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Meta-synthesising 5G and OTT transformation in radio broadcasting

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ABSTRACT

A conceptual paper is essential as it is a potent tool for developing theory. However, researchers grapple to plan and write non-empirical articles due to the absence of well-recognised models to direct their creation. Thus, this study reviews the literature through a meta-synthesis method on the 5G and OTT concepts in radio broadcasting. Access to broadcast infrastructure is vital for every radio service. However, the switchover from conventional to digital, as envisaged by the Asia-Pacific Broadcasting Union and International Telecommunication Union, presents both challenges and opportunities for such stations. The saturation of FM frequency shows the urgency to make technological changes in the radio industry. This meta-analysis combined and summarised previous research findings to generate causal conclusions regarding radio players' preferences for using 5G or OTT and how and why these preferences have failed to prevail. We identified 25 relevant articles from an initial pool of 5,080 articles through a systematic search. These articles demonstrate that other researchers frequently use PRISMA techniques for data analysis, often utilizing MAXQDA software. Researchers will address that gap, which is viewed as still a work in progress due to various influencing factors. This concept builds upon the various insights undertaken by researchers in the 5G and OTT technology field to bridge the gap of radio's migration from conventional to digital to gain a competitive advantage. This measurable and pragmatic concept of 5G or OTT should improve aspects of understanding amongst radio practitioners, government officials and listeners that may later benefit the radio industry in the digital era.

Keywords: ***5G, OTT, radio broadcasting, technological disruptions***

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INTRODUCTION

Radio technology has undergone a century of transformation, tracing it roots to the late nineteenth century when Thomas Edison, in 1877, completed Scott's initial experiment and invented the phonograph, initially intended for transmitting spoken messages via postal systems (Couch, 2007; Johnson, 2014).The conceptual leap from mechanical sound reproduction to wireless communication was realised a decade later when Heinrich Hertz verified Maxwell's electromagnetic theory, paving the way for Guglielmo Marconi's invention of radio in the early 1900s (Ibrahim & Wahab, 2021). Since then, radio standards have evolved through successive technological paradigms from analogue to digital and more recently, to alternative Internet-based frameworks.

Analogue radio standards such as Amplitude Modulation (AM), Frequency Modulation (FM) and Short Wave (SW) dominated the twentieth century (Ala-Fossi, 2013; Fornatale & Mills, 2018; Hirschmeier et al., 2019). Digital standards consist of High-Definition (IBOC), Digital Radio Mondiale (DRM), Digital Audio Broadcasting (DAB) and satellite (Joao dos Santos, 2021; Oziewicz, 2022). These formats sought to improve signal efficiency, spectrum utilisation and sound quality. However, the twenty-first century introduced alternative standards that integrated radio into the broader digital ecosystem such as Internet radio, mobile applications, 5G and Over-the-Top (OTT) delivery platforms (Patzold, 2019).

Among these alternatives, 5G and OTT technologies demonstrate distinct comparative advantages over conventional digital standards such as DAB+ or DRM. While conventional digital systems enhance transmission quality within regulated broadcast infrastructure, 5G and OTT extend radio's functionality beyond spectrum-bound broadcasting which can enable a fully convergent and interactive environment. 5G networks provide ultra-low latency, high data throughput and the capacity to support real-time, high-resolution audio streaming to multiple devices simultaneously. Moreover, 5G broadcast merges broadcast and broadband delivery, reducing dependence on costly transmitter networks and allowing efficient spectrum sharing (Patzold, 2019). OTT platforms, on the other hand, enable content distribution without reliance on terrestrial frequencies or satellite transponders, supporting personalised, on-demand, and globally accessible radio experiences. These affordances make 5G and OTT particularly attractive for developing markets seeking cost-effective, scalable and audience-centric digital solutions.

In Malaysia, the trajectory of radio digitalisation reflects a long-standing policy challenge. The digital radio broadcasting initiative, first proposed in 1997 under Working Party 14, faced limited adoption due to industry resistance, infrastructure costs and the absence of cohesive regulatory support (Ibrahim, 2020; Ibrahim & Wahab, 2021). Despite DAB+ trials, stakeholders have been reluctant to migrate from FM, citing uncertain revenue models and high entry costs. Concurrently, the growth of social media and streaming services after 2010 fundamentally altered audience behaviour, transforming audio radio into visual-audio ecosystems that emphasise interactivity and portability (Ibrahim, 2020). Against this backdrop, 5G and OTT offer a more flexible and future-proof path toward digital radio adoption, aligning with Malaysia's wider 5G deployment and Internet penetration strategies.

Yet, despite their potential, academic research exploring 5G and OTT within Malaysia's radio context remains scarce. Existing studies on digital radio primarily focus on technical feasibility or regulatory barriers, overlooking emerging paradigms of network convergence, media hybridisation and audience engagement enabled by these technologies. To address this gap, this article systematically analysed the global literature on 5G and OTT in the radio industry using a meta-analytic approach, synthesising empirical evidence to identify trends, challenges, and policy implications. This approach transcends descriptive reviews by integrating quantitative and qualitative findings to derive more reliable conclusions. Ultimately, the paper aims to provide a comprehensive framework for understanding how 5G and OTT can catalyse Malaysia's transition towards complete radio digitisation, ensuring technological resilience and industry sustainability in the era of network convergence.

