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The Evolution of Mobile Messaging: From SMS to RCS and Beyond

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Abstract

This study examines the evolution of mobile messaging technologies, tracing the progression from short message service to rich communication services and evaluating the potential of RCS to redefine mobile communication. With the integration of features such as multimedia sharing, read receipts, and interactive functionalities, RCS is positioned to bridge traditional SMS capabilities and modern OTT messaging, offering an enhanced, unified platform directly within mobile carrier infrastructure. Employing a systematic literature review guided by PRISMA standards, we analyzed relevant literature from leading databases to identify the technological, business, and social impacts of RCS adoption. Our comparative analysis addresses RCS's strengths and limitations relative to SMS, MMS, and popular OTT platforms, focusing on interoperability, regulatory compliance, and data security as key adoption challenges. Additionally, we investigate RCS's role in advancing business communication through A2P messaging and its potential for conversational commerce, especially when integrated with AI-driven chat-bots and personalized customer engagement tools. Findings reveal that while RCS holds promise for creating a secure, feature-rich messaging ecosystem, overcoming regulatory and technological hurdles is essential for realizing its full potential. This research provides actionable insights for industry stakeholders and highlights strategic pathways for expanding RCS adoption within a rapidly evolving digital landscape.

Keywords: Mobile Messaging SMS, MMS RCS, Mobile Messaging Evolution, Interoperability And Regulatory Compliance, A2p Messaging And Conversational Commerce

1. Introduction

The evolution of cellular messaging encompasses progression over 200 years, systematically building upon preceding technological advancements, and culminating in the diverse communication tools that are integral to contemporary digital communication. Consequently, messaging applications have evolved and proliferated, offering range of features such as textual exchange, multimedia sharing, group chats, and real-time communication, which were not feasible with traditional SMS (Ren, Dong, Liu, Li and Yang, 2012). Today, textual messaging functions as a ubiquitous communication medium, utilized by billions of individuals globally. It remains a critical tool for both personal and professional interactions, underscoring its continued relevance in the digital era. In the United States alone, 81% of the population engages in text messaging, with over 27 trillion texts transmitted annually and approximately 6 billion sent daily (Olia, 2024). Approximately 4.2 billion users engage with the SMS channel, in comparison to around 3.7 billion who utilize email (Yang, 2010).

Initial innovations, includes Samuel Morse's telegraph in 1837 (Morse, 2014) and Teletex service by the German Reichspost in 1933 (Rueggeberg, 1987) that established the foundational protocols for longdistance text communication. Such technological advancements led to the first short message service (SMS) back in 1992, when Neil Papworth transmitted the message "Merry Christmas" to Richard Jarvis, the director of Vodafone (Linge and Sutton, 2014). The instance transformed way of communication by enabling concise, instantaneous exchanges of textual messages between cellular network users. The introduction of person-to-person (P2P) and application-to-person (A2P) SMS showcased the versatility and widespread appeal of text-based communication. The primary limitation of SMS, however, was its 160-character constraint (Taylor and Vincent, 2005). SMS messages were also subject to a queuing system, wherein they must await their turn for transmission to the intended recipient.

Over the following decades, text messaging evolved rapidly in order to meet the growing demand for more interactive and feature-rich solutions. From the first SMS back in 1992 to the introduction of predictive texting by Tegic in 1995 (Silfverberg, MacKenzie and Korhonen, 2000), and the expansion to multimedia through multimedia messaging.

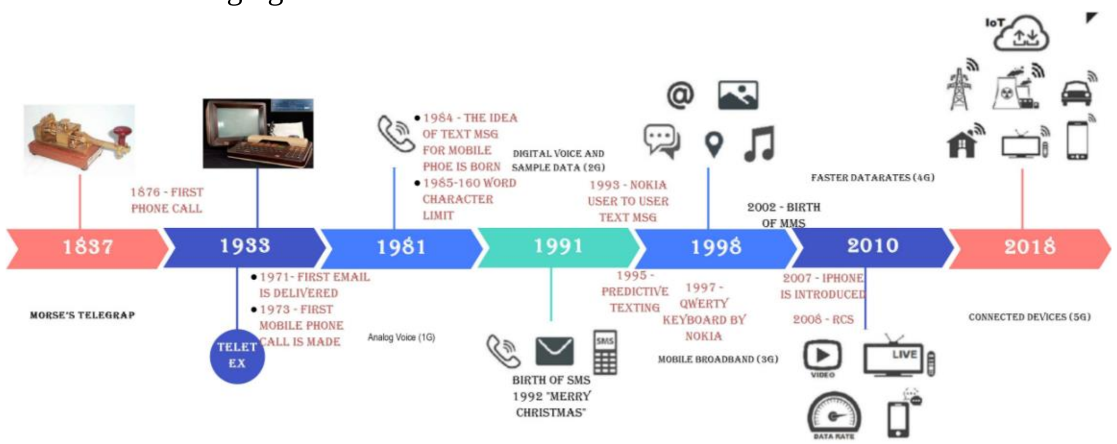

Figure 1: A brief historical evolution of mobile messaging from SMS to RCS

service center (MMSC) developed by 3rd generation partnership project (3GPP) (Sevanto, 1999), each advancement enhanced the user experience and broadened communication possibilities. Particularly with the introduction of MMS, the transmission of pictures, videos, and audio clips became possible, albeit with some data restrictions. MMS version

1.2 permitted up to 300 kilobytes, while version 1.3 allowed up to 600 kilobytes of transmission data (Setyono, Alam and Eswaran, 2014).

With the widespread adoption of smartphones, however, limitations inherent in SMS and MMS protocols, specially the data restrictions, became visible as user requirements evolved towards more sophisticated and interactive messaging experiences. Such experiences necessitated features including, group communication capabilities, message status notifications, and the ability to transmit high-resolution multimedia content. This demand precipitated the emergence of over-the-top (OTT) messaging applications, such as WhatsApp, Facebook Messenger, and iMessage, which offered enhanced functionalities that conventional SMS and MMS were unable to provide (Ogidiaka and Ogwueleka, 2020). In the late 2000s global system for mobile communication association (GSMA) conceptualized rich communication services (RCS) as a standardized protocol. It officially adopted RCS in 2008 and introduced the RCS universal profile in 2016 to standardize RCS features across various mobile networks and devices (TYXHARI, GORISHTI et al., 2014). The aim of RCS was to deliver messaging capabilities that function across various networks (including 4G/5G and Wi-Fi) and devices (such as SIM-based phones and SIM-free tablets or gadgets), enabling users to communicate seamlessly regardless of their network or device (Zhao, Li, Yuan, Zhang and Lu, 2022a). It was designed to enhance the messaging experience within the existing cellular network infrastructure without the need of third party applications, thereby bridging the technological gap between legacy systems and modern communication requirements. Features like real- time typing notifications, read receipts, the ability to send images and videos up to 10 megabytes (with potential for expansion), location sharing were core to RCS.

Recently, Google became a key proponent of RCS, pushing it as a universal platform and working with GSMA to establish it as a global standard. Numerous high-end Android devices released within the past two years already possess RCS capabilities. Also, Google has advocated for broader adoption by offering an RCS client to network providers, thereby enabling RCS messaging functionality on Android devices operating on version 5.0 or later. This enhancement improves compatibility across Android devices; however, implementation is contingent upon network support, which varies by geographical region and telecommunications carrier, thus influencing the overall availability and usage of RCS features. Additionally, Apple has launched RCS on IOS 18 and onward, allowing RCS to function alongside iMessage and expanding messaging capabilities for iPhone users. Major telecoms companies like T-Mobile (first to launch RCS in US), AT&T in U.S. and Vodafone in Europe have implemented RCS, but public awareness remains low. As of 2023, Google reported that RCS has surpassed one billion active monthly users, a figure expected to grow further with Apple's partial adoption in certain regions. With Android holding over 70% of the global mobile OS market, RCS benefits from a vast user base, which contributes to a projected global market value of USD 8.37 billion in 2023, with estimates reaching USD 19.48 billion by 2028 (P and Hallur, 2023; Mobilesquared Ltd, 2024). Currently, RCS services have been launched by 47 operators in 34 countries (P and Hallur, 2023). Fig. 1 shows a brief graphical visualization of historical evolution of mobile messaging.

