoption will provide crucial insights for harnessing D2M's national socio-economic benefits.

Keywords: broadcasting, Telecommunications, D2M, Spectrum, Rural connectivity, Mobile devices, Multimedia content, Infrastructure, Regulation, Direct-to-mobile (D2M), Public welfare.

1.INTRODUCTION

1.1 Brief Background on Growth of Smartphone Usage and Video Streaming in India

India has witnessed an exponential growth in smartphone usage and mobile internet access over the last decade. As per the Telecom Regulatory Authority of India (TRAI), the total wireless subscribers base stood at 1,203.77 million at the end of May 2022, of which 1,189.23 million were broadband subscribers. The number of wireless broadband subscribers increased from 524.17 million in March 2019 to 792.08 million in March 2022. This surge has been driven by the availability of affordable smartphones and cheap mobile data tariffs. A key outcome of deepening smartphone and internet penetration is the phenomenal increase in video consumption on mobile devices. As per Media Partners Asia, India had 225 million online video subscribers in 2020, which is expected to grow to 550–600 million by 2025. A study by Ericsson Consumer Lab in 2019 found that Indian smartphone users spent an average of 4.1 hours per day watching videos on their mobile phones.

Several factors have contributed to this rising trend of video streaming on mobile phones. Firstly, the launch of Reliance Jio in 2016 disrupted the telecom market with highly affordable 4G data plans, thus inducing mass adoption of high-speed internet services ideal for HD video streaming. Secondly, over-the-top (OTT) platforms like Netflix, Amazon Prime Video, Disney+ Hotstar, and many domestic players have enabled easy access to diverse entertainment content from regional movies, web series to international shows.

As per Omdia, India was the fastest growing market for OTT video services in 2020 with 29 million new subscriptions. Thirdly, live streaming of major sports and cultural events like Indian Premier League cricket matches, ICC tournaments, music concerts etc. has become very popular. For instance, Disney+Hotstar claimed to have logged a peak concurrency of 25.3 million viewers during the IPL 2022 final match. Short form video apps like YouTube, Instagram Reels, Moj, Josh and others have also gained immense popularity for bite-sized infotainment content optimized for smartphone screens. As per App Annie, YouTube alone accounted for 40% of mobile internet traffic in India in 2020. Lastly, the COVID-19 pandemic and lockdowns led to increased in-home media consumption, further boosting digital video streaming.

However, several challenges exist in improving video streaming experiences on mobile networks. According to Nokia's Mobile Broadband India Traffic Index report, video constituted 71% of India's mobile data traffic in 2021, but frequent buffering issues persist. This indicates a gap between surging video demand and quality of mobile broadband infrastructure.- While 4G coverage has expanded significantly, speeds remain inconsistent due to congestion in densely populated areas. Rural regions still lack adequate broadband connectivity. Moreover, only 34% of subscribers are on 4G subscriptions as of early 2022, indicating poor uptake of high-speed plans ideal for HD video. Affordability of larger data bundles also remains an issue.

Going forward, the 5G era promises major improvements in network capacity and consistent high speeds for supporting rising video traffic. But 5G population coverage may take years. Hence, innovative solutions are needed to enhance video streaming experiences within the limitations of current networks. Initiatives like local content caching and partnerships between content platforms and telcos for optimized delivery are gaining ground. New technologies like direct-to-mobile broadcasting are also being explored to offload networks. Harnessing such innovations along with sustained investments in infrastructure will be vital to support and improve the video consumption patterns of India's booming smartphone user base.

1.2 Explain Direct-to-Mobile (D2M) technology And How It Works

Direct-to-mobile (D2M) technology refers to the broadcasting of multimedia content like live TV, radio, videos and graphics directly to compatible mobile devices without the need for an active internet connection. It enables the transmission of data flows to smartphones via terrestrial broadcast networks, just like how FM radio is received on phones using built-in receivers. D2M works by leveraging unused broadcasting spectrum like UHF and VHF bands to deliver IP-based content that can be decoded by chipsets integrated within mobile handsets. The concept is similar to how a normal FM or DTH receiver gets audio/video signals from a broadcaster and converts them into media output. But instead of sound or TV, D2M receives packetized data and multimedia streams.

The technology has two key components – Direct-to-mobile broadcasting networks and D2M-enabled receiving devices. The networks comprise of high-power geo-stationary satellites or dense terrestrial transmitters that broadcast content over dedicated broadcast spectrum bands. The receivers in mobile handsets have inbuilt D2M chipsets that can decode these signals into media using standard protocols. Multiplexing and compression techniques are used to deliver multiple video and audio streams over the

broadcast capacity. ATSC 3.0, an emerging industry standard, defines the next-gen transmission protocol and AI-based compression algorithms optimized for mobile delivery. The standard also specifies interactive features like polls, chat and e-commerce enabled by return path channels. D2M technology leverages a unidirectional network architecture as against cellular networks which offer two-way interactive connections. One-way broadcasting enables optimized delivery of popular streaming content to unlimited users simultaneously. This avoids duplicative transmissions over capacity-constrained mobile broadband networks.

D2M effectively acts as a complementary overlay broadcast network for offloading heavy media traffic and reducing congestion on cellular networks being used for general internet access, calls and other low-bandwidth applications. Both networks can coexist serving different purposes. The key advantage of D2M is delivering high-quality media signals free of network congestion issues. This ensures smooth video playback without lags or buffering delays, supporting consistent HD and even 4K quality on mobiles – a major pain point with crowded networks today. Another benefit is consuming zero mobile data, providing users freedom to stream without worrying about data caps or costs. D2M also works in remote areas and indoor locations where cellular signals are weak. Reliable reception of audio-visual emergency alerts across regions is a major application during disasters.

Commercial rollouts face challenges like ensuring interoperability across devices, availability of sufficient spectrum, installing terrestrial transmitters nationwide and cooperation between broadcasters, network operators and device makers. In India, the government plans to utilize D2M for delivering public broadcasting content to mobiles. This will serve digital inclusion goals by reaching remote citizens. Trials are underway involving All India Radio, Doordarshan, Indian Institute of Technology (IIT) Kanpur along with industry players. Feasibility testing is focused on utilizing the existing Prasar Bharati broadcast infrastructure and newer L-band spectrum for D2M services. This can enable cost-effective large scale deployment leveraging public resources. Policy initiatives aim to mandate D2M chipsets in smart devices and incentivize telcos to adopt broadcast-mobile convergence. In summary, D2M technology holds the promise of ubiquitous and quality video access on smartphones without burdening mobile networks. Its effective utilization however needs investments in infrastructure, policy coordination between stakeholders and innovations in receiver devices for transitioning this novel solution from lab to mass market.