METHODOLOGY

In this research, we employed a meta-synthesis approach in studying 5G technology and Over-the-Top (OTT) as a substitute for FM technology. We considered the need to analyse past research to construct reliable research in the future. A meta-synthesis is also crucial for more robust validation of past and current research. Meta-synthesis is a relatively new technique for examining qualitative research (Jensen & Allen, 1996). This technique has been applied in areas as diverse as transformational leadership (Pielstick, 1998), as well as nursing and medical (Campbell et al., 2003; Paterson et al., 2001). According to Walsh and Downe (2005), meta-synthesis is an essential technique for qualitative researchers, integrating results from inter-related qualitative studies and deepening the understanding of the healthcare context. Similarly, Barry and Hafiz (2024) used meta-analysis to map interdisciplinary linkages and identify how Public Relations (PR) research is evolving beyond traditional boundaries.

Our search through Google Scholar, AI Dimensions, and Science Direct (2019–2024) revealed that while the technique is predominantly applied in medical and nursing fields, its use is gradually extending into the social sciences and communication studies. Thus, this study applied the meta-synthesis approach to radio digitisation to uncover conceptual patterns, theoretical models, and implementation strategies that can inform Malaysia's digital radio transformation.

Table 1. Database search

Year	Search Engine	Articles
2019–2024	Google Scholar	17,700
	AI Dimensions	12,409
	Science Direct	174

It is vital to note that meta-synthesis is not a mere summarisation of the findings and conclusions of qualitative studies. More specifically, it involves reconceptualising the findings, and then researchers interpret them to create new insights. The outcome of this meta-synthesis will generate a new theory, develop conceptual models, identify research

gaps, and add breadth of understanding to existing epistemology. Thus, it is essential for us to follow the steps and procedures in conducting a meta-synthesis analysis.

In order to perform a meta-analysis, a necessary preliminary step consists of constructing one's meta-data.

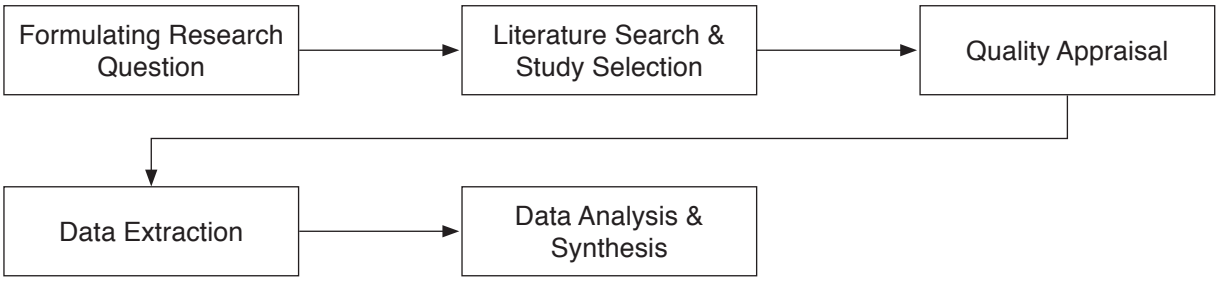

Figure 1. Research design

The first stage is to formulate a research question. Before we create a research question, we establish a problem statement. In Malaysia, studies on the radio are minimal. Despite this, we noticed that conventional radio is on the brink of FM's frequency saturation, which has created no new players in the Malaysian radio industry (Ibrahim, 2020). Over the years, considerable innovations have been made to replace frequency modulation, such as digital audio broadcasting (DAB+), 5G, and OTT. However, a vital issue for broadcasters in moving to DAB+ is that there is no clear pilot test result, no digital radio action plan, and a reluctance to change among FTA broadcasters. Since there is no structured technology roadmap for radio broadcast technology, the Malaysian radio industry is a laggard in many ways compared to Vietnam, Myanmar, and Thailand.

In Malaysia, the debate on digital radio broadcasting is like a chicken and egg dilemma. Ibrahim and Wahab (2021) found that the digital radio broadcasting plan was initiated in 1997 by setting up a task force group known as Working Party 14. However, the reluctance of industry players (at that time) to change from FM to DAB+ and insufficient financial support have caused the radio digitisation project to become delayed. In 2010, the radio landscape changed, when social media disrupted conventional radio. If industrial players refuse to accept digital terrestrial radio, what other potential exists to replace it?

After formulating the research questions, we conducted the literature search through three database searches: Google Scholar, AI Dimensions, and Science Direct. Articles from 2019–2024 written in English were included. In order to collect a representative sample of high-quality studies, we focused on articles, books, and chapters in the book, and the reports were identified through an iterative process based on the journal articles.

Our systematic search was conducted using a specific combination of selected general keywords (5G, OTT, radio industry and preference). We ended the search at a saturation point by combining different keywords and adding new ones, resulting in the same articles. By applying this systematic search strategy, we noticed that around 30,283 articles appeared to have the keywords. Thus, we limited our study selection to works that clearly defined 5G and OTT to implementation. Amongst them, only studies that provide sufficient information to assess industrial radio preferences for 5G and OTT and their implementation were selected.