Table 1 Criteria used for Selecting Articles

Database indexing	**Web of Science or Scopus**
Publisher	MDPI, IEEE, Springer, ACM
Digital library sources	ACM, ScienceDirect, IEEE Xplore, Nature, MDPI, and Google Scholar
Lower- and upper-time limit	1953 to 2023
Paper categories included	Conference proceedings and Journals
Relevance of a potential article to the research topic	Evolution of messaging services for cellular networks
Paper Selection	Excluded from consideration are materials such as newspapers, posters, demonstrations, and extended abstracts

This research paper comprehensively examines the evolution of mobile messaging technologies, from the inception of SMS to the current state of RCS. Our Objective is to provide a thorough comparative analysis of various messaging technologies, emphasizing the advantages of RCS for small businesses and its potential to address longstanding mobile communication challenges. Moreover, by examining the technical, business, and social implications of this shift, we seek to elucidate the potential of RCS to reshape the mobile messaging ecosystem, enhance business communication, and improve user experiences.

Additionally, this study will explore the role of artificial intelligence (AI) specially chat-bots in RCS messaging and its potential to further transform customer engagement and automated services for businesses of all sizes. To be precise we aim to:

1. Conduct analysis on evolution of mobile messaging technologies, from SMS and MMSC to RCS, evaluating the relative merits of each.
2. Analyze RCS in comparison to popular messaging platforms like WhatsApp, focusing on unique features, its potential to reduce SMS-based fraud, and the impact of its implementation across Android and iOS for creating a unified messaging ecosystem.
3. Examine the global impact of RCS on communication and business practices.

The remaining of the paper is organized as sections, where Section 2 discusses methodology, research questions and sources database repositories. Section 3 carries the research on traditional messaging technologies, whereas Section 4 discusses RCS as modern messaging platform. Section 5 carried a detailed discussion on present challenges to the RCS adoption to various business practices. Section 6 and Section 7 consider integration of AI and RCS and challenges and ethical consideration for the RCS respectively. Finally, Section 8 concludes the research work by summarizing and presenting major highlights of the work.

2. Methodology

The study employs systematic literature review (SLR) approach for its methodology for evidence-based analysis (Massaro, Dumay and Guthrie, 2016). Also, research adheres to the PRISMA (preferred reporting items for systematic reviews and meta-analyses) guidelines, ensuring a comprehensive analysis of the literature (Moher, Shamseer, Clarke, Ghersi, Liberati, Petticrew, Shekelle, Stewart and Group, 2015). Fig. 2 presents the research process framework for the survey whereas table 1 contains supplementary standards that were considered.

2.1. Search Process: An extensive literature review was conducted using major scientific databases including telecommunication policy journal. Searches were also performed on repositories like Web of Science (WoS), IEEE Xplore, and Google Scholar. WoS, with over 171 million records (Golbabaei, Yigitcanlar, Paz and Bunker, 2020), is considered the most compre- hensive and authoritative source globally, encompassing other major databases. Moreover, to identify relevant studies, targeted search queries combined logical combinations of keywords such as "mobile messaging," "SMS evolution," "Rich Communication Services," "RCS adoption," "business messaging," "messaging platforms comparison," along with specific technological terms like "A2P messaging," "P2P messaging," "messaging APIs," and names of major industry players such as "Google RCS," "Apple Business Chat," and "WhatsApp Business API." Additionally, we included terms related to emerging trends like "AI in messaging," "chat-bots," and "conversational commerce" to ensure comprehensive coverage of the latest developments in the field.

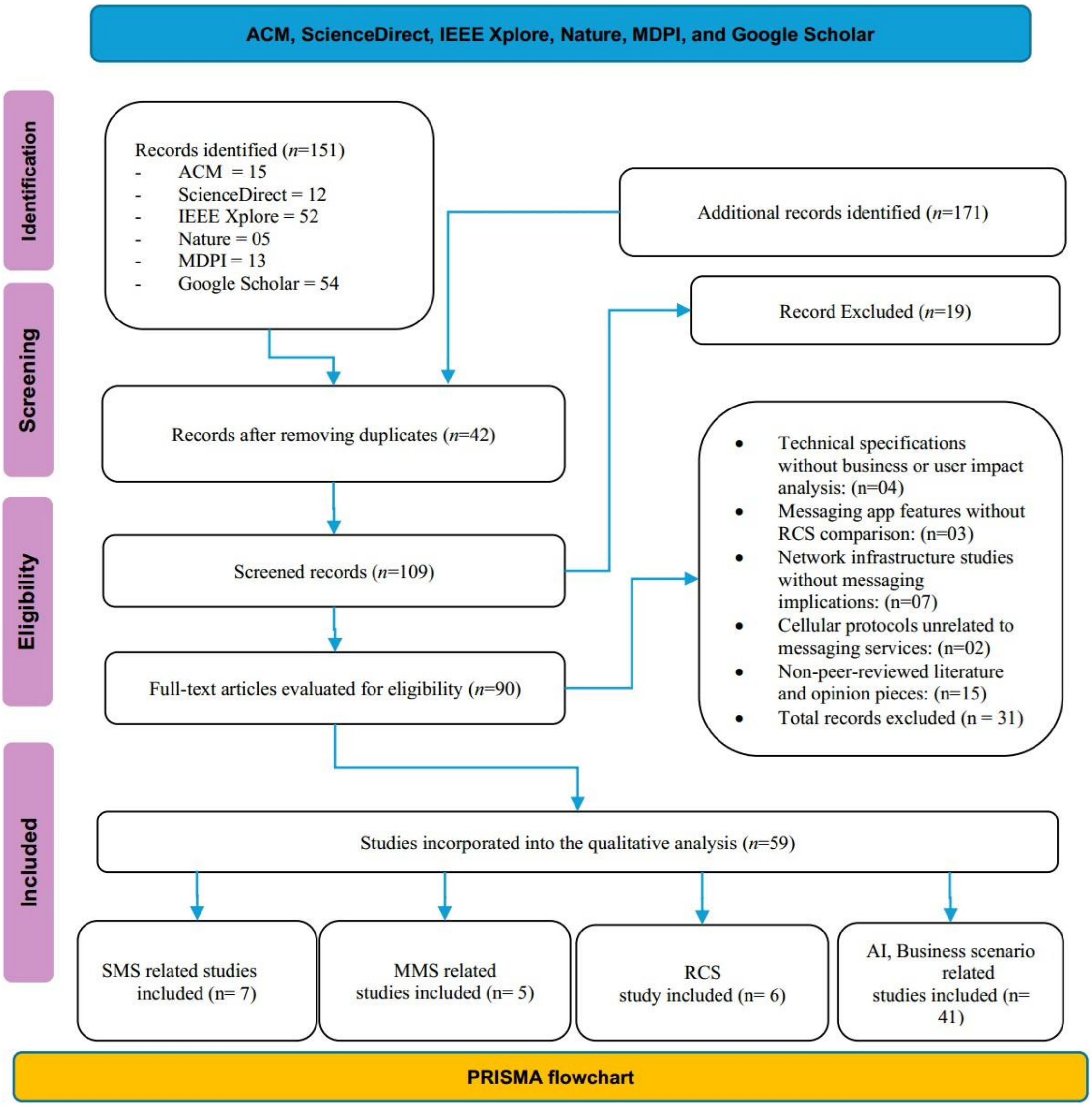

Figure 2: PRISMA flow diagram of study selection

To filter out relevant literature methodology adhered to established guidelines (Petticrew and Roberts, 2008) and entailed two discrete phases: preliminary screening and in-depth appraisal. The initial phase focused on screening titles and abstracts from the search results to accumulate publications potentially apposite to research emphasis on messaging evolution technologies. Subsequently, the retrieved full-text articles were thoroughly reviewed for closely mapping to the study objectives and inclusion criteria. Inclusion criteria for papers included peer-reviewed papers published between 1990-2024. Whereas exclusion criteria was non-peer-reviewed literature outside date range, non-academic or non-English publications. The preliminary searches yielded an initial corpus of 151 articles. After administering the exclusions, eliminating duplicates, and screening titles and abstracts, 90 full-text articles were selected for an in-depth appraisal. To maintain emphasis on the current advances, the results were further focused on 59 articles published between 2000-2024.