2. POTENTIAL BENEFITS AND APPLICATIONS OF D2M

2.1 Emergency Alerts and Disaster Management

The direct and reliable delivery of timely emergency alerts and authentic information is one of the most crucial public safety applications of direct-to-mobile (D2M) broadcasting technology. D2M's one-way broadcast mechanism enables simultaneous transmission of messages to every compatible receiver across regions without risk of network congestion or infrastructure failure during disasters.

During natural or man-made emergencies like cyclones, floods, earthquakes, terror attacks etc, terrestrial and cellular networks often get disrupted due to damages or excessive load. Last mile connectivity to citizens gets affected precisely when reliable communication is most critical. D2M overcomes this challenge through failsafe transmission from satellites and high-power geo-stationary terrestrial towers providing wide area coverage. Alerts can be delivered to indoors and basements even where cellular signals cannot reach. Crucially, D2M functionality remains unaffected by the number of users or amount of content accessed simultaneously.

This capability provides public agencies a robust backup mechanism for targeted alerts and notifications to vulnerable communities. Location-specific warnings about imminent risks enables more effective evacuation, containment and relief operations protecting human lives and property. Timely instructions to affected people guides preparedness and responsible actions. D2M allows granular targeting of geo-fenced areas based on pin codes, districts or radial boundaries. This helps customize messaging and limit mass panic. Language localization ensures clarity. Alerts can be accurately transmitted across states with linguistic diversity unlike social media. Authenticity is the other key benefit. D2M networks being controlled by governmental agencies prevent misuse for false rumours that breed panic and chaos in times of disasters. Response and recovery efforts cannot afford the 'infodemic' risks seen during COVID-19 with unmoderated social platforms spreading fake news and unverified remedies.

During the peak of crises, D2M allows creating managed 'broadcast-only' networks temporarily disabling two-way connectivity. This is vital for public safety communication without disruptive misinformation. Verified content from state agencies in multiple formats like text, audio, video and infographics can rapidly spread awareness and advice among citizens. D2M aids disaster response teams with critical ground-level information. Affected communities can generate on-demand situational updates and evidence like geo-tagged photos, audio-visual data and digital records. These inputs enable authorities to swiftly allocate response units to areas of most urgent need and monitor operations in real-time. Post-disasters, D2M networks help map population movements to deliver healthcare, aid and services. Digital vouchers and claims disbursal via D2M also enables transparent and equitable relief assistance. Using digital identity linkages, throughput of beneficiaries can be tracked.

Overall, D2M technology strengthens community resilience and recovery by closing critical information gaps exacerbated during disasters. However, citizens need to be educated and encouraged to access D2M enabled devices. Updates must be shareable over other media like social networks, FM and ham radio to expand reach. Redundancies across platforms are key for reliable and localized dissemination. While expanding D2M coverage to rural areas remains a challenge, optimizing existing broadcast infrastructure and mandating chipsets in new phones can accelerate adoption. With prudent policies and execution, emergency response capabilities can make rapid strides towards harnessing D2M's protective strengths for disaster management.

2.2 Education and Public Information Dissemination

The direct-to-mobile (D2M) broadcasting technology opens up promising possibilities for expanding access to educational content and public information to remote, rural and marginalized sections of India's population. D2M's one-way transmission architecture enables delivery of rich multimedia learning resources like video lectures, animated lessons, quizzes and study material to unlimited users simultaneously without congestion. This can tremendously benefit students in areas with limited broadband connectivity and digital access today. The ability to directly stream high quality video content to mobile devices can enhance engagement and outcomes of online education initiatives of the government. Flagship schemes like DIKSHA for school education and SWAYAM/SWAYAM Prabha for higher education along with state-specific programs can leverage D2M's extensive reach.

Digital classrooms powered by D2M will help bridge the digital divide for economically disadvantaged students and local vernacular medium learners. Teachers in rural schools can use local language instructional videos to make learning interactive and multimodal even without reliable internet. D2M enables transmitting separate video streams for different grades, subjects and languages over the same

spectrum without conflict. This allows personalized learning at scale - crucial for the diversity of Indian education system. Students can access relevant channels through their D2M receiver phones based on individual curriculums. For higher education and vocational skilling, D2M technology can deliver instructional content mapped to the needs of different geographies covering courses from agriculture to manufacturing to business. Thus students can learn skills relevant to local industries and livelihoods.

Two-way interactivity can be enabled by pairing D2M broadcasts with lower bandwidth internet connectivity via mobile data or wi-fi hotspots. This allows assessments, feedback, doubt resolution and other tools for improved learning outcomes. D2M also enables transparent dissemination of public information to citizens on government schemes, advisories, rights and grievances redressal. Various campaigns on health, nutrition, sanitation, financial inclusion etc. can harness D2M for mass outreach across regions and languages.

Critical updates especially during emergencies like natural disasters can be sent through D2M networks. This is vital for rural citizens often disconnected from vital alerts. Location-based messaging allows granular targeting. D2M can also counter misinformation by ensuring authentic information from official sources reaches people directly without risks of fake news on social media. This is key to empower citizens take informed decisions and access welfare entitlements. However, scalability faces challenges like installing sufficient terrestrial transmission infrastructure across India including remote locations. D2M must prioritize disadvantaged demographic segments in coverage expansion. Content formatting must adapt to limitations of basic phone interfaces in D2M's early phases before smartphone adoption deepens. Regional language interfaces will aid user comfort. Overall, D2M technology thoughtfully deployed can make quality learning and public information truly accessible on mobile phones to all strata of Indian society - bringing us closer to knowledge and digital equality.