Titles and abstracts were examined for relevancy for each search element, and references to the full-text document were made as needed to confirm the breadth and depth of any review work mentioned in the abstract. For many of the 5G and OTT publications, it was challenging to determine whether the literature review contained in the document provides a thorough and well-reasoned critique of other techniques, and the abstract did not assist in differentiating between a broad and narrow literature study.

To ensure methodological transparency and rigour, the researchers defined explicit inclusion and exclusion criteria. The inclusion criteria were:

- Studies published between 2019–2024 to capture current developments in 5G and OTT technologies.
- Studies focusing on radio, broadcasting, telecommunications or digital media.
- Studies that explicitly discuss 5G technology, OTT platforms, or their application to radio, media distribution, or audience behaviour.

While, the exclusion criteria comprised:

- Non-scholarly or commercial materials such as news articles, blogs and promotional content.
- Studies referencing 5G or OTT only tangentially without examining implementation or adoption.
- Duplicate publications.

This process refined the initial 30,283 search results to a final sample of 15 studies (10 focusing on 5G and OTT definitions, and 5 examining industry preferences and implementation). Titles and abstracts were screened for relevance, and the full texts were reviewed to confirm conceptual depth and methodological transparency.

Table 2. Database search vs. inclusion & exclusion

Year	Search Engine	First Search	Second Search	After Inclusion & Exclusion (n)
2019–2024	Google Scholar	17700	5590	6
	AI Dimensions	12409	3192	5
	Science Direct	174	50	4

To ensure the credibility and interpretive quality of the synthesis, each study underwent a systematic quality evaluation using the Critical Appraisal Skills Programme (CASP) checklist. Each study was appraised according to the following criteria:

- Clarity of research aims and questions
- Appropriateness of research design and data collection
- Transparency and trustworthiness of analysis
- Depth and relevance of interpretation
- Direct connection to 5G or OTT implementation in media and broadcasting

Only studies achieving at least 70% of the quality indicators were retained. After the quality appraisal, data were systematically extracted using a structured matrix capturing: author(s), year, country, research design, context, methodological approach and key findings. The synthesis followed Noblit and Hare's (1988) meta-ethnographic procedure, which involves three key interpretive stages:

- Identifying convergent themes and conceptual parallels across studies
- Examining contradictory or divergent findings to uncover contextual nuances
- Integrating individual insights to develop a higher-order framework that explains how 5G and OTT technologies can accelerate radio digitization

In summary, this meta-synthesis followed a systematic, transparent, and replicable process grounded in established qualitative synthesis frameworks. By applying clearly defined inclusion criteria, rigorous quality assessment, and structured interpretive analysis, the study ensures credibility and contributes new theoretical and practical insights into how 5G and OTT can reshape the Malaysian radio industry's digital future.

FINDINGS

From our meta-synthesis, we discovered that the evolving concept of 5G and OTT in radio broadcasting presents a dynamic and multifaceted landscape. The meta-synthesis study of the current literature highlights the transformative potential of these technologies while also underscoring the need for a comprehensive understanding of the technical, regulatory, and user-centric implications. We noticed that this concept is new to the radio industry, and some countries are still weighing whether to deploy it or not.

The concept of 5G Radio & OTT

Based on the 10 5G radio and OTT articles, we uncovered a wealth of potential in these technologies. Their reputation and user benefits are promising, leading us to the pivotal question of how these two technologies could revolutionise analogue and digital broadcasting standards.

Our meta-synthesis analysis uncovered that the 5G New Radio (5G NR) and Over-the-Top (OTT) services are distinct but interconnected technologies—each playing a different role in the digital ecosystem. Table 3 shows the 5G radio and OTT concepts from various scholars.

Table 3. Citation identifier vs 5G Radio and OTT

Citation Identifier	5G	OTT
Prasad & Sridhar (2023)	Mobile Network Operator (MNO).	Over-the-Top is an Information and Communication Technology service provided over the Internet, untethered from the underlying network.
Jang & Kim (2024)	5G technology is seen as a critical enabler for advanced communication networks, offering faster speeds, lower latency, and more excellent connectivity, which is essential for supporting new applications like D2D caching.	OTT refers to media and communication services delivered over the Internet, bypassing traditional telecom channels.
Ahmad & Atzori (2020)	5G is the next-generation mobile network that handles massive multimedia traffic, especially video streaming.	OTT (Over-the-Top) refers to services like YouTube, Netflix, and other multimedia platforms that deliver content directly to users via the Internet, bypassing traditional network operators.