3.Traditional Messaging Technologies: SMS and MMS

Over the past two decades, text messaging has undergone a swift transformation as a means of communication. This swift transformation is primarily driven by technological progress, evolving user preferences, and societal changes and marked by notable shifts in usage patterns and adoption behaviors (Peslak and Hunsinger, 2018). The main catalysts are broad uptake of smartphones, enhancements in mobile network infrastructure, and a growing inclination towards quick, asynchronous communication, especially among younger users (Peslak, Ceccucci and Sendall, 2010). Research suggests that since the inception of first SMS back in 1992 till 2009 adoption of text messaging was driven by perceived usefulness, mental effort, user control, and visibility (Yoon, Jeong and Rolland, 2015). By 2016, usefulness had become the primary factor affecting frequency, while ease of use and productivity gains substantially impacted time spent texting (Peslak and Hunsinger, 2018). This transition reflects the technology's evolution from a novel concept to an indispensable, mature communication tool. The surge in text message volume from billions to trillions annually further emphasizes the swift evolution and pervasiveness of this technology in modern-day communication (Hall, Cole-Lewis and Bernhardt, 2015). A comprehensive analysis of historical data showed that SMS messages had the largest sample size (106,359), followed by Twitter (13,616), Email (6,538), and Facebook (4,539) (Altamimi, Shaman, Alruban et al., 2020). These results suggest that traditional text messaging remains the dominant form of text-based communication, despite the rise of social media platforms. This section briefly explores the evolution of mobile messaging - SMS and MMS.

3.1. Classical Modes of Messaging

3.1.1. Short Message Service (SMS): SMS technology emerged in the 1980s as part of the GSM standards, with Friedhelm Hillebrand and Bernard Ghillebaert playing key roles in its development (Trosby, Holley and Harris, 2010). The first SMS was sent on December 3, 1992, when Neil Papworth used a computer to send "Merry Christmas" to a colleague's mobile device (Linge and Sutton, 2014). Although, initially intended for network operators to send alerts to users (Taylor and Vincent, 2005), SMS quickly became popular for personal communication as mobile phones became more widespread. In today's mobile data service market, SMS generates approximately 60% of the revenue (Hung, Lin and Luo, 2012). While, 90% of SMS are read within three minutes (Mobilesquared Ltd, 2024). This demonstrates that despite the availability of broadband technology, the narrow-band SMS remains the most widely used wireless data service. Within the SMS domain, two primary types of messaging are prevalent: peer-to-peer (P2P) and application-to-person (A2P), the latter facilitating business-to-consumer (B2C) communications. It has also applications beyond personal messaging, including marketing, commercial notifications and healthcare (Friedrich, Gröne, Hölbling and Peterson, 2009; Downer, Meara, Costa and Sethuraman, 2006)

SMS communicates via cellular networks utilizing a variety of protocols, depending on the network generation. Traditional 2G and 3G networks use the short message peer-to-peer (SMPP) protocol, which runs on top of the signaling system 7 (SS7) network (Peersman, Cvetkovic, Griffiths and Spear, 2000). SMS messages are sent over specialized control channels that are independent from speech channels, enabling for efficient delivery without the need for a dedicated data connection (Trosby et al., 2010). However, SMS can now be transmitted via IP-based protocols in 4G LTE and 5G networks (Poikselkä and Mayer, 2013). SMS is efficient because it uses short data packets that may be easily conveyed alongside other signaling information, rather than during specified idle periods (Le Bodic, 2005). It is also characterized by its simplicity, low bandwidth requirements, and cost-effectiveness, making it a widely adopted communication tool (Leu, 2010).

3.1.2.Multimedia Messaging Service (MMS): MMS is a logical advancement from SMS. It integrates mobility and comprehensiveness with enhanced content, and is regarded as a potent application in wireless application protocol (WAP), general packet radio service (GPRS), and third-generation (3G) wireless communication (Mostafa, 2002). Both the 3GPP and WAP forum have developed MMS (Mostafa, 2002) to not only address the known constraints of existing messaging platforms but also to support richer communication capabilities. MMS supports various media types including joint photographic experts group (JPEG), graphics interchange format (GIF), and portable network graphics (PNG) for images, adaptive multi-rate (AMR) and MPEG-1 audio layer III (MP3) for audio, and third generation partnership project (3GP) for video (Le Bodic, 2005).

MMS requires packet-switched data transmission, unlike SMS, which uses circuit-switched networks, thus necessi- tating GPRS, 3G, or more advanced networks (Ahonen, 2004). Moreover, it also utilizes the synchronized multimedia integration language (SMIL) to synchronize multiple media elements within a single message (Coulombe and Grassel, 2004). Although the theoretical maximum size for an MMS message is much larger than SMS (up to 300 KB standardized, with some networks supporting up to 1 MB), the practical limit is often determined by device capabilities and network constraints (Ahonen, 2004).

3.2.Technical Deficiencies of SMS and MMS

Both SMS and MMS infrastructure can struggle with high-volume traffic, leading to delays/failures during peak times or emergencies (Reaves, Bowers, Scaife, Bates, Bhartiya, Traynor and Butler, 2017). SMS is also inherently limited to 160 7-bit character that can impede comprehensive communication (Le Bodic, 2005). Moreover, it lacks built-in encryption therefore, it is it vulnerable to interception, necessitating the development of encryption algorithms to secure sensitive data (El Bakry, Taki_el_deen and El, 2014).

While larger file sizes associated with multimedia content can result in increased data costs for users in MMS (Chang and Pan, 2011). MMS also faces device compatibility challenges due to varying handset capabilities, necessitating media transformation to adapt content for different devices (Vatsa and Kumar, 2005). Adding to that, lack of a mandated maximum message size can cause delays and losses if the network is not properly designed (Ghaderi and Keshav, 2005), requiring optimal storage management and careful network planning. Interoperability with other messaging systems, such as IMS instant messaging, demands complex gateway architectures and translation mechanisms to ensure seamless integration (Gomez, Megias, Bueno and Brocal, 2005).

4. Modern Messaging Technologies: Rich Communication Services (RCS)

RCS is a next-generation messaging service designed to supersede legacy messaging systems as well as compete with prevalent IP-based services such as Skype and WhatsApp (Carriedo, Beltrán and Recio, 2014). It is an initiative administered by the GSMA, uniting key stakeholders in the telecommunications industry to establish an interoper- able, convergent, and access-technology-independent rich communication experience for end-users (Noldus, Olsson, Fikouras, Ryde, Stille and Mulligan, 2011). RCS is also included in the standard for the ongoing transition to 5G. The GSMA's NG.114 specification defines RCS as a mandatory service for 5G terminals, enhancing traditional SMS messaging by offering features like group chats, file sharing, and read receipts (GSMA, 2020). The core functionalities of RCS encompass enhanced presence, augmented call capabilities through image and video sharing, enhanced messaging, file transfer, and chat facilities (Henry, Liu and Pasquereau, 2009; Noldus et al., 2011). A primary advantage of RCS is its native support on mobile devices, especially Android, where it is integrated into the default messaging app. This integration allows users to access RCS features without installing an additional application. RCS also provides a network address book (NAB) and supports both mobile and PC/broadband clients (Noldus et al., 2011). These features are constructed on IP multimedia subsystem (IMS) technology, which furnishes an all-IP core network enabling convergence across multimedia applications (Sayyad, Ansari, Burli, Shah and Khatanhar, 2011). The table 2 provides a comparative analysis of SMS, MMS, and RCS features, highlighting key differences in aspects such as network generation, connectivity, character limits, media support, file size, and security. It underscores the evolution from basic text messaging services (SMS and MMS) to the richer, more interactive, and secure features offered by RCS, illustrating the technological advancements in mobile communication. Fig. 3 shows brief development history of the RCS.