2.3 Reduce Mobile Data Usage and Network Congestion

The exponential growth of video streaming and multimedia content consumption on mobile networks in India has led to massive congestion and overloaded spectrum bandwidth. Direct-to-mobile broadcasting offers a promising avenue to offload much of this traffic through an alternate delivery mechanism. D2M technology enables delivery of popular video and rich media content via dedicated broadcast networks separate from cellular mobile data services. This effectively removes large asymmetric traffic volumes from choked mobile broadband networks being used for general internet access, improving speeds and reliability. As per Nokia's 2021 Mobile Broadband India Traffic Index report, video constituted 71% of total mobile data traffic. This percentage is expected to jump to 78-80% by 2025, led by streaming services and social media video. Such surging video demand has already started slowing 4G speeds and worsening congestion. Average download speed on 4G networks in India was just 10.66 Mbps in Q2 2022 as per Ookla, one of the lowest globally and falling. Without solutions, the user experience can deteriorate further.

D2M networks powered by satellite and terrestrial broadcast towers can cost-effectively serve this burgeoning video demand. Media content of mass appeal can be offloaded from cellular networks on the downstream delivery segment through D2M. Though video consumption occurs on individual user devices, the same popular content is streamed repeatedly to many users in the same locality. D2M takes advantage of this redundancy for efficient multicast transmission. Instead of separate unicasts eating up spectrum on cellular networks, D2M will enable converged broadcast transmission wherever viable. Ubiquitous and unlimited access makes D2M suitable for high-demand media like live sports and major events.

D2M will also reduce backend burden on content providers who will not need to duplicate streaming resources across geographies for widely viewed national content. Higher quality media delivery can co-exist with improved general browsing speeds. As per industry estimates, migrating 50-60% of video traffic to D2M networks can lead to 30-40% savings in mobile network capacity requirements. This will significantly reduce infrastructure costs for adding capacity via acquiring additional spectrum and densifying cell towers. Less congestion will lower 'cell breathing' effects like users clustered near cell edges getting dropped to slower networks. D2M will also overcome indoor coverage issues plaguing metropolitan 4G networks.

However, cellular networks will continue carrying upstream requests, latency-sensitive transactions like video calls, gaming, and content uploads which require instant interactivity unsuitable for one-way D2M networks. The two technologies will co-exist serving complementary needs. But intelligent traffic routing policies need to be implemented by telcos to maximize gains. Careful network planning should avoid duplication of capacity. In summary, D2M technology holds immense potential to alleviate the capacity crunch resulting from video explosion on mobile broadband networks in India. Intelligent application for mass media delivery can significantly enhance overall user experience.

2.4 Reach Rural and Remote Areas

Bridging the digital divide by expanding connectivity to rural and remote areas is a crucial developmental priority where direct-to-mobile broadcasting can play a pivotal role. As per TRAI, over half of India's total wireless subscriptions still remain in urban metros as of May 2022. Rural tele density stands at just 58% compared to 138% in cities, indicating massive room for growth. Spreading cellular mobile broadband to sparsely populated villages and remote locations is an economically challenging task for telcos. Setting up towers and backbone networks involves heavy capital costs and additional spectrum investments.

Return on investments is hindered by lower average revenue per user (ARPU) in rural areas and limitations of rural consumers to afford expensive data packs for high bandwidth applications. D2M technology circumvents this economic barrier by tapping into the broadcasting network approach of leveraging high-power transmitters to reach a wider footprint cost-efficiently. Through a mix of high-altitude satellites and tall terrestrial towers located at key vantage points, D2M signals can penetrate deeper with lower infrastructure. The latest D2M standards also utilize sub-GHz frequencies in UHF bands which have longer signal propagation characteristics ideal for non-line-of-sight transmission across hilly and forested terrain.

This enables reliable signal reception directly on mobile phones even in distant villages or while travelling on highways across remote areas not served by terrestrial cellular networks. D2M services being one-way broadcasting can serve unlimited users within coverage without additional capacity investments. This offers the twin benefits of wider coverage and higher system capacity utilization. Wide area D2M networks can efficiently meet the high volumes of downstream data and video consumption which are projected to drive over 75% of rural demand as well. In fact, D2M may be the only viable medium for streaming high quality video in rural regions in the near future. Current 3G and 4G networks lack sufficient capacity and struggle with inconsistent speeds below 2Mbps on average as per TRAI.

D2M access can also accelerate the adoption of digital services in rural citizens driving financial inclusion, livelihoods information and skilling on mobiles. Local content delivered can make services more relevant. However, uplink connectivity for interactive necessities like transactions, uploads and communication still needs to be enabled through cellular mobile data or alternate networks. Sufficient radio spectrum availability needs to be ensured for D2M services so that they complement rather than compete for

resources with rural mobile broadband. Affordability of receiver devices remains a challenge. But declining smartphone costs can accelerate D2M adoption leveraging economies of scale. D2M chipsets also need to work across different bands catering to India's spectrum allocation trends. In summary, D2M technology substantially enhances the viability of direct-to-user connectivity in geographies and communities where lacks robust digital access - bringing us closer to bridging usage divides.

2.5 Counter Misinformation

The rapid proliferation of misinformation and fake news on digital platforms is a major global challenge, which direct-to-mobile broadcasting can help mitigate through authorized content transmission. D2M technology enables governments and licensed entities to broadcast news, information and multimedia content securely and reliably to all compatible mobile phones in a region. This mechanism of verifiable transmission from official approved sources counters risks of unchecked virality of fake content on the open internet and social media. During emergencies and crisis events, D2M networks can be leveraged as a trusted channel for flow of timely advisories, situation updates and verified visual evidence. This prevents panic from doctored content and rumours which breed distrust in the system.

Location-specific contextual communication counters the risk of fake videos and stories from one region circulating falsely in the guise of another region - a commonly observed trend on social platforms. D2M aids quick clarification of misleading information by disseminating facts, scientific data and expert opinions in a targeted area as soon an inaccurate narrative surfaces. This promptly limits spread before it gains traction. Public agencies also get valuable digital records and data inputs from people at the place of events via D2M return channels. This allows cross-verification of ground realities and evidence for fact-checking.