Table 3. (con't)

Citation Identifier	5G	OTT
Oliveira & Vazão (2023)	5G radio refers to advanced technologies in 5G networks that enable efficient wireless communication. It uses multiple frequency bands, including millimetre waves, to provide higher data rates, lower latency, and support for many connected devices. The 5G RAN (Radio Access Network) is a crucial component of this, enabling the slicing of network resources.	OTT (Over-the-Top) services, such as video streaming (e.g., Netflix, YouTube), are internet-based services that operate independently of the underlying telecommunications infrastructure.
Adil et al. (2024)	5G radio enables ultra-fast data transmission, low latency, and reliable communication, which are critical for immersive experiences in the metaverse.	OTT refers to media services provided directly to users via the Internet, bypassing traditional broadcasting mediums.
Park et al. (2024)	Its high-speed data transmission, low latency, and increased bandwidth pave the way for a new era of media consumption.	OTT services, the new frontier of media distribution, are gaining traction. These platforms, which deliver media content over the Internet, bypass traditional channels like cable or satellite TV.
Singh & Sehgal (2023)	Its high-speed internet capabilities, low latency, and enhanced connectivity allow users to stream content without interruptions, even in high-definition formats. The reliability and speed of 5G networks are seen as essential in meeting the increasing demands for better quality, faster access, and mobile media consumption.	OTT platforms, which provide on-demand content via the Internet.
Hallur et al. (2023)	5G transforms digital media and entertainment by offering high-speed Internet, low latency, and enhanced mobile connectivity.	OTT services are highlighted as disruptive in the entertainment sector, offering direct-to-consumer content delivery over the Internet.
Henttonen et al. (2024)	The 5G radio access network (RAN) includes control and user plane functions, signalling, and data transfer protocols.	N/A
Lin et al. (2019)	5G New Radio (5G NR) is the foundation for 5G wireless communications.	OTT services by offering faster, more reliable connectivity for high-definition video streaming

Table 3 shows that these concepts differ in terms of definition, function, purpose and scope of technology. 5G radio is the wireless communication standard for the 5G mobile network. It governs how data is transmitted over the airwaves between devices and network infrastructure. Meanwhile, OTT refers to services that deliver media content (like video, music, or messaging) over the Internet, bypassing traditional broadcasting or telecom networks.

Subsequently, the function of 5G radio is to focus on the technical aspects of how data is sent and received, including using higher frequency bands (like millimetre waves), massive MIMO (multiple-input, multiple-output) for better data throughput, and

beamforming to direct signals more efficiently. In contrast, OTT services are platforms like Netflix, YouTube, and Spotify that provide users with media and entertainment through the Internet. These services rely on high-speed Internet but do not manage or control the physical network infrastructure.

5G radio is designed to provide faster data rates, low latency, and increased capacity, enabling the smooth operation of everything from smartphones to IoT devices. OTT is designed to offer content and services directly to users via apps or websites without the involvement of cable or satellite providers. However, regarding the scope of 5G radio, it is part of the network infrastructure and handles the physical communication between devices. Meanwhile, OTT exists on the application layer, delivering content that is consumed over networks like 5GNR.

As listed in Table 3, most scholars agreed that 5G is generally the fifth generation of mobile network technology, offering significantly higher data speeds, reduced latency, and the ability to connect a massive number of devices simultaneously. They highlighted the benefits of 5G, which offers advanced capabilities such as low latency, increased bandwidth, and enhanced connectivity, making it ideal for multimedia services. Ahmad and Atzori (2020) claimed that 5G is essential for managing video streaming effectively. Meanwhile, Oliveira and Vazao (2023) stated that RAN (radio network) slicing is a technique that divides the physical network into multiple virtual networks, each with its own unique characteristics and resources. This slicing allows the network to dynamically allocate specific resources for different services (such as IoT, video streaming, or autonomous vehicles) based on real-time demand. The introduction of green machine learning techniques is intended to make this allocation more energy-efficient and sustainable.

The core technologies driving the 5G revolution, as highlighted in the literature, include ultra-densification, millimetre-wave (mmWave) communication, and massive multiple-input multiple-output systems (Mattisson, 2018; Silva & Guerreiro, 2020). These technologies, coupled with the increased virtualisation of the core network and the potential integration of past and current cellular and Wi-Fi standards, are expected to provide a ubiquitous, high-rate, low-latency experience for network users (Andrews et al., 2014).

OTT includes streaming platforms, messaging apps, and video conferencing tools. OTT services heavily rely on technologies like HTTP adaptive streaming (HAS) to optimise video quality based on network conditions. However, they often lack direct control over network resources, which can affect quality. According to Oliveira and Vazao (2023), in the context of the metaverse, OTT platforms will enable high-quality content streaming, interactive media, and user-generated content within a fully immersive environment. Thus, the 5G new radio and OTT operationally cannot replace terrestrial and digital radio broadcasting since the way it transmits is different from terrestrial and digital radio broadcasting.

Table 4. The difference between 5G NR, OTT, digital and terrestrial radio

Technology	Transmission Method
5G New Radio (5G NR)	Wireless communication standard using cellular networks. Transmits data over sub-6 GHz and milimeter-wave frequency bands. Utilises advanced technologies such as massive MIMO and beamforming to ensure fast, low-latency, and high-capacity data transmission.

