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5G Technology Empowerment and Communication Model Reconstruction: An Analysis Based on the Three Core Characteristics of EMBB, URLLC, and MMTC

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ABSTRACT

To explore the intrinsic connection between 5G technology and communication models, this study adopts an interdisciplinary perspective integrating communication engineering and communication studies, systematically analyzing the mechanism by which the three core characteristics of 5G (eMBB, uRLLC, mMTC) influence the "5W Model". Combining theoretical analysis with case verification, the study selects typical scenarios such as the CCTV VR Spring Festival Gala and 5G remote surgical demonstration and teaching, while citing data from authoritative institutions including the China Academy of Information and Communications Technology (CAICT) and Tencent Research Institute to empirically evaluate the communication value of 5G characteristics. The results show that: eMBB drives the transformation of information forms toward "immersive experience", with over 80% of users recognizing its role in enhancing sense of participation; uRLLC enables "synchro. nous symbiosis" between communicators and audiences, with over 90% of professional users affirming its value in real-time interaction; mMTC constructs an "everything-as-a-medium" ecosystem, with nearly 80% of residents recognizing the timeliness of its information push. These three characteristics work synergistically to promote the evolution of traditional linear communication toward an "intelligent networked model of human-machine-thing collaboration". Based on the theories of digital justice and data sovereignty, the study also proposes governance strategies for three types of ethical risks: digital divide, privacy leakage, and information overload. Finally, a three-dimensional analytical framework of "technology-communication-ethics" is constructed to provide support for research and practice in the field of 5G communication.

KEYWORDS

5G technology; Communication model reconstruction; EMBB; URLLC; MMTC; Intelligent networked communication; Communication ethics

1 Introduction

The global commercial launch of 5G in 2019 marked the official entry of digital communication into the new stage of "intelligent interconnection". According to the Operation of the Communications Industry in June 2024 released by the Ministry of Industry and Information Technology (MIIT), the total number of 5G base stations in China has reached 3.86 million, and the proportion of 5G mobile phone users has exceeded 52.1%. Such a scale of infrastructure provides a solid foundation for innovation in the communication field [1]. Unlike the superficial transformation of "mobile Internet life" by 4G technology, 5G, with its characteristics of high speed, low latency, and wide connectivity, has completely broken the boundaries of traditional communication: the eMBB characteristic supports the transmission of ultra-high definition (UHD) video and VR/AR content, the uRLLC characteristic enables real-time interaction in remote scenarios, and the mMTC characteristic makes the implementation of "everything as a medium" possible [2-3]. Scholars such as Yu Guoming pointed out in their 2022 research that 5G is not a "linear upgrade" of communication technology, but a "key variable" triggering a communication paradigm revolution—it redefines the relationship between "communicators and audiences" and shifts communication from an "exclusively human activity" to a "human-machine-thing collaborative ecosystem" [4]. Against this backdrop, clarifying the connection between the three 5G characteristics and communication elements has become a core issue in understanding the current transformation of digital communication.

Existing research on 5G and communication still has obvious shortcomings. On the one hand, most studies regard 5G as an overall technical variable, failing to deeply decompose the differentiated impacts of eMBB, uRLLC, and mMTC on communication elements [5]; on the other hand, empirical support mainly relies on industry case descriptions, lacking quantitative verification with authoritative user data [6]; in addition, discussions on the ethical risks of 5G communication are relatively fragmented, failing to form a systematic governance framework combined with theories such as digital justice and data sovereignty [7]. Based on these shortcomings, this study focuses on three core questions: Which links of the "5W Model" are affected by each of the three 5G characteristics? How do these impacts jointly promote the transformation of communication models? How to address the ethical risks existing in the 5G communication ecosystem? In terms of theoretical value, the three-dimensional "technology-communication-ethics" framework constructed in this study can fill the gap in interdisciplinary research between communication technology and communication studies; in terms of practical value, it can provide application paths for media institutions in scenarios such as VR live broadcasting and sensor-based journalism, and also offer references for policymakers in areas such as digital aging adaptation and data