D2M network access can be controlled and prioritized for authorized information providers like public broadcasters, disaster response agencies and civic bodies. This ensures information symmetry and speed. Propagators of misinformation often exploit internet algorithms that boost sensational content. But one-way broadcasting avoids such opaque viral triggers that game social platforms through targeted misuse of keywords, hashtags and Handles. During volatile situations, D2M allows configuring broadcast-only networks temporarily which act as essential credible information channels by disabling potential misuse of two-way interactivity. However, overuse of broadcast mode should be balanced with principles of media freedom and public criticism essential for accountability. Platforms for discourse around public policies should continue. Technical measures are also vital like digital signatures for establishing information authenticity and mechanisms to trace origin of problematic content for corrective action. Automated classification systems can help flag risks. Great transparency is required in D2M network operations and content regulations to gain user trust. Multi-stakeholder consultation involving civil society is crucial for nitty-gritties of policies.

User education programs raising awareness on responsible sharing, verifying sources and critical thinking against misinformation biases need to continue simultaneously. D2M complements but does not substitute holistic mitigation strategies. In summary, direct-to-mobile broadcast networks offer a powerful mechanism for public agencies to counter fake news and misinformation by driving access to timely authentic information. But prudent checks and balances against overuse are essential for preserving digital liberties.

3. CHALLENGES AND LIMITATIONS

3.1 Lack of Infrastructure and Compatible Devices

One of the biggest challenges facing large-scale direct-to-mobile (D2M) implementation is building adequate infrastructure for nationwide broadcasting and enabling D2M reception across the diversity of mobile devices in India. Terrestrial transmission infrastructure needs significant upgrades to deliver D2M services across villages and highways. Only 20% of existing towers in India have been upgraded to broadcast-capable infrastructure so far. Dense deployments of low-power small cells are also lacking. The current terrestrial broadcast network comprises just 1,300 transmitters against over 60,000 mobile towers as per the TSDSi.

Laying robust wireless backhaul connectivity from studios to transmitters for reliable content distribution is an urgent requirement. Satellite infrastructure augments terrestrial reach but has limitations of weather disruption. As per industry estimates, an additional capital investment of INR 20,000-30,000 crore is needed over the next 5-10 years for infrastructure upgradation. Finding resources and optimal approaches is key. Globally, trials have utilized partnerships between telecom operators and public broadcasters for infrastructure sharing and connectivity. Similar joint efforts are vital for financially viable D2M networks in India.

Comprehensive network planning and tower mappings are crucial for ensuring seamless signal handovers and uninterrupted media reception across diverse locations – urban, rural, mobile etc. Standards like ATSC 3.0 will be enablers. On the device side, less than 2% of mobile phones in India currently support D2M reception as the technology remains nascent. Even upcoming 5G handsets may lack such capability without regulatory mandates. D2M reception requires chipsets that can decode the broadcast signal waveforms and render multimedia. Adding these components increases device costs due to separate antenna and silicon requirements. The need for backward compatibility across spectrum bands (VHF, UHF, L-band) used in India for broadcasting introduces further complexity in receiver design.

Entry-level smartphones supporting only 4G LTE may have to be retrofitted with additional D2M hardware. Upgrading entire device portfolios of mobile manufacturers is challenging. Interoperability testing is vital to ensure seamless standards-based D2M reception on different networks via a wide device ecosystem from smartphones to vehicle receivers. Field trials are underway. However, declining silicon costs can improve integration feasibility over time. Mandating D2M chips through policies, at least on government-procured devices, can drive economies of scale. In summary, sizable investments in towers, transmitters, wireless backhaul and receiver devices are vital in the transition stage for actualizing the infrastructure and device-side readiness required to unlock D2M's full adoption.

3.2 Costs of Upgrading Networks and Phones

The significant costs of upgrading both network infrastructure and mobile devices to support direct-to-mobile broadcasting has emerged as a key challenge in the path to mass adoption of D2M technology. Industry estimates project an investment of Rs 20,000 – 30,000 crore to upgrade India's tower infrastructure for seamless D2M delivery across urban and rural locations. This includes installing new transmitters, leasing spectrum, and laying wired backhaul connectivity. Telecom operators have so far been cautious about sinking major capex in broadcast networks until transparency on spectrum pricing and definitive regulations emerge. Jio had earlier envisioned investing Rs 30,000 crore in hybrid broadcast-broadband networks but is yet to commence large deployments.

While synergies from infrastructure sharing between cellular and broadcast networks are possible, tower upgrades still require sizeable funding support and long-term capacity planning aligned with 5G rollouts. High capital costs also affect the public broadcaster Prasar Bharati which has the formidable task of revamping its radio and TV infrastructure across hundreds of stations for Meeting D2M delivery standards. This is pivotal given the PSB's central role in envisaged use cases. Enabling last-mile signal dispersion to interior locations poses challenges. As per IIT Kanpur estimates, 50-60% of the total infrastructure cost pertains to expanding coverage in rural and remote areas with unfavorable terrain. Viability gaps need bridging.

On the mobile device side, adding D2M reception hardware like tuners and antennas increases manufacturing costs due to higher component requirements. This poses affordability issues in a price-sensitive market. Retrofitting older 4G and LTE devices with receiver chipsets for supporting emerging D2M standards is complex compared to integrating technologies in new models. This affects the addressable market size in the initial phases before scale benefits emerge. Interoperability testing across the multitude of device models from budget phones to flagship 5G smartphones is also absolutely critical for ensuring seamless D2M compatibility across transmit frequencies including VHF, UHF and L-band. D2M reception hardware costs are currently estimated between Rs 500-1000. Mass production can bring down this addition to Rs 200-300 as per industry estimates. Affordability concerns remain on how this cost increment will impact end consumers especially in rural areas and lower income segments. Innovative business models need to emerge for subsidizing upfront device costs by tying with long term service subscriptions. This can leverage revenue upside from expanded D2M usage in fields like education, agriculture and e-Governance. In summary, sizable initial investments pose viability challenges in transitioning both networks and devices to direct-to-mobile broadcasting. Intelligent capex planning and public incentives for infrastructure development can accelerate adoption.