Table 4. (con't)

Technology	Transmission Method
OTT (Over-the-Top)	Transmits content (audio and video) over the Internet via existing broadband or cellular networks. Uses IP-based data delivery, relying on infrastructure like 5G, Wi-Fi, or fibre-optic Internet for transmission.
Digital Satellite Radio	Transmits digital audio signals from satellites orbiting the Earth. It uses frequency bands such as L-band and S-band, providing comprehensive geographic coverage and high-quality digital audio. Receivers must have satellite antennas.
Terrestrial Digital Radio	Uses digital broadcasting technology to transmit radio signals over land-based transmitters (DAB+ & DRM). Transmits in specific digital frequency bands (VHF Band III, L-band) and offers enhanced audio quality and additional data services such as track info and station ID.
Analogue Radio	Traditional AM (Amplitude Modulation) or FM (Frequency Modulation) methods are used to transmit audio signals over radio waves. Transmits over specific frequency ranges (530-1700 kHz for AM or 88-108 MHz for FM) with limited audio quality and susceptibility to interference.

The implementation of 5GNR or OTT

The impact of these evolving wireless technologies on radio broadcasting is multifaceted. The integration of 5G and beyond technologies into radio broadcasting can unlock new possibilities, such as enhanced audio and video quality, low-latency live streaming, and the support of innovative content delivery models (Silva & Guerreiro, 2020). Additionally, the convergence of 5G and OTT platforms can enable the development of personalised, interactive, and immersive audio-visual experiences, catering to the diverse preferences of modern audiences (Nayak & Biswal, 2021).

However, the implementation of these advancements is not without challenges. The industry must navigate the complexities of integrating legacy systems with emerging technologies, address regulatory and policy considerations, and ensure the seamless adoption of these innovations by both service providers and end users. From five articles that underwent meta-synthesis analysis, we discovered that Park et al. (2024), Forge and Vu (2020), Cave (2023), Blind and Niebel (2022), as well as Mitomo (2020) highlighted the potential of 5G from a social and economic aspect.

According to Forge and Vu (2020), determining the degree of future market demand for 5G is a fundamental difficulty, as it depends on the existence of viable business models that yield sufficient returns. Therefore, to avoid potential difficulties, policymakers—especially those in low- and middle-income countries—should have a practical understanding of the 5G deployment strategies adopted by the early adopting, high-income nations. 5G deployments are underway in Argentina, Brazil, Chile, Thailand, Colombia, and Mexico (Forge & Vu, 2020). While this may well encourage investments, Forge and Vu (2020) are concerned with identifying the fundamental problems that such a "showcase" strategy may face in "realpolitik" terms.

Besides that, the equipment supply side still needs to churn the telecoms market for new revenues. Forge and Vu (2020) contended that even if it is uncertain if mobile network operators (MNOs) really want (or need) this cutting-edge technology that will drastically alter the current market structure and its ecosystem—5 G's high-speed communications for far more video content—it promotes 5G as a big opening to a new "business use of radio." In that market, the MNOs are fighting for a certain amount of dominance. The

loss of consumer control via the OTT channel is the thing that matters most. This is serious because 5G has the potential to give online web services platforms more significant market influence by transferring consumer "ownership." These platform companies might also be in charge of the markets for mobile phones and/or device operating systems and browsers, which would give them more leverage if 5G was to roll out.

According to Forge and Vu (2020), in countries such as China, the MNOs have already agreed to pool the 5G network construction costs to reduce financial risk by sharing a common 5G infrastructure to cut capex (capital expenditure) significantly. Despite MNOs' reluctance—which is frequently incited by the government and equipment suppliers—over 296 mobile operators in over 100 countries had invested in 5G as of late 2019. Of this amount, 154 operators across 66 nations have committed large sums of money and started 5G technology field trials (GSA, 2019).

According to Mitomo (2020), the focus of telecommunication policies in Japan is OTT since it is the consumer preference due to the streaming services. However, 5G New Radio is seen as a critical enabler for improved data speeds, capacity and low latency, which are essentials for high-quality OTT services. Mitomo emphasised that 5G infrastructure enhances consumer experiences by enabling uninterrupted and mobile access to streaming platforms, impacting consumer choices and behaviour in media consumption. In other words, the Japanese society prefers OTT over other media preferences; however, 5G is used to support OTT.

The Ministry of Internal Affairs and Communications (MIC) has been a critical player in the deployment of ICT. Japan's ICT policy framework, which integrates regulation and promotion, sets it apart from many other countries with independent regulators. However, due to the limited availability of information in English, understanding Japan's policies has been challenging.

The Telecommunications Business Act, the Radio Act, and the Wired Telecommunications Act are the primary legislation governing the Japanese telecommunications sector. The Telecommunications Business Act outlines requirements for universal service, carrier connection standards, fees and services, confidentiality of communications, as well as entry and exit from the telecom industry. Radio station licenses, radio equipment, technical rules, radio operators, and conformance certification of specific radio equipment are all outlined in the Radio Act. The Wired Telecommunications Act outlines the requirements and usage of wired telecommunications equipment. The regulatory body for the telecommunications sector is the Ministry of Internal Affairs and Communications.

Furthermore, the increased network agility, connection to billions of smart devices, and the widespread adoption of machine learning models and open-source software in the 5G and OTT ecosystems have introduced unique security threats and privacy concerns that require careful consideration (Mitra & Marina, 2021).