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classification authorization [8]. This study mainly adopts three research methods: first, literature analysis, systematically sorting out 5G technical standards released by institutions such as ITU and 3GPP [9-10], as well as classic communication theories including Lasswell's 5W Model and digital justice theory [11-12]; second, case study, selecting three typical cases: the CCTV VR Spring Festival Gala (corresponding to the eMBB scenario), remote surgical demonstration and teaching at Peking Union Medical College Hospital (corresponding to the uRLLC scenario), and Xinhua News Agency's sensor-based flood monitoring in the Yangtze River Basin (corresponding to the mMTC scenario) [13-15]; third, data support, citing authoritative data from CAICT's 5G Application Development White Paper (2024) and Tencent Research Institute's 5G Communication User Experience Report (2024). These data cover more than 2,000 samples, and both reliability and validity have undergone professional verification [16].

2 Literature review

The International Telecommunication Union (ITU) clearly classifies 5G application scenarios into three categories in the IMT-2020 standards: eMBB (Enhanced Mobile Broadband), uRLLC (Ultra-Reliable Low-Latency Communication), and mMTC (Massive Machine-Type Communication). Among them, the user experience rate of eMBB should reach 100 Mbps-1 Gbps, the end-to-end latency of uRLLC should be less than 1 ms with a reliability of no less than 99.999%, and mMTC requires no less than 1 million connections per square kilometer [9-10]. 3GPP further refined the parameters in Technical Specification TS 38.306: the downlink peak rate of eMBB can reach 20 Gbps, the latency jitter of uRLLC is controlled within 0.1 ms, and the standby time of mMTC terminals can exceed 10 years [17]. Huawei Technologies Co., Ltd. mentioned in the 5G White Paper (2023 Edition) that these three characteristics can be customized for scenarios through "network slicing" technology—for example, allocating eMBB slices for live broadcasting scenarios and matching uRLLC slices for remote surgery, thereby providing customized network services for different communication needs [18].

Research in the field of communication studies on 5G and communication transformation mainly focuses on three directions. Scholars such as Li Liangrong argued in their 2023 research that the eMBB characteristic drives the evolution of media forms from the linear progression of "text-image-video" to "VR/AR immersive media", upgrading information communication from "two-dimensional symbols" to "three-dimensional scenarios" and significantly reducing the audience's cognitive load [5]. Peng Lan proposed in her 2022 research that the uRLLC characteristic frees "real-time interaction" from the limitation of "delayed response" and enters the stage of "synchronous symbiosis"—for example, the doctor's operations and the feedback of the patient's physiological data in telemedicine can be synchronized in real time, and the player's operations and screen updates in cloud games have almost no perceptible latency. This change completely blurs the boundary between communicators and audiences [6]. Scholars such as Yu Guoming emphasized in their 2024 research that mMTC technology expands the communication subject from "humans" to "non-human subjects" such as sensors and intelligent devices, forming a new form of "Machine-Generated Content (MGC)" and promoting communication to truly enter the era of "everything as a medium" [3]. Although existing research has paid attention to the impact of 5G on communication, there are still three obvious gaps: first, the logical connection between technical characteristics and communication elements is not clear enough, as most studies analyze 5G as an overall variable without decomposing the respective roles of eMBB, uRLLC, and mMTC; second, empirical support is relatively weak, focusing on case descriptions and lacking quantitative verification with authoritative user data; third, discussions on ethical risks remain at the phenomenological level, failing to form a systematic governance framework combined with theories such as digital justice and data sovereignty [5-7, 19]. Compared with existing research, the contributions of this paper are as follows: accurately decomposing the corresponding relationship between the three 5G characteristics and communication elements, strengthening empirical support with data from authoritative institutions, and constructing a systematic analytical framework of "technology-communication-ethics".

3 Empowerment mechanism of the three 5G characteristics on communication elements

3.1 EMBB: innovating information forms and promoting "experiential communication"

As the core characteristic of 5G supporting the communication of immersive content, the most critical breakthrough of eMBB lies in solving the bandwidth bottleneck of the 4G era. Its user experience rate has jumped from 10-50 Mbps in the 4G era to 100 Mbps-1 Gbps, and the peak rate has even reached 20 Gbps. Even in scenarios with high network load such as dense urban areas and transportation hubs, it can still maintain stable transmission of over 100 Mbps, which provides technical support for the smooth communication of large-traffic content such as 8K UHD video and VR panoramas [9, 17].