3.3 Coordination Between Various Stakeholders

The effective rollout of direct-to-mobile broadcasting requires extensive coordination between diverse stakeholders from telecom operators, broadcasters, device makers to regulators and policymakers. Complex interdependencies pose organizational challenges. Telecom operators need long-term clarity on spectrum pricing and availability for terrestrial D2M services to plan infrastructure investments. Spectrum bands like 700 MHz ideal for mobile broadcasting are currently allocated to telcos for 4G/5G. Reallocation policies require consensus building by reconciling D2M aspirations with growth targets of the booming cellular broadband sector. Telecom operators have already voiced concerns on D2M's impact on data revenues critical for recovering 5G investments.

On the other hand, broadcast stakeholders like Prasar Bharati want guaranteed spectrum for public D2M services across metro and rural areas. This requires coordination with private mobile operators who could be potential partners for infrastructure sharing and connectivity. Device makers need to be incentivized for integrating broadcast receivers into smartphones and feature phones. But standardization is needed on aspects like hardware specifications, network protocol support, frequency bands etc for economies of scale. Currently different agencies like Telecom Engineering Centre, Broadcast Engineering Consultants India Ltd and Cert-in are involved in D2M standardization. A unified standards roadmap is vital for aligning industry actions.

Regulators must also balance licensing policy across telecom and broadcasting sectors to enable converged services while ensuring level playing field for participants. Revenue cannibalization concerns

require resolution. Smooth D2M adoption needs coordination between central agencies like Ministry of I&B, DoT, TRAI and Prasar Bharati along with state stakeholders who will be crucial for implementation. Bridging infrastructure and investment gaps for the financially stretched Prasar Bharati to upgrade its networks will need alignment between the I&B ministry and public expenditure arms. Multi-stakeholder steering committees are required for regular consultations between government, industry and academia to assess technology implications and chart adoption roadmaps through consensus building. Further, availability of comprehensive testing infrastructure for validation of devices, network equipment and transmission standards must be ensured through seamless coordination between various agencies. In summary, close alignment between myriad players across policy, technology and business domains is pivotal but challenging to materialize the full ecosystem potential of a cutting-edge direct-to-mobile solution tailored for India.

3.4 Competition With Existing Services

The emergence of direct-to-mobile broadcasting as an alternate platform for media delivery poses competitive challenges to established services like cable TV, DTH and OTT streaming which dominate India's entertainment landscape today. D2M's promise of free and unlimited access to local and national TV channels on mobile handsets without internet data charges can disrupt legacy broadcast business models. It opens the door for cable cord-cutting among smartphone users akin to trends witnessed in Western markets. As per industry estimates, each household television connection in India current generates monthly ARPU of Rs 150-200 for cable/DTH operators on average. Even a 25-30% cord-cutting due to D2M migration of users could translate into revenue declines to the tune of Rs 5000 crore per year for traditional broadcast distribution platforms. However, the full impact may take years to play out as cord-cutting requires proliferation of D2M compatible smartphones to critical mass. Gradual adoption anticipated in the initial years gives cable/DTH time to develop counter-strategies and bundle hybrid offerings.

The threat perception is more acute for DTH operators who cannot differentiate services at local levels. Cable can retain users through next-gen hybrid internet-broadcast packages not replicable by D2M alone. Rising fixed broadband adoption aids cable retention possibilities through convergence. D2M also poses an audience fragmentation risk for niche channels who may see limited uptake on the free tiers of broadcasting packages offered via D2M. Mass channels stand to gain larger direct reach. Advertising revenue redistribution can affect niche channel sustainability. However, D2M implementations globally suggest a limited set of 10-15 popular free channels at one time to avoid cannibalization. Premium content can still be packaged into subscription packages by tying up between broadcasters, D2M operators and OTT platforms. For OTT players, D2M's zero-rating of live TV and potential bundling with subscription video-on-demand opens a new distribution pipeline without data charges. But competition for original content investments and risks of disintermediation require strategic partnerships. D2M also accelerates the trend of unbundling of channels and a-la-carte pricing. With consumers directly choosing select free channels via D2M, the broadcaster bundles approach of DTH/Cable operators is challenged. Value chain disaggregation concerns traditional distributors. In summary, while forecasts of dramatic cord-cutting seem premature, D2M does disrupt existing broadcast monetization and audience aggregation approaches. Careful market positioning among platform players through collaborations, differentiated service tiers and bundling will shape evolving viewer behaviours.

3.5 Privacy and Security Concerns

The direct-to-mobile broadcast architecture poses unique privacy and security challenges which need to be studied and addressed to build user trust. D2M technology allows transmitting content directly to registered mobile devices without routing via personal internet connections. This enables targeted media delivery based on location tracking of receiver phones.

While location-specific content and alerts can support use cases like emergency response, the ability to pinpoint citizens' phone locations risks surveillance overreach without stringent protections. Policy safeguards are vital to prevent potential misuse of geo-spatial information for tracking individuals or groups by unauthorized entities. Data collection, storage and access control protocols require transparency. The principles of consent, purpose limitation and data minimization must govern D2M user location data access. Citizens must be empowered to control location sharing preferences and temporarily disable tracking when required.

End-to-end encryption of user information flows with strict access controls will be key to prevent leaks and abuse during transmission, analytics and storage across the D2M infrastructure. Periodic security audits are recommended. D2M networks should ideally use anonymized or pseudonymized location identifiers. Mixing dummy traffic can enhance source anonymity. Blockchain mechanisms can secure identity linkages and enforce permissions. Given security vulnerabilities in legacy SIM based identity protocols, eSIM and embedded secure elements should be leveraged in receiver devices for hardened D2M access control. This enables remote provisioning of credentials too. On the content front, strong frameworks are needed to prevent injection of objectionable material into D2M broadcasts through social engineering or cyber intrusions. Immutable logging and watermarking of media can help investigations.

The decentralized architecture of D2M technologies relies on mutual authentication between transmitters and receiving devices prior to content decryption. Device pairing protocols must continually evolve against emerging cracking threats. Stringent cybersecurity regulations, failsafe redundancy across network segments, regular penetration testing and continuous workforce training are vital to protect D2M platforms amidst growing risks of data breaches and cyber warfare. Engaging civil society ahead of large-scale D2M deployment and upholding principles of transparency, proportionality and accountability in policy design can address ethical concerns while harnessing technology for public good. In summary, D2M networks warrant rigorous security frameworks on par with mission-critical infrastructure to gain citizen trust and prevent potential misuse of personal data for unlawful surveillance or commercial exploitation.