Blind and Niebel (2022) explored the complexities surrounding the implementation of 5G in the EU, highlighting the challenges, or "failures," in the rollout process and the policy measures taken to address them. However, in 2023, Cave conducted a case study to explore the essential components of the EU's digitalisation strategy, mainly through the lens of universal gigabit connectivity and technological transformation. Blind and Niebel (2022) highlighted the key points that led to the failures in the complex 5G ecosystem.

According to them, the 5G ecosystem in Europe is multifaceted, with various stakeholders, including government regulators, service providers, equipment manufacturers, and civil infrastructure providers. These diverse interests make it difficult to assess and implement effective policy measures.

Blind and Niebel (2022) also identified multiple types of innovation failures, system and transformational systems failures, as the most significant in the 5G rollout. These failures relate to the complexity of coordinating various stakeholders and ensuring that 5G infrastructure is adequately financed and developed. Innovation policies have been implemented to tackle these failures, promoting investment in 5G infrastructure, encouraging competition, and supporting technological advancements like Open RAN. However, market failures due to the inadequate consumer demand for 5G are less addressed by these policies.

Furthermore, Blind and Niebel (2022) highlighted that the 5G rollout faced challenges, such as the lack of "killer applications" to attract consumer interest, competition from other technologies like Wi-Fi, and spectrum allocation and coverage issues. These factors complicate the commercial success of 5G in Europe. In other words, the article sheds light on the hurdles in deploying 5G in the EU. It discusses the innovation policies created to address these challenges, mainly focusing on system and transformational failures.

In 2023, Cave studied 5G New Radio (5GNR) in the EU. Cave (2023) stated that 5G is a crucial technology to achieve the EU's targets of providing gigabit connectivity and universal 5G coverage by 2030. Cave also highlighted the importance of 5GNR in supporting various sectors (public and private), enabling the digitalisation of manufacturing, healthcare, and other industries. In discussing the potential challenges of deploying 5G in rural and remote areas, Cave (2023) also noted that network sharing and competition policies must balance the needs for investment and the goals of universal coverage. Regulators may have to ease competitive pressures on incumbents to stimulate investment in 5G infrastructure.

At the same time, Cave (2023) discovered the potential of OTT providers, such as Alphabet and Meta, to contribute financially to the infrastructure supporting the significant internet traffic they generate. No doubt, there is a debate around whether OTT companies should help fund the 5G networks and gigabit connectivity infrastructure, given the massive data load they place on the system. While there is a proposition for OTTs to pay a "fair share" toward network costs, practical challenges exist in regulating and implementing such a system. The discussion reflects ongoing debates in the EU about whether and how OTT platforms should significantly contribute to network infrastructure financing, as they benefit from the enhanced connectivity that 5G provides. This article examined 5GNR as a cornerstone for achieving the EU's digitalisation objectives by exploring the evolving role of OTT platforms in contributing to the infrastructure that supports their services.

Jang and Kim (2024) highlighted the importance of addressing user concerns and enhancing trust to facilitate the adoption of D2D caching networks in a 5G environment. For OTT service providers, understanding and mitigating the factors that lead to user resistance is crucial for leveraging 5G's full potential to improve content delivery and user engagement.

Comparative insights from Europe, Japan, South Korea, the United States, and the United Kingdom provide a broader context for Malaysia's progress. European nations such as Germany and Finland, have piloted 5G Broadcast testbeds through national broadcasters. Those projects integrate 5G Broadcast as a complementary tool to DAB+, allowing free-to-air transmission of live radio and television directly to mobile devices without data consumption. Japan exemplifies the coexistence of 5G and OTT-driven convergence. This dual strategy demonstrates how national regulation and network innovation can harmonise media convergence.

South Korea's high 5G penetration has enabled broadcasters such as KBS and SBS to integrate live radio and on-demand streaming through 5G-enabled OTT platforms. South Korea's success underscores the commercial and cultural benefits of rapid 5G-OTT integration in broadcasting. In the United States, OTT platforms such as iHeartRadio and TuneIn operate as hybrid radio aggregators powered by 5G connectivity. These platforms offer personalized radio streams, podcasts, and AI-curated playlists, redefining audience interactivity. While in the United Kingdom, BBC's BBC Sounds represents the fusion of OTT and conventional broadcasting models which is similar to Malaysia.

As explained above, Malaysia's trajectory in digital radio adoption remains exploratory. While 5G infrastructure is expanding under the national Digital Economy Blueprint, the radio sector lacks a unified digital roadmap. Traditional FM broadcasting remains dominant, and policy efforts have primarily focused on television digitalization. The absence of large-scale 5G Broadcast trials and limited OTT-radio integration reveals a developmental gap relative to the European Union and East Asia.

However, Malaysia's growing OTT ecosystem and mobile penetration suggest readiness for a hybrid adoption model which would be able to leverage 5G for mobile distribution and OTT for interactive, personalized radio experiences. Lessons from Japan's regulatory coherence and Europe's testbed innovation could guide Malaysia in crafting a flexible and sustainable framework for radio digitization.