4.1. Comparative Analysis of RCS and Popular Messaging Platforms

Despite the standardization efforts of RCS, alternative messaging platforms such as WhatsApp (with over 2 billion users), Telegram (400 million users), and Discord (250 million users) have garnered significant global user bases (Hoseini, Melo, Júnior, Benevenuto, Chandrasekaran, Feldmann and Zannettou, 2020). A primary factor contributing to this disparity is that, unlike WhatsApp, which operates independently of mobile carriers, RCS is inherently tied to the infrastructure of mobile carriers. While the integration with carrier systems allows for features like enhanced phone- books and enriched calls (Henry et al., 2009), the tight coupling also presents challenges and barriers to widespread adoption when compared to over-the-top (OTT) messaging services. Also, implementation of RCS requires significant investment in IMS infrastructure, which can be a barrier for some carriers (Qiao, Xue, Chen and Fensel, 2015) A study in the Netherlands, France, and Spain found users were most interested in presence features but showed less appreciation for device switching, media sharing, file sharing, and group communication services (Nikou, Bouwman and de Reuver, 2012). However, reliability, security, and interoperability were consistently valued as essential requirements across all services (Nikou et al., 2012).

4.2. RCS Ecosystem and Market Penetration: Android and iOS

Though the acceptance of RCS across different countries and platforms has witnessed some progress, universal adoption has proven to be problematic thus far. Two major operating systems (OS), iOS from Apple and Android from Google - both combined account for nearly 90% of the mobile market share (Latif, Nawi, Nasir and Herdiana, 2023) - have taken different approaches. While Android is proactive towards integrating RCS into its ecosystem, with Google playing a pivotal role. RCS has been integrated to native Android Messages app, which utilizes the Jibe RCS cloud platform to deliver enhanced messaging functionalities (Cruz and Svanborg, 2021). This implementation follows

Table 2 Comparison of SMS, MMS, and RCS features

Feature	**SMS (Short Message Service)**	**MMS (Multimedia Messaging Service)**	**RCS (Rich Communication Services)**
Generation	2G (Second Generation)	2.5G (GPRS	4G (Fourth Generation)
Connectivity	Cellular network	Cellular network	Requires (WiFi/LTE) Data connection

Character Limit	160 characters	Up to 1,600 characters	No strict limit
Media Support	Text Only	Images, videos, audio, and longer text	High-quality images, videos, audio, GIFs
File Size Limit	3.5 KB	Typically up to 300 KB	Up to 10 MB
Delivery Confirmation	Basic delivery notifications	Limited delivery confirmation	Read receipts and typing indicators
Group Messaging	No	Limited group messaging	Yes
Security Features	None	None	Transport Layer Security encryption
Integration Capabilities	Limited	Limited	Transport Layer Security encryption
User Experience	Basic text messaging	Enhanced with multi- media	Interactive features (e.g., rich cards)
Interoperability	Universal across carriers	Limited due to carrier dependencies	Open standard; interoperable across devices

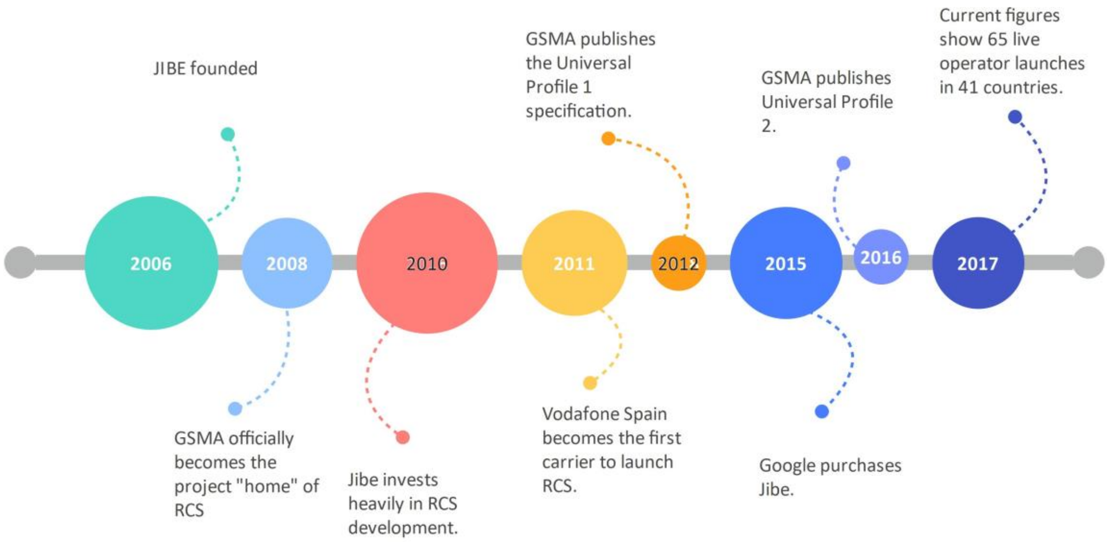

Figure 3: RCS timeline

the GSMA's Universal Profile standard, ensuring interoperability. Key features include fallback to SMS when RCS is unavailable, end-to-end encryption for one-on-one chats using the signal protocol, and support for RCS business messaging. Google's approach also allows for interconnection with other RCS hubs and provides APIs for developers to incorporate RCS features into their own apps. This integration significantly enhances messaging capabilities on Android devices, offering a more feature-rich alternative to traditional SMS.

Apple's iOS on the other hand, has been slower in adopting RCS, maintaining its proprietary iMessage system for communication between Apple devices. However, in November 2023, Apple declared at worldwide developers conference (WWDC) 2024, to support RCS Universal Profile on iOS 18 devices, with implementation expected in late 2024 (MacRumors Staff, 2024; Apple, Inc., 2024). This Apple's decision may have been influenced by regulatory pressures from the EU's digital markets act, which mandates interoperability among messaging services (Sinch, 2023). RCS functionality will operate alongside iMessage, with messages presented in green bubbles to differentiate them from iMessage's blue bubbles. The implementation is anticipated to facilitate enhanced resolution media sharing, read receipts, typing indicators, voice conversations, Wi-Fi messaging, group chats accommodating up to 100 members, and file sharing. Despite this advancement, some limitations remain. Initial implementations of RCS on iOS will focus on person-to-person messaging (P2P). Moreover, concerns about security and encryption persist since RCS does not inherently provide end-to-end encryption like iMessage does.

4.2.1. RCS Adoption

Adoption rates of Rich Communication Services create marked differences between P2P and A2P messaging, mainly based on device type and geographic location. United States is predominantly iPhones in the market(Van De Vliert, 2021); hence, RCS adoption is lower compared with other regions where Androids have better penetration. That difference is quite large since RCS currently works only on Android phones. An estimated 10% of U.S. users could utilize RCS for P2P messaging, while only 2% could for A2P (Mobilesquared Ltd, 2024). While rates are always higher where P2P is applied mainly in consumer-to-consumer communication, the main concern for businesses using RCS to connect with their customers is A2P rates. In 2019, P2P-enabled RCS devices in the U.S. rose to 21%, while A2P reached around 16%, showing gradual growth in adoption. Over time, the gap between P2P and A2P rates does converge.