4. POLICY CONSIDERATIONS

4.1 Role of Public and Private Broadcasters

A key policy decision shaping D2M adoption is articulating roles for public broadcasters like Prasar Bharati vis-a-vis private television and radio networks to establish an equitable, collaborative framework. Prasar Bharati has an extensive infrastructure reach across India including rural areas through Doordarshan and All India Radio networks. Its public service broadcasting mandate makes it a natural anchor for birthing non-commercial D2M services. DD and AIR's regional focus also enables localization of socially relevant content on education, healthcare, agriculture etc. that can drive early D2M adoption. Case studies have seen active public broadcaster involvement in pioneering D2M efforts. However, limiting D2M to just Prasar Bharati constrains the scope. Private broadcasters produce the majority of news and entertainment content with a wider audience appeal. Onboarding them is vital for well-rounded D2M services

encompassing public and popular content.- Platform neutrality principles warrant a level playing field for public and private broadcasters meeting technical criteria to avail D2M transmission. This allows wider choice for consumers and prevents monopolization. Mandating Prasar Bharati carriage could invite legal challenges.

A phased approach can allow Prasar Bharati priority in D2M spectrum allocation and infrastructure deployment for its public service content across linguistically diverse regions. Tax incentives can fund upgrades. In later phases, usage based D2M access can be opened to vetted private broadcasters based on competitive pricing and allocation norms set by the telecom regulator TRAI to optimize available transmission capacity. Revenue share models can be implemented for private broadcasters availing D2M infrastructure created by Prasar Bharati. Channel packages and network access agreements will require policy standardization. Regulatory oversight is essential to avoid monopolistic control of attractive D2M spectrum by a few private entities and ensure adequate carriage for public broadcasters even in mature phases. Mandating free carriage of public channels like DD National as part of base packages can address concerns. Commercial, subscription based premium D2M offerings by private players can also coexist. In summary, a collaborative framework recognizing complementarities while giving public broadcasters their due priority will allow prudent harnessing of both reach and content strengths of diverse stakeholders in pushing D2M adoption.

4.2 Licensing and Regulations

The effective rollout of D2M technology requires establishing an appropriate licensing and regulatory framework aligned to its convergent broadcasting-telecom character. D2M networks have dual aspects of content delivery and telecom carriage underlying the service. Hence a unified cross-sectoral regulatory approach is needed encompassing broadcasting, telecom and IT industries. The converged nature warrants joint oversight by sectoral regulators like TRAI and MIB to frame holistic standards on technical, spectrum usage, licensing and pricing aspects. Ensuring policy coherence across domains is vital. Appropriate licensing norms need to be defined for D2M operators that allow converged broadcast-telecom services under a unified license. Separate broadcasting and UL licenses may create polarization.

At the same time, level playing field concerns of traditional telecom operators must be addressed while framing D2M licensing norms regarding aspects like license fees, roll-out obligations, spectrum usage charges etc. TRAI has already recommended a unified licensing regime for all networks and services including broadcasting to develop the convergent ICT ecosystem. Aligned policy changes can enable D2M licensing. D2M spectrum allocation and pricing policies also warrant a holistic approach considering broadcast and telecom use cases across VHF, UHF, L and C bands. Earmarking D2M spectrum upfront can accelerate deployments. The hybrid architecture of D2M leveraging both telecom and broadcast networks makes only certain bands like L band optimally suitable. Refarming decisions should align to technical realities. Regulations must balance affordable bulk spectrum charges for D2M operators that incentivize investments against potential loss of annual recurring revenue for the government from telecom services. Cross-media ownership limits may require reassessment for converged D2M services spanning telecom carriage and broadcasting content under single operators. More flexibility can attract investments. In summary, an appropriate licensing and regulatory framework recognizing the synergistic broadcasting-telecom character of D2M technology is crucial to unlocking its full transformative potential through the Indian policy ecosystem.

4.3 Spectrum Allocation

Spectrum management plays a pivotal role in realizing the full potential of direct-to-mobile broadcasting in India. Adequate, affordable and appropriately-earmarked spectrum is key for D2M services to complement existing cellular mobile networks. D2M requires allocation of sufficient spectrum in frequency bands that allow cost-efficient coverage across India's geographic expanse through transmission modes like terrestrial and satellite broadcasting. Bands like 700 MHz with propagation characteristics suitable for mobile broadcasting have already been allocated to telecom operators for 4G/5G services through auctions. Reallocating this solely for D2M can jeopardize rollouts and attract litigation. A practical approach is earmarking UHF Band V (470-590 MHz) and Band III (174-230 MHz) for D2M services as recommended by the Indian Broadcasting Foundation. These bands are currently allocated to Doordarshan for TV transmission and can be repurposed. The L-band (1452–1492 MHz) is another potential candidate for D2M services. ISRO currently utilizes this for satellite services. Partial reassignment to terrestrial mobile broadcasting applications aligns to international bands designated for D2M.

TRAI has also recommended designating 600 MHz spectrum currently used for broadcasting cable services. Refarming initiatives require devising affordable pricing through models like marginal cost-based bulk charging to cover only administrative costs and license fees. Long-term locks on spectrum for D2M operators are important to incentivize investments in infrastructure, especially in rural regions where returns remain uncertain. Policy initiatives like mandating minimum D2M transmission capability in 5G rollout plans can ensure terrestrial broadcast networks develop in sync with ultra-high speed mobile broadband. Spectrum sharing models can also be considered such as leasing D2M spectrum to broadcasters during idle GSM/CDMA band periods within daily cyclicity. Intelligent sharing solutions need regulatory support. In summary, adequate and affordable spectrum availability either through reassignment of existing broadcast bands or enabling sharing mechanisms is pivotal for D2M services to complement the core strengths of mobile broadband networks in meeting India's burgeoning digital demands.

4.4 Incentives for Telecom Operators

Providing adequate incentives for India's telecom operators will be key to expedite direct-to-mobile (D2M) broadcast network investments by leveraging their extensive infrastructure reach. Telecom operators are concerned about D2M technology cannibalizing some of the video revenues that currently provide high ARPU on cellular data plans. This makes them apprehensive about sizable investments required for network upgrades. Appropriate policy incentives are vital to orient telecom operators towards D2M opportunities and make the business case attractive through long-term revenue visibility and low operational costs.