Global experiences demonstrate that 5G and OTT technologies are not merely infrastructure or content tools but strategic enablers of convergence that are reshaping how radio content is produced, distributed, and monetised. For Malaysia, these insights provide both a roadmap and a caution, whereas the country must balance technological readiness with policy clarity, ensuring that the transition to digital radio aligns with broader digital transformation goals.

To provide a quantitative overview of the synthesis process, all 15 selected studies were systematically coded using a thematic matrix. The frequency analysis results are summarised in Table 5.

Table 5. Frequency analysis

Thematic Dimension	Subcategory	Frequency (n=15)	Percentage (%)
Technological focus	5G NR (infrastructure, latency, RAN slicing)	10	67
	OTT (platform, distribution, monetisation)	8	53
Research orientation	Technical/ engineering aspects	6	40
	Policy and regulatory frameworks	5	33
	User behaviour and audience preferences	4	27

Table 5. (con't)

Thematic Dimension	Subcategory	Frequency (n=15)	Percentage (%)
Geographical scope	Europe (EU, UK, Finland Germany)	5	33
	East Asia (Japan, South Korea, China)	4	27
	Nort America (USA, Canada)	2	13
	Southeast Asia (Malaysia, Thailand, Vietnam, Myanmar)	4	27
Identified opportunities	Improved connectivity and low latency	9	60
	New business and content models	8	53
	Audience personalisation and interactivity	6	40
Identified challenges	Regulatory and policy alignment	7	47
	Financial and infrastructure investment	6	40
	Market readiness and digital literacy	5	33

The meta-synthesis statistics reinforce the qualitative findings by demonstrating clear thematic patterns across the literature. The frequency of technological and regulatory discussion indicates that adoption depends not only on network readiness but also on institutional and market factors. Quantitatively, regulatory alignment (47%) and investment barriers (40%) emerged as recurring challenges, while innovation opportunities (60%) and new business models (53%) were dominant positive trends. This combination of qualitative interpretation and statistical overview strengthens how 5G and OTT technologies can transform radio broadcasting.

Theoretical framework – relevant perspectives

In the realm of technological advancement, understanding how innovations spread among individuals, institutions, and communities is crucial for effective adoption and utilisation. Understanding this pattern will help policymakers and the government decide on technology adoption. Everett Rogers's innovation diffusion theory provides a comprehensive framework for comprehending the process through which new ideas, products, or technologies are adopted and disseminated within a society or social system (Ibrahim, 2020; Rogers, 2003) —we believe this theory can support this research.

The diffusion of innovations theory posits that adopting a new idea or technology—in this research context, 5G and OTT—follows a predictable pattern characterised by the adoption curve. However, it is often driven by the propensity for risk-taking and experimentation. The theory also emphasises the role of communication channels and social networks in disseminating innovations. Specific channels, such as interpersonal communication and mass media, serve as conduits for spreading information about new technologies. Moreover, individuals, institutions and communities are more likely to adopt an innovation when they perceive it as compatible with their values, needs, and experiences. Additionally, the relative advantage, complexity, trialability, and observability of 5G and OTT influence their adoption rate.

In the technology domain, the diffusion of innovations theory offers valuable insights into the adoption and proliferation of technological advancements—for instance, the adoption of terrestrial digital radio among industrial players. Upon their introduction, innovators were the first to embrace Digital Audio Broadcasting Plus (DAB+) or Digital

Radio Mondiale (DRM), drawn to their novel features and functionalities over analogue technologies (Berry, 2014; Halbert, 2015; Hallett, 2021; Ibrahim & Wahab, 2021; Ismandianto et al., 2022; Jedrzejewski, 2014; Llorens Maluquer et al., 2014; Noone, 2013; Oziewicz, 2022; Federal Ministry of Transport and Digital Infrastructure, 2017). Early adopters, including tech enthusiasts and opinion leaders, followed suit, driving initial market penetration.

As technology was promoted and its benefits became evident, it gained acceptance among the early and late majority (Ala-Fossi, 2013; Jauert et al., 2017). Factors such as compatibility with existing communication habits, perceived utility, and observable benefits contributed to its widespread adoption (Biernacka-Ligieza, 2010). Moreover, the influence of social networks and peer recommendations significantly accelerated the diffusion process (Ibrahim, 2020). The central question is, how about 5G and OTT since the rollout of digital terrestrial radio is sluggish in many countries?

Considering or reconsidering the use of any technologies to substitute for frequency modulation (FM) was crucial after Ibrahim (2020) discovered the saturation of FM in Malaysia and its profound implications on the radio ecosystem. Over the years, considerable innovations have been made to replace frequency modulation, such as digital audio broadcasting (DAB+), 5G, and OTT. However, a vital issue for broadcasters in moving to DAB+ is that there is no clear pilot test result, no digital radio action plan, and a reluctance to change among FTA broadcasters. Since there is no structured technology roadmap for radio broadcast technology, the Malaysian radio industry is a laggard in many ways compared to Vietnam, Myanmar, and Thailand. Thus, we must conduct a meta-analysis to examine the challenges and opportunities of 5G or OTT.

From our reading, we noticed that from 2019 to 2024, there are 17,700 articles about 5G & OTT through Google Scholar. At the same time, AI Dimensions discovered 12,409 articles.