4.3. Security Challenges with the RCS Ecosystem

While the messages are encrypted in transit to prevent interception (Rastogi and Hendler, 2017), RCS does not offer proper end-to-end encryption—as both WhatsApp and Telegram do—since the decryption keys remain available to wireless carriers or other intermediaries who handle the data, even if end-users cannot access the messages. This means that while RCS leaves communications open to interception at different stages of transmission, WhatsApp's E2EE prevents even the service provider from accessing message content. That is a critical distinction for privacy advocates who prefer messaging systems that do not permit any intermediary to decrypt messages. In practice, encryption in RCS serves little purpose other than safely transmitting sensitive business information, such as banking details or two-factor authentication codes, but true user privacy is not part of the equation. Though, some RCS applications, like Google Messages, offer end-to-end encryption (E2EE) optionally (Alatawi and Saxena, 2023). This is thus dependent on the actual implementation of RCS, including two parties that must use compatible iterations of the app with RCS enabled. What this means is that only the parties that are communicating could get their messages because it is encrypted.
Table 3 compares some popular messaging and communications apps on the E2EE feature set. In general, E2EE provides two main operating modes: "opportunistic by default" allows encryption automatically to turn on, while "opportunistic via opt-in" needs users explicitly to switch it on. Features are compared in regards to one-to-one—that would be direct communication between two users—and to group scenarios, possibly shaped with chat, audio, and video capability. One critical security observation is that all apps are vulnerable to a MitM attack, in which an active attacker might be able

to intercept the communications. As a mitigation of this, most applications offer the possibility of availability of the authentication ceremony to switch into E2EE authenticated mode for more security by means of user-side verification. The comparison shows that though encryption of chat is available on nearly all platforms, encryption of video and audio calls is inconsistent across different platforms. Other services, such as Apple's FaceTime and Messages, have a number of limitations that are listed as N/A, and still, others—a service like Telegram—provides limited encryption of groups. Google Meet is an outlier in supporting encryption of calls but not chat. Other services, including Signal, WhatsApp and Wire, support full E2EE across all their features. Applications vary widely in terms of completeness regarding how much E2EE they implement. Indeed, there are quite a few applications that are very insecure compared to the rest.

5. Impact and Challenges to RCS Adoption in Business Practices

Traditional business communication channels like SMS, MMS, call centers, and email face challenges despite widespread customer usage. Data suggests 85% of mobile device time is spent on just 5 apps, reducing new app downloads (Li, Xia, Wang, Tu, Tarkoma, Han and Hui, 2022). Call centers incur high costs, while email suffers from low response rates and spam issues. Consequently, users have shifted towards OTT messaging apps with enhanced features and no costs. Yet, this shift has impacted traditional operators, as voice and text messaging increasingly

Table 3: Comparison of E2EE characteristics in Various Applications

Application	E2EE Mode	E2EE Features in One-on-One			E2EE Features in Group			Vulnerable to Active MitM Attack	Switch to Authenticated E2EE Mode
		During Chat	During Audio Call	During Video Call	During Chat	During Audio Call	During Video Call		
Element	Opportunistic by default	✓	✓	✓	✓	✓	✓	Yes	Yes, requires optional user authentication
Facebook (Messenger)	Opportunistic by default	✓	✓	✓	✓	✓	✓	Yes	Yes, requires optional user authentication
Face-Time	by default Opportunis	✓	✓	N/A	✓	✓	N/A	Yes	No

	tic								
GoogleMeet	by default Opportunistic		✓	✓		✓	✓	Yes	No
KakaoTalk	Opportunistic through opt-in	✓	✓	✓	✓	✓	✓	Yes	Yes, requires optional user authentication
LINE	Opportunistic via opt-in	✓	✓	✓	✓	✓	✓	Yes	Yes, requires optional user authentication
Linphone	Opportunistic via opt-in	✓	✗	✗	✓	✗	✗	Yes	Yes, requires optional user authentication
Messages by Apple	Opportunistic by default via iMessage	✓	N/A	N/A	✓	N/A	N/A	Yes	No
Messages by Google	Opportunistic by default in RCS	✓	N/A	N/A	✓	N/A	N/A	Yes	Yes, requires optional user authentication
Signal	Opportunistic by default	✓	✓	✓	✓	✓	✓	Yes	Yes, requires optional user authentication
Silent Phone	Opportunistic by default	✓	✓	✓	✓	✓	✓	Yes	Yes, requires optional user authenticati

									on
Skype	Opportunistic via default	✓	✓	✗	✓	✓	✗	Yes	Yes, requires optional user authentication
Telegram	Opportunistic via default	✓	✗	✗	✗	✗	✗	Yes	Yes, requires optional user authentication
Threema	Opportunistic by default	✓	✓	✓	✓	✓	✓	Yes	Yes, requires optional user authentication
Viber	Opportunistic by default	✓	✓	✓	✓	✓	✓	Yes	Yes, requires optional user authentication
WhatsApp	Opportunistic by default	✓	✓	✓	✓	✓	✓	Yes	Yes, requires optional user authentication
Wickr	Opportunistic by default	✓	✓	✓	✓	✓	✓	Yes	Yes, requires optional user authentication
Wire	Opportunistic by default	✓	✓	✓	✓	✓	✓	Yes	Yes, requires optional user authentication

Zoom	Opportunistic by default	✓	✓	✓	✓	✓	✓	Yes	Yes, requires optional user authentication

migrate to these OTT platforms. In response to these challenges, mobile operators, in collaboration with the GSMA,

have developed a new communication standard: RCS business messaging. RCS introduces a two-layer messaging structure encompassing P2P and A2P capabilities. While P2P RCS has been available for several years—branded as "Advanced Messaging" by t-mobile and AT&T—the A2P application layer is a novel addition. This advancement aims to provide a richer, more integrated messaging experience to address the evolving needs of both consumers and businesses. With Android devices adopting TLS 1.3 encryption protocols, reaching some 90 million units—or 30% of all RCS-enabled devices in the U.S. market—RCS is in a strong position to expand the possibilities of mobile marketing and business-to-consumer (B2C) interaction beyond traditional SMS and MMS services (NativeMsg, 2024). RCS's interactive messaging capabilities, powered by JSON-based templates, enable secure, two-way communication via RESTful APIs, incorporating sender authentication and brand elements to align with modern consumer expectations. This architectural approach facilitates conversational e-commerce through standardized endpoints, supporting features like typing indicators, read receipts, and chat-bot integration through natural language processing (NLP) frameworks. The protocol implements webhook-based real-time event notifications, enabling immediate response handling and dynamic content updates. This technical infrastructure significantly reduces latency in customer interactions while maintaining session persistence through sophisticated connection management. Due to these features RCS is an ideal way out for many businesses. Statistics reveal a 40% increase in RCS business messaging in 2023, showing faster growth than any other messaging platform (Mobilesquared Ltd, 2024). Companies that have adopted RCS are reporting up to a tenfold increase in click-through rates and significant revenue growth, highlighting its effectiveness in enhancing the consumer conversion rates(NativeMsg, 2024).

RCS also provides for much more advanced analytics. The different metrics of engagement monitoring message open, button clicks, session duration, and granular engagement with carousels or links fall under (Zhao, Li, Yuan, Zhang and Lu, 2022b). This gives a view of customer behavior and preference on radically different scales and with added value for campaign optimization and personalization of future interactions. The data-driven capabilities also offer the power of real-time decision-making, where the business dynamically reads the user engagement patterns and responses and adapts its strategy accordingly.