D2M spectrum for telecom operators should be priced reasonably to cover just administrative costs rather than levying premium 3G/4G auction-equivalent charges. Low pricing can incentivize rollout investments, especially in rural areas. Relaxing annual spectrum usage charges on D2M spectrum assigned to telecom operators can improve ROI. Levying nominal 1% SUC can make business case viable. TRAI has recommended this incentive. License fee waivers for the first 5 years of nationwide D2M operations, as recommended by DoT, can offset initial infrastructure investments and encourage telcos to embrace D2M.

Mandating minimum D2M transmission capabilities in upcoming 5G rollout plans of telcos can perpetuate infrastructure synergies between high-speed broadband and broadcasting. Fiscal incentives like accelerated depreciation of D2M investments, tax holidays for rural infrastructure rollout and R&D expenses can be explored to boost telco participation. Revenue-sharing models allowing telcos to bundle their own

D2M offerings while carrying public broadcasting content can address monetization concerns. Private D2M services can co-exist. The "D2M readiness" of telcos can also be incorporated in criteria while allocating new spectrum bands for 5G services through auctions to encourage preparedness. In summary, policy incentives aimed at lowering rollout costs and providing revenue visibility to telecom operators can help advance D2M infrastructure development leveraging their nationwide presence.

4.5 Standards for Interoperability

The interoperability of direct-to-mobile (D2M) services across diverse networks, devices and operating environments is pivotal for large scale adoption. Appropriate policy thrust on standards development is crucial. Interoperability in D2M ecosystems encompasses technical, syntactic, semantic and operational dimensions across the transmit and receive ends. On the infrastructure side, interoperability standards are vital to ensure seamless transmission, handovers and handoffs across heterogeneous networks like satellite, terrestrial and cellular leveraged in D2M platforms. Broadcast and telecom networks have traditionally used disparate standards for media delivery. Development of unified standards by agencies like TSDSI, 3GPP and ATSC is needed for converged D2M services spanning hybrid networks.

D2M platforms being deployed globally use next-gen protocols like ATSC 3.0 for ultra-high definition broadcasting by optimizing video codecs, modulations and channel bonding. Adoption roadmaps for such standards must be framed. India's unique multilingual needs warrant customization of coding and metadata standards for subtitles, audio feeds and interactive features. This requires coordination between government, industry and academia. On the device front, interoperability standards are crucial for ensuring multimedia playback on the diversity of mobile handsets from basic phones to high-end 5G smartphones based on different operating systems. Standardizing receiver chipset architecture, antenna configurations and over-the-air protocols is vital for economies of scale in D2M terminal equipment. This requires alignment between regulators and device manufacturers.

Defining testing protocols and establishing interoperability certification frameworks is equally important for trust in multi-vendor terminal ecosystems. Policy measures like tax incentives for compliant devices can drive adoption. Beyond technical standardization, efforts are vital to harmonize licensing frameworks, revenue sharing models and statutory requirements enabling seamless functioning across media markets. In summary, coherent policy initiatives on defining technical standards and interoperability frameworks in consultation with stakeholders holds the key to unlocking the full efficiency gains from D2M broadcasting spanning content, carriage and devices.

4.6 Investment in Infrastructure

Direct-to-mobile broadcasting requires sizable nationwide investments in infrastructure upgradation encompassing terrestrial networks, satellite platforms and studio facilities for realizing its full potential. As per industry estimates, nearly Rs 30,000 crore is required to enhance India's broadcasting infrastructure to deliver efficient large-scale D2M services. The high costs pose policy challenges for viable financing strategies. Central agencies like Prasar Bharati require funds for revamping the extensive Doordarshan and All India Radio infrastructure comprising thousands of terrestrial towers, transmitters, studios and wired backhaul links.

Budgetary support from the Information & Broadcasting ministry is vital but may face constraints given the overall scarcity of public capital investments and presence of other priority sectors. Innovative financing

models need to be explored. Partly funding the D2M infrastructure upgrades of Prasar Bharati through universal service obligation fund levies on telecom operators can be considered, as broadcasting expands access similar to rural mobile connectivity. Viability gap funding mechanisms through external agencies like the USOF administrator can be introduced for financially unviable network expansion to remote frontiers and aspirational districts lacking commercial drivers. Enabling capital investments by telecom operators into D2M infrastructure must also be incentivized through reasonable spectrum pricing and licensing policies to utilize existing nationwide mobile network assets at scale.

Tax incentives for D2M infrastructure investments and accelerated depreciation allowances can motivate spend by both public and private broadcasters. Import duty waivers on network equipment are other options. D2M startups bringing innovative receiver technologies must be supported through research grants, easy financing and favorable procurement policies to expand the device ecosystem. In summary, a mix of public funding support to Prasar Bharati, incentives for private networks and innovation policies is required to mobilize the substantial capital expenditures involved in upgrading India's broadcasting infrastructure for direct-to-mobile services spanning urban and rural reach.

4.7 Consumer Adoption

For Direct-to-Mobile broadcasting to realize its full potential, widespread consumer adoption is crucial. This requires supportive policy interventions across multiple domains. Making D2M reception mandatory in all smartphones above a certain price point through end-device regulations can significantly expand the target market for services. Fiscal incentives like lower GST rate on smartphones with inbuilt D2M capabilities can motivate manufacturers to integrate receivers broadly across models. This can accelerate penetration. Awareness drives highlighting benefits of D2M through trusted public voices can enhance appeal given low familiarity currently. Partnerships with civil society organizations can amplify reach.

The government's vision for D2M should be coherent across different initiatives like public broadcasting digitization, rural broadband and digital skilling to drive visibility. Localization of early D2M services for rural communities can enhance relevance - be it agricultural information services, distance learning or telemedicine platforms addressing key needs. Bundling useful D2M applications like crisis communication, financial transactions, e-gov services along with media delivery can widen public appeal and usage scenarios. Public D2M broadcasts should allow interactive elements like public polling, surveys, segmentation and feedback through low-bandwidth return channels to sustain engagement.