We think understanding the principles of diffusion theory can inform strategies for promoting the adoption of terrestrial digital radio broadcasting adoption or 5G or OTT. For technology developers and innovators, identifying early adopters and leveraging their influence can facilitate the initial uptake of innovations. Moreover, emphasising technologies' relative advantages and compatibility with users' needs can enhance their appeal and accelerate adoption. Furthermore, recognising the importance of communication channels and social networks enables stakeholders to disseminate information effectively and reach target audiences. By fostering a conducive environment for trialability and providing opportunities for users to experience the benefits firsthand, organisations can encourage adoption among hesitant individuals and drive widespread diffusion of technological innovations.

The theory of diffusion of innovations provides a robust framework for understanding the dynamics of technology adoption and dissemination within societies. By elucidating the roles of different adopter categories, communication channels, and perceived attributes of innovations, the theory offers valuable insights for technology developers, policymakers, and marketers seeking to promote the adoption of new technologies. Applying the principles of diffusion theory can facilitate the seamless integration of innovations into everyday life, ultimately fostering technological progress and societal advancement. This potential for societal advancement should inspire us to embrace and promote technological innovations.

Building on Roger's diffusion of innovation theory and the international experiences analyses in this study, several practical strategies can be proposed to facilitate the adoption of 5G and OTT technologies in Malaysia's radio industry. First, Malaysia requires a clear National Digital Radio Roadmap that integrates 5G and OTT into its broader digital economy and media policies. Regulatory agencies such as the Malaysian Communications and Multimedia Commission (MCMC) and the Ministry of Communications should collaborate with the industry to establish spectrum allocation guidelines for 5G Broadcast use in radio and multimedia and simplify licensing frameworks for OTT-based content delivery. These initiatives would mirror successful policy interventions in Japan and the EU, where regulatory flexibility accelerated early adoption.

Second, to build local capacity and demonstrate feasibility, pilot programs should be initiated through public-private partnerships. Selected broadcasters such as RTM, Astro or UMSfm could conduct 5G Broadcast and OTT integration trials in collaboration with network operators like Celcom Digi, Maxis or Telekom Malaysia. Third, collaboration between industry, academia, and government. Universities, particularly Universiti Malaysia Sabah and other research institutions, can act as living laboratories for innovation. Collaboration, for example, between MCMC, RTM, and private broadcasters can support joint research on 5G-enabled content production, audience analytics and OTT monetisation. Apart from that, curriculum modules and professional training focused on 5G and OTT competencies can also be designed. This triple-helix collaboration aligns with Malaysia's MySTIE 10-10 framework and supports SDG 9 (industry, innovation and infrastructure).

By aligning policy structures, industry experiment and academic collaboration, Malaysia can move from conceptual awareness to actionable adoption of 5G and OTT in broadcasting. The diffusion process can be accelerated if key stakeholders collaborate under a unified strategy that balances innovation, inclusivity and economic sustainability.

CONCLUSION

5G new radio is expected to transform various industries by enabling new applications and services that require real-time data processing and high reliability, such as smart cities, telemedicine, and enhanced mobile broadband experiences. Furthermore, 5G is expected to enhance OTT services by providing faster and more reliable internet connections, enabling higher-quality streaming, and supporting new interactive features. The combination of 5G and OTT could lead to new business models and services, further blurring the lines between the telecom, media, and technology sectors.

However, if Malaysia is serious about opting for 5G NR services, Malaysia has to consider its profound impact on technological, economic, and societal advancements. First, technology is evolving from time to time. Malaysia must ensure it aligns with evolving technological needs and future use cases. Second, 5G NR can be a crucial enabler of economic growth, driving innovation across manufacturing, healthcare and logistics industries. Reconsidering the deployment ensures that policies and infrastructure investment are optimised to unlock the full economic potential of 5G.

We must bear in mind that OTT services disrupt traditional media and telecommunications, providing consumers with flexible and on-demand content. A

thoughtful deployment of 5G can further fuel OTT's growth, creating new business models and revenue streams while increasing market competitiveness.

Finally, the deployment of 5G NR and OTT must be aligned with thoughtful policy and regulatory frameworks that balance competition, investment and innovation. Reconsidering 5G policies ensures that network sharing, spectrum allocation, and infrastructure investments effectively address market and system failures.

While this study has synthesised global insights and identified Malaysia's readiness challenges, several research avenues remain open for further exploration. Future research should empirically test the diffusion-based conceptual framework proposed in this study using mixed-methods or Delphi approaches. Surveys and in-depth interviews with broadcasters, regulators and network providers could help quantify readiness levels and validate key determinants such as cost, infrastructure capacity, and audience acceptance.

In conclusion, the integration of 5G and OTT technologies presents transformative opportunities for Malaysia's broadcasting ecosystem. To realise these benefits, future research must continue bridging technological, regulatory and social dimensions through evidence-based inquiry. Addressing the identified research gaps through empirical, comparative, and policy-driven approaches will ensure that Malaysia's transition to digital radio is technologically feasible, economically sustainable, and socially inclusive.

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