However, there are some challenges too with regard to the widespread adoption of RCS into business practices. A key challenge for RCS services is the lack of standardized pricing, as varying rates across carriers leave the monetization model unclear. GSMA has proposed three monetization frameworks for RCS messaging based on message types (basic messages, rich card messages, rich card conversations) and geographical location. The per-message model is operationally rather similar to traditional billing schemes for SMS and can get very expensive in high-volume interactive applications. The per-session model utilizes advanced timing algorithms in concert with connection management protocols to allow unlimited interactions within predetermined estimated time-frames and is useful in customer care operations or automated response systems. The hybrid model takes advantage of dynamic routing algorithms and usage pattern optimization and is expected to provide the best possible compromise between operational efficiency and cost- effectiveness. This model requires high-level integration with carrier billing infrastructures through standardized APIs, including quality of service (QoS) metrics and redundancy mechanisms. The final pricing model adopted by carriers, as well as the investments required to implement these billing systems, will heavily influence the cost-effectiveness and region of interest (ROI) of RCS for businesses. Platform compatibility is the scond main concern. Though well-integrated with Android devices, RCS remains unsupported by Apple's iMessage, limiting its reach in iOS-dominant markets. However, with major industry players such as Google, AT&T, T-Mobile, and Samsung, backing RCS and newer Android devices featuring it by default, compatibility issues are expected to diminish over time. The ultimate success of RCS hinges upon standardization of pricing models, widespread carrier adoption, and technological advancements that ensure cross-platform compatibility. For businesses, the transition to RCS requires a careful analysis of expected returns versus costs, but for those positioned to leverage its unique capabilities, RCS presents a promising pathway to higher engagement, conversion, and consumer satisfaction.

6.Artificial Intelligence and RCS

6.1.AI-Driven Customer Engagement

AI is becoming central in transforming the realm of customer interactions especially in text-based communication mediums. Traditionally, text messaging in customer service was limited to simple, rule-based responses. However, the evolution of AI-driven systems has introduced a new level of personalization and responsiveness. Through advancements in NLP, AI can now interpret, analyze, and respond to customer queries with a level of sophistication that closely mimics human conversation (Patel and Trivedi, 2020). Furthermore, AI-powered sentiment analysis enables to gauge the emotional tone of messages, adjusting responses to better meet customer expectations and improve satisfaction (Burlacu, 2023). AI-powered customer service is fundamentally transforming how businesses engage with their clientele by delivering efficient, personalized, and proactive support (Zhao et al., 2022a).
Currently, ample research highlights the central role of AI in enhancing RCS chat-bots and virtual assistants. In commercial applications, chat bots can improve customer experience and provide smooth interactions, making it easier for customers to engage with an organization and providing lower-cost customer service than live agents (Williams, 2023). Also, within closed-loop systems, including applications like meteorological services (Qu, Tang, Li, Sun, Tang and Zhao, 2022) and large-scale user management (Jia, 2024) AI chat-bots enable automated yet personalized responses that effectively address diverse user needs The GSMA's standardization of RCS through the Universal Profile has paved the way for a unified approach to these AI-enhanced chat bots, allowing original equipment manufacturers (OEMs) and mobile network operators (MNOs) to ensure consistent, high-quality experiences across devices. The RCS chat-bots facilitate direct user connectivity to a diverse array of services, encompassing merchants, restaurants, and financial institutions, among others (Zhao et al., 2022a). In a conversation, users can take similar operations as on the webpage. Business chat-bots enable quick actions in a conversation, like placing delivery orders, booking a flight, and viewing transaction history. Such an appealing feature makes it easier for users to access the services of a

business and thus increases user engagement and sales.

6.2. RCS Automation for Small Businesses - Case Studies

In messaging, AI applications consider four major factors: 'who' is the consumer, 'what' is the content of the message, 'when' is the best time, and choosing the medium — essentially answering the "who, what, when, and where" of communication. Therefore, it becomes possible to create effective and personalized messaging strategies, especially in A2P SMS, where such data includes but is not limited to message status like sent, delivered, or failed, response times of the messages, or third-party analytics that are very scarce. An example of creative application of SMS-based AI is seen in the chat bot developed by Cosmopolitan of Las Vegas (The Cosmopolitan of Las Vegas, 2024), which handles guest inquiries through SMS. Surprisingly, 80% of guests' requests were responded to without human intervention, which is a great use of NLP and dialogue management. However, the absence of data signals limits its performance, underscoring the need for richer data inputs provided by RCS.

RCS enhances the AI of messaging by integrating more extensive data metrics, like delivery and read receipts, and interactive features such as buttons, which allow for processing more intelligent and targeted messaging. This shift from generic segmentation to personalized, one-to-one communication enables more refined customer engagement strategies. Messaging can be tailored to user behavior-for instance, what time users actually do read messages-which better assures desired responses. A case study involving Subway (Google Jibe, 2024) illustrates the business effect of RCS. By porting its SMS subscribers onto RCS, Subway saw engagement rise by 144% due to the ability it gained to send feature-rich enriched messages via RCS. The move underlines the potential for RCS to change customer interaction through AI-driven and personalized communication. RCS offers a competitive alternative to OTT messaging applications like WhatsApp and Viber by enabling similar or enhanced functionalities directly within the carrier network. This model positions RCS as a "conversational e-commerce" platform, allowing companies to harness the power of AI and chat-bots to elevate their customer service and marketing efforts through direct, interactive messaging

7.Challenges and Ethical considerations

7.1. Challenges in Widespread RCS Adoption

RCS faces notable challenges in achieving widespread adoption. Technical hurdles are prevalent, as successful RCS deployment depends on seamless inter-connectivity between carriers to facilitate cross-network communication. The process of aligning various messaging standards and technical protocols across different regions and networks is complex and time-consuming. This issue is especially relevant for carriers and service providers in the US and Europe, where efforts to establish reliable P2P and A2P inter-connectivity are ongoing. In addition, there are considerable economic challenges a well. Implementing RCS infrastructure requires a substantial investment from mobile network operators (MNOs) and can be costly, particularly for smaller operators who may not see immediate financial returns from P2P traffic due to consumer expectations of free messaging services.

The industry's response to these challenges has been multi-faceted. MNOs and aggregators are exploring revenue- sharing models and other monetization strategies that leverage RCS's A2P and P2A capabilities. These approaches focus on charging enterprises for branded communication sessions rather than traditional message volume, aligning pricing with the value derived from consumer interactions. Additionally, efforts to increase trust in the RCS ecosystem have led to initiatives such as bot verification processes, which authenticate brands and reduce spam, establishing RCS as a more secure and reliable platform for consumers.

7.2. Ethical implications of AI-driven communications

One of the primary ethical concerns surrounding AI-driven communications is data privacy. The integration of AI in chat-bots often involve the collection of vast amounts of personal data (Hasal, Nowaková, Ahmed Saghair, Abdulla, Snášel and Ogiela, 2021) to tailor responses and improve user experience. This raises significant privacy issues, as users may not be fully aware of how their data is being utilized or the extent of data collection practices (Huang, Zhang, Mao and Yao, 2022). Therefore, ensuring that organizations adhere to strict data protection regulations and maintain transparency about data usage is crucial.

Algorithmic bias (Akter, Dwivedi, Sajib, Biswas, Bandara and Michael, 2022) is another critical ethical issue in AI-driven communications. AI systems, including chat-bots, can inadvertently perpetuate or exacerbate existing biases present in the training data, as they learn from diverse data sources (Qadir, 2023). This could lead to unfair or discriminatory interactions. For instance, if a chat-bot is trained on data that reflects societal biases, it may generate responses that reinforce stereotypes or exclude certain demographics. Addressing these biases requires a commitment to algorithmic fairness and the implementation of diverse training datasets to ensure equitable treatment of all users; however, overall algorithmic transparency is low (Schumann, 2020).

The implications of AI-driven communications extend beyond individual interactions; they also impact broader societal norms and expectations. As AI technologies become more integrated into communication practices, there is a risk of diminishing human agency and expertise. Over-reliance on AI chat-bots may lead to a reduction in human interactions, potentially eroding trust and empathy in customer service (Jeong and Park, 2023). Striking a balance between automation and human oversight is crucial to maintaining the quality of interactions and ensuring that ethical standards are upheld (Kerr, Barry and Kelleher, 2020).