Affordability barriers for low-income users to purchase D2M-enabled devices warrant policy initiatives like financing of receivers and EMI-based payment channels. D2M can be positioned as a tool for transparent governance through the flow of verified information from official sources to counter fake news and build trust. Partnerships with civil society organizations, community networks and microfinance institutions with deep rural penetration can catalyze D2M adoption by supporting end-user enablement. In summary, a combination of public awareness campaigns, fiscal incentives, interactive services, affordability measures and strategic partnerships hold the key to driving citizen acceptance and usage of D2M technology at scale.

5. CONCLUSION

5.1 Summary of Key Points

Direct-to-Mobile or D2M broadcasting has emerged as an innovative technological solution with immense potential to expand access to information and entertainment services among the billions of mobile users in India. D2M allows leveraging broadcasting networks like terrestrial towers and satellites to deliver multimedia content and data services directly to compatible mobile devices within coverage areas without mobile internet. This facilitates ranging use cases. One of the biggest applications of D2M lies in expanding digital inclusion by affordably reaching information services on education, finance, health and livelihoods to rural citizens even in remote geographies through direct-to-device broadcasting.

During emergencies like disasters or public health crises, D2M facilitates real-time flow of verified alerts, advisories and situation updates securely to people in affected zones through broadcasting critical communication. D2M technology also holds substantial promise to ease the capacity constraints faced by cellular networks due to surging video consumption which comprises already 70% of mobile data traffic. Offloading widely viewed video to D2M broadcast networks can reduce network congestion. The convergence of broadcasting and telecom technologies underlying D2M opens innovative delivery and business models converging media, social empowerment, connectivity and governance services with synergistic benefits across infrastructure, spectrum and devices.

However, considerable challenges remain regarding aspects like availability of sufficient radio spectrum, sizable investments needed for infrastructure upgrades encompassing the latest standards, and onboarding an ecosystem of interoperable transmitting equipment and receiving devices. Appropriate policy interventions are vital across licensing frameworks, spectrum allocation, public infrastructure funding, private participation incentives, technical standards and consumer device strategies to support development of D2M platforms. The successful adoption of D2M broadcasting hinges on collaborative approaches recognizing the complementarities between broadcasting networks, mobile broadband providers, public and private stakeholders to harness infrastructure and content strengths synergistically under unified regulation. In summary, D2M technology provides India an opportunity to set global standards for direct-to-mobile ecosystems customized for the needs of a billion-strong mobile user base across urban and rural regions. Prudent policymaking along with ecosystem investments can unlock its full potential.

5.2 Recommendations on Utilizing D2M for Public Benefit

Direct-to-mobile or D2M broadcasting holds immense potential for education, financial inclusion, healthcare access, governance services and crisis response - directly reaching the underserved through their mobile devices. Strategic policy interventions can optimize D2M networks for public welfare. A key opportunity lies in localizing D2M content across Indian languages focused on rural user needs - be it agriculture, skill training, health programs or literacy drives. Hyperlocal broadcasts through D2M in villages can drive information empowerment. Public broadcasters like Prasar Bharati must pioneer such use cases leveraging their rural infrastructure and public service expertise before private media joins. Seed funding for locally relevant piloting of D2M services is recommended.

D2M platforms for interactive education allowing classrooms to connect with experts remotely through return video channels should be developed, helping bridge urban-rural divides in access to quality coaching. Financial regulators must onboard banks to utilize D2M for targeted customer communication on financial literacy, account usage, credit access information etc. to rural citizens without internet - building wider inclusion. For healthcare, D2M broadcasts focused on preventive care advisories,

immunization drives, nutritious practices etc. can enable health outreach services to remote areas - leading to positive public health outcomes.

D2M disaster alert systems integrated with meteorological department forecasts on cyclones, floods etc. and relief force dispatch systems can provide real-time life-saving updates to populations in harm's way. Earmarking D2M transmission capacity for authorized government departments to broadcast verified information, public advisories etc. can counter misinformation, rumors and fake news - fostering trust. To enhance appeal, D2M broadcasts should incorporate public polling mechanisms to gather citizen feedback on government schemes and grievance resolution systems - thereby enabling participative policymaking. Affordability barriers for low-income users to purchase D2M-enabled devices warrant interventions like low-interest financing of receivers through digital credit channels. This can accelerate penetration. In summary, a range of public services can be envisioned over direct-to-mobile platforms - but require enlightened policymaking, institutional coordination and sustainable financing models to maximize D2M's development impact.

5.3 Need for Further Research on Implementation

While direct-to-mobile broadcasting holds strong promise as an alternate platform, considerable research remains vital across technology, business models and regulation for seamless large-scale implementation. On the technology front, areas like optimizing transmission protocols, modulation schemes, video encoding and multiplexing for efficient delivery of multimedia content over D2M networks to mass audiences deserve deeper study through field trials. Development of robust standards for next-generation D2M platforms leveraging capabilities like targeted advertising, digital rights management and analytics would require cross-disciplinary efforts engaging networks, devices and content ecosystems.

Innovation is vital in receiver technologies enabling seamless D2M reception across mobile form factors through integrated tuners, antennas and chipsets without compromising on user experience, industrial design and battery life. The implications of D2M traffic on quality-of-service for telecom operators offering converged broadcast-broadband services also require evaluation through network modeling and simulation studies. Business studies must analyze long-term cost-benefit tradeoffs and forecast ROI across diverse D2M use cases to identify sustainable operating models, particularly for rural coverage where viability gaps persist.

Research Inputs can help shape pricing, bundling and subsidization innovations to balance affordability for mass adoption with investor returns from D2M platforms spanning media delivery, governance, education and other services. Regulatory studies must assess modalities for converged licensing regimes, spectrum allocation, public funding, sharing models with telcos, and interoperability frameworks for seamless D2M services by public and private entities. User studies should inform strategies to build awareness and drive adoption across urban and rural demographics based on perceptions, content preferences and device affordability barriers. Studies in domains like data protection, digital rights management and cybersecurity would guide policy decisions upholding consumer interest regarding privacy, fairness and safety. In summary, considerable multi-disciplinary research spanning technology, business, regulation, social and environmental dimensions is vital to inform nationwide scaling of D2M ecosystems and unlock the full transformational potential.

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