8. Conclusion

The evolution of mobile messaging from SMS to RCS marks a significant transformation in global communication, driven by the increasing demand for feature-rich, secure, and integrated messaging solutions. Our study aimed to thoroughly examine this progression, exploring the technological advancements, business implications, and user-driven innovations that have shaped messaging services from basic text-based SMS to advanced RCS. We conducted a systematic literature review, adhering to PRISMA guidelines and analyzing studies from major scientific databases to ensure a comprehensive understanding of the landscape. Our research focused on comparing RCS with SMS, MMS, and popular OTT platforms to evaluate RCS's potential as a unified messaging solution that bridges traditional carrier services and modern communication needs. Through this analysis, we also addressed critical challenges—such as interoperability, security, and regulatory compliance—that continue to impact RCS adoption and its potential as a business messaging platform. This study contributes valuable insights into how RCS can reshape both personal and business communication, highlighting the critical steps required for widespread adoption and positioning it as a pivotal element in the future of mobile messaging within the context of 5G and AI-driven customer engagement.

References

1. Ahonen, T.T., 2004. m-Profits: Making money from 3G services. John Wiley & Sons.

2. Akter, S., Dwivedi, Y.K., Sajib, S., Biswas, K., Bandara, R.J., Michael, K., 2022. Algorithmic bias in machine learning-based marketing models.
3. Journal of Business Research 144, 201–216.
4. Alatawi, M., Saxena, N., 2023. Sok: An analysis of end-to-end encryption and authentication ceremonies in secure messaging systems, in: Proceedings of the 16th ACM Conference on Security and Privacy in Wireless and Mobile Networks, pp. 187–201.
5. Altamimi, A., Shaman, F., Alruban, A., et al., 2020. A message length verification of modern messaging systems. Journal of Computer and Communications 8, 103.
6. Apple, Inc., 2024. Wwdc24 highlights: Discover the future of software innovation. URL: https://www.apple.com/newsroom/2024/06/ wwdc24-highlights/. accessed: 2024-10-11.
7. Burlacu, C., 2023. The Impact Of Ai-Powered Content Generation On Customer Experience. B.S. thesis. University of Twente.
8. Carriedo, F., Beltrán, M., Recio, J.M., 2014. Extending the jcr standard to work efficiently in mobile rcs environments, in: Proceeding of IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks 2014, IEEE. pp. 1–3.
9. Chang, S.E., Pan, Y.H.V., 2011. Exploring factors influencing mobile users' intention to adopt multimedia messaging service. Behaviour & Information Technology 30, 659–672. URL: https://doi.org/10.1080/01449290903377095, doi:10.1080/01449290903377095, arXiv:https://doi.org/10.1080/01449290903377095.
10. Coulombe, S., Grassel, G., 2004. Multimedia adaptation for the multimedia messaging service. IEEE Communications Magazine 42, 120–126. Cruz, E., Svanborg, A., 2021. Rcs chatbots vs. single-purpose apps.
11. Downer, S.R., Meara, J.G., Costa, A.C.D., Sethuraman, K., 2006. Sms text messaging improves outpatient attendance. Australian Health Review 30,389. doi:10.1071/ah060389.
12. El Bakry, H.M., Taki_el_deen, A.E., El, A.H.A., 2014. Implementation of a hybrid encryption scheme for sms/multimedia messages on android.
13. International Journal of Computer Applications 85.
14. Friedrich, R., Gröne, F., Hölbling, K., Peterson, M., 2009. The march of mobile marketing: New chances for consumer companies, new opportunities for mobile operators. Journal of advertising research 49, 54–61.
15. Ghaderi, M., Keshav, S., 2005. Multimedia messaging service: System description and performance analysis, in: First International Conference on Wireless Internet (WICON'05), IEEE. pp. 198–205.
16. Golbabaei, F., Yigitcanlar, T., Paz, A., Bunker, J., 2020. Individual predictors of autonomous vehicle public acceptance and intention to use: A systematic review of the literature. Journal of Open Innovation: Technology, Market, and Complexity 6, 106.
17. Gomez, M., Megias, J.L., Bueno, C., Brocal, C., 2005. Interworking between the multimedia messaging service (mms) and the 3g ip multimedia subsystem (ims) instant messaging service, in: 2005 IEEE 16th International Symposium on Personal, Indoor and Mobile Radio Communications, IEEE. pp. 2274–2278.
18. Google Jibe, 2024. Case study - Subway. URL: https://jibe.google.com/success-stories/subway/. accessed: October 30, 2024. GSMA, 2020. Ims profile for voice, video and messaging over 5gs. URL: https://www.gsma.com/newsroom/wp-content/uploads//NG.

19. 114-v2.0-2.pdf. accessed: 2024-10-11.
20. Hall, A.K., Cole-Lewis, H., Bernhardt, J.M., 2015. Mobile text messaging for health: a systematic review of reviews. Annual review of public health 36, 393–415.
21. Hasal, M., Nowaková, J., Ahmed Saghair, K., Abdulla, H., Snášel, V., Ogiela, L., 2021. Chatbots: Security, privacy, data protection, and social aspects.
22. Concurrency and Computation: Practice and Experience 33, e6426.
23. Henry, K., Liu, Q., Pasquereau, S., 2009. Rich communication suite, in: Proceedings of the 13th International Conference on Intelligence in Next Generation Networks, IEEE. doi:10.1109/icin.2009.5357089.
24. Hoseini, M., Melo, P., Júnior, M., Benevenuto, F., Chandrasekaran, B., Feldmann, A., Zannettou, S., 2020. Demystifying the messaging platforms' ecosystem through the lens of twitter, in: Proceedings of the ACM internet measurement conference, pp. 345–359.
25. Huang, C., Zhang, Z., Mao, B., Yao, X., 2022. An overview of artificial intelligence ethics. IEEE Transactions on Artificial Intelligence 4, 799–819. Hung, H., Lin, Y., Luo, C., 2012. Deriving the distributions for the numbers of short message arrivals. Wireless Communications and Mobile
26. Computing 14, 450–459. doi:10.1002/wcm.2194.
27. Jeong, J., Park, N., 2023. Examining the influence of artificial intelligence on public relations: Insights from the organization-situation-public- communication (ospc) model. Asia-Pacific Journal of Convergent Research Interchange 9, 485–495.
28. Jia, X., 2024. A 5g rcs system optimization method for large-scale users, in: 2024 6th International Conference on Electronics and Communication, Network and Computer Technology (ECNCT), IEEE. pp. 437–442.
29. Kerr, A., Barry, M., Kelleher, J.D., 2020. Expectations of artificial intelligence and the performativity of ethics: Implications for communication governance. Big Data & Society 7, 2053951720915939.
30. Latif, N.S.A., Nawi, M.H.M., Nasir, N.N.M., Herdiana, R., 2023. Stability analysis of competition model of ios and android. Journal of Advanced Research in Applied Sciences and Engineering Technology 30, 372–382.
31. Le Bodic, G., 2005. Mobile messaging technologies and services: SMS, EMS and MMS. John Wiley & Sons.
32. Leu, J., 2010. Crafting a real-time information aggregator for mobile messaging. Journal of Computer Systems, Networks, and Communications 2010, 1–7. doi:10.1155/2010/209617.
33. Li, T., Xia, T., Wang, H., Tu, Z., Tarkoma, S., Han, Z., Hui, P., 2022. Smartphone app usage analysis: datasets, methods, and applications. IEEE Communications Surveys & Tutorials 24, 937–966.
34. Linge, N., Sutton, A., 2014. The road to 4g. J. Inst. Telecommun. Prof 8, 9–16.
35. MacRumors Staff, 2024. Rcs: Everything you need to know about the next-generation sms protocol. URL: https://www.macrumors.com/guide/ rcs/. accessed: 2024-10-11.
36. Massaro, M., Dumay, J., Guthrie, J., 2016. On the shoulders of giants: undertaking a structured literature review in accounting. Accounting, Auditing & Accountability Journal 29, 767–801.
37. Mobilesquared Ltd, 2024. Mobilesquared - mobile intelligence. https://www.mobilesquared.co.uk/. URL: https://www.mobilesquared. co.uk/. phone: +44 (0) 1182 149 777, Mobile: +44 (0) 7976 057 052.

38. Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L.A., Group, P.P., 2015. Preferred reporting items
39. for systematic review and meta-analysis protocols (prisma-p) 2015 statement. Systematic reviews 4, 1–9.
40. Morse, S.F.B., 2014. Samuel FB Morse. volume 2. Cambridge University Press.
41. Mostafa, M.E., 2002. Mms-the modern wireless solution for multimedia messaging, in: The 13th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, IEEE. pp. 2466–2472.
42. NativeMsg, 2024. Nativemsg - rich communication services. URL: https://nativemsg.com/. accessed: October 30, 2024.
43. Nikou, S., Bouwman, H., de Reuver, M., 2012. Mobile converged rich communication services: A conjoint analysis, in: 2012 45th Hawaii International Conference on System Sciences, IEEE. pp. 1353–1362.
44. Noldus, R., Olsson, U., Fikouras, I., Ryde, A., Stille, M., Mulligan, C., 2011. Rich Communication Suite. Elsevier. doi:10.1016/ b978-0-12-382192-8.00012-3.
45. Ogidiaka, E., Ogwueleka, F.N., 2020. Over-the-top services (ott) on telecommunication operators in nigeria: exploring consumers' behaviour.
46. International Journal of Information Technology 12, 437–446.
47. Olia, A., 2024. Text message statistics & trends for 2024 [and beyond!] URL: https://www.intradyn.com/category/sms-text-messaging/. accessed: 2024-09-24.
48. P, A., Hallur, G., 2023. Demystifying domain-specific key drivers in telecom technologies, in: 2023 Intelligent Computing and Control for Engineering and Business Systems (ICCEBS), pp. 1–9. doi:10.1109/ICCEBS58601.2023.10449118.
49. Patel, N., Trivedi, S., 2020. Leveraging predictive modeling, machine learning personalization, nlp customer support, and ai chatbots to increase customer loyalty. Empirical Quests for Management Essences 3, 1–24.
50. Peersman, C., Cvetkovic, S., Griffiths, P., Spear, H., 2000. The global system for mobile communications short message service. IEEE Personal Communications 7, 15–23.
51. Peslak, A., Ceccucci, W., Sendall, P., 2010. An empirical study of instant messaging behavior using diffusion of innovation theory. Journal of Information Systems Applied Research 3, 3–13.
52. Peslak, A., Hunsinger, D.S., 2018. The evolution of text messaging: An expanded review of influencing variables over time. Issues in Information Systems 19.
53. Petticrew, M., Roberts, H., 2008. Systematic reviews in the social sciences: A practical guide. John Wiley & Sons. Poikselkä, M., Mayer, G., 2013. The IMS: IP multimedia concepts and services. John Wiley & Sons.
54. Qadir, J., 2023. Engineering education in the era of chatgpt: Promise and pitfalls of generative ai for education, in: 2023 IEEE Global Engineering Education Conference (EDUCON), IEEE. pp. 1–9.
55. Qiao, X., Xue, S., Chen, J., Fensel, A., 2015. A lightweight convergent personal mobile service delivery approach based on phone book. International Journal of Communication Systems 28, 49–70.

56. Qu, H., Tang, W., Li, Y., Sun, S., Tang, S., Zhao, X., 2022. Weather china: A 5g rcs solution for meteorological service, in: 2022 3rd Asia Conference on Computers and Communications (ACCC), IEEE. pp. 84–92.
57. Rastogi, N., Hendler, J., 2017. Whatsapp security and role of metadata in preserving privacy. arXiv Prepr. arXiv1701 6817, 269–275.
58. Reaves, B., Bowers, J., Scaife, N., Bates, A., Bhartiya, A., Traynor, P., Butler, K.R., 2017. Mo (bile) money, mo (bile) problems: Analysis of branchless banking applications. ACM Transactions on Privacy and Security (TOPS) 20, 1–31.
59. Ren, X., Dong, J., Liu, H., Li, Y., Yang, X., 2012. Low-overhead accrual failure detector. Sensors 12, 5815–5823. doi:10.3390/s120505815. Rueggeberg, R., 1987. The teletex service development in the federal republic of germany and in the international arena, in: The Upper Layers of Open
60. Systems Interconnection: Proceedings of the Second International Symposium on Interoperability of ADP Systems, The Hague, The Netherlands, 25–29 March 1985, Springer. pp. 211–231.
61. Sayyad, M., Ansari, N., Burli, S., Shah, H., Khatanhar, A., 2011. Review of ip multimedia subsystem, in: Proceedings of the International Conference & Workshop on Emerging Trends in Technology, pp. 937–941.
62. Schumann, M., 2020. Chatbots for the information acquisition at universities–a student's view on the application area. Chatbot Research and Design
63. , 231.
64. Setyono, A., Alam, M.J., Eswaran, C., 2014. Mobile telemedicine system application for telediagnosis using multimedia messaging service technology.
65. International Journal of Wireless and Mobile Computing 7, 348–361.
66. Sevanto, J., 1999. Multimedia messaging service for gprs and umts, in: WCNC. 1999 IEEE Wireless Communications and Networking Conference (Cat. No. 99TH8466), IEEE. pp. 1422–1426.
67. Silfverberg, M., MacKenzie, I.S., Korhonen, P., 2000. Predicting text entry speed on mobile phones, in: Proceedings of the SIGCHI conference on Human factors in computing systems, pp. 9–16.
68. Sinch, 2023. Apple support rcs on ios18. URL: https://sinch.com/blog/apple-support-rcs/. accessed: 2024-10-11. Taylor, A., Vincent, J., 2005. An sms history. Mobile world , 75–91.
69. The Cosmopolitan of Las Vegas, 2024. Meet rose, our digital concierge. URL: https://cosmopolitanlasvegas.mgmresorts.com/en/ amenities/rose.html. accessed: October 30, 2024.
70. Trosby, F., Holley, K., Harris, I., 2010. Short message service (SMS): the creation of personal global text messaging. John Wiley & Sons. TYXHARI, G., GORISHTI, A., et al., 2014. Evolution of mobile messaging services in internet era. International Journal of Science, Innovation & New Technology 1.
71. Van De Vliert, D., 2021. Apple iphone: a market case study. MacEwan University Student eJournal 5.
72. Vatsa, R., Kumar, V., 2005. Role of media transformation in multimedia messaging, in: 2005 IEEE International Conference on Personal Wireless Communications, 2005. ICPWC 2005., pp. 258–262. doi:10.1109/ICPWC.2005.1431344.
73. Williams, R., 2023. Think piece: ethics for the virtual researcher. Practice 5, 41–47. Yang, L.T., 2010. Mobile intelligence. volume 69. John Wiley & Sons.
74. Yoon, C., Jeong, C., Rolland, E., 2015. Understanding individual adoption of mobile instant

messaging: A multiple perspectives approach. Information Technology and Management 16, 139–151.
75. Zhao, J., Li, Q., Yuan, Z., Zhang, Z., Lu, S., 2022a. 5g messaging: System insecurity and defenses, in: 2022 IEEE Conference on Communications and Network Security (CNS), pp. 37–45. doi:10.1109/CNS56114.2022.9947238.
76. Zhao, J., Li, Q., Yuan, Z., Zhang, Z., Lu, S., 2022b. 5g messaging: System insecurity and defenses, in: 2022 IEEE Conference on Communications and Network Security (CNS), IEEE. pp. 37–45