In terms of communication effects, eMBB directly drives a "three-level leap" in information forms: from text (KB-level), ordinary video (10-100 MB-level) to 8K video (1 GB per hour) and VR content (5-10 GB per hour) [18]. The "5G + 8K + VR" technology adopted in the 2024 CCTV Spring Festival Gala is a typical application of the eMBB characteristic—users can adjust their viewing perspective by 360° through VR devices and interact simply with virtual hosts; the 8K image quality presents details such as actors' facial expressions and costume textures clearly, with the information capacity increased by

4 times compared with 4K video in the 4G era [13]. A survey conducted by CAICT on this scenario (sample size: 1,500) shows that 83.3% of users believe that the VR immersive experience significantly enhances their sense of participation in the Spring Festival Gala, 76.7% of users indicate that 8K image quality enables more comprehensive information acquisition, and only 6.7% of users perceive little difference from traditional live broadcasting [16].

From the perspective of communication theory, eMBB reconstructs the relationship between "information and audience". In traditional communication, audiences need to understand information through "symbol decoding" —for example, imagining a news scene through text descriptions; in contrast, immersive communication supported by eMBB allows audiences to directly "enter" the information scene and become "scene participants". This change not only enhances the appeal of information but also expands the application scenarios of communication. New forms of "experiential communication" such as "VR history classrooms" in the education field and "cloud museum tours" in the cultural tourism field are all realized based on eMBB [20].

3.2 URLLC: optimizing feedback mechanisms and realizing "synchronous symbiosis"

The core advantage of the uRLLC characteristic lies in "low latency + high reliability". Its end-to-end latency is controlled within 1 ms, which is only 1/20 to 1/50 of that of 4G, and its reliability reaches 99.999% (equivalent to downtime of no more than 5 minutes per year). Even when the network load reaches 90%, its performance can still remain stable, providing key technical support for remote real-time interaction scenarios [10, 17].

This characteristic completely solves the "feedback lag" problem in traditional communication. The "5G + uRLLC remote surgical demonstration and teaching" carried out by Peking Union Medical College Hospital in 2023 is a typical case: when experts in Beijing performed a deep brain stimulator implantation surgery, primary-level doctors in multiple regions watched the surgical video in real time through the 5G network, and could ask real-time questions via voice and text. The experts' answers were almost synchronized with the surgical operations; during the entire demonstration and teaching process, the video transmission latency was less than 0.8 ms, with no freezes or interruptions, ensuring the accurate transmission of medical knowledge [14]. A survey conducted by the Chinese Hospital Association on the primary-level doctors participating in this demonstration and teaching (sample size: 500) shows that 92.5% of doctors believe that low latency makes the interaction effect close to on-site learning, 87.5% of doctors recognize that high reliability avoids the omission of key operation information, and only 2.5% of doctors report slight latency impacts [14]. From the perspective of Lasswell's 5W Model, uRLLC reconstructs the key link of "audience feedback". In traditional communication, feedback requires a long process of "audience expression - channel transmission - communicator reception" —for example, when viewers feedback on TV programs via email, the latency often reaches several hours or even days; in contrast, uRLLC embeds feedback "in real time" into the communication process. For instance, in distance education, students' questions can be transmitted to teachers immediately, and teachers' answers can be presented synchronously, forming a real-time interactive closed loop of "teaching-learning". Scholars such as Hu Yiqing pointed out in their 2023 research that this "synchronous symbiosis" relationship blurs the fixed boundary between communicators and audiences, turning communication into a "dynamic process jointly participated in by both communicators and audiences" [21].

3.3 MMTC: expanding communicators and channels and constructing "everything as a medium"

The core capability of the mMTC characteristic is to support "massive low-power device connections". Its number of connections per square kilometer can reach 1 million, which is 10 times that of 4G. The standby time of terminals can exceed 10 years, and the module cost is less than 5 US dollars. Such parameters make the interconnection scale of "5 billion people + 50 billion things" possible [10, 17-18].

The impact of mMTC on communication is mainly reflected in two aspects. On the one hand, it expands communicators— "non-human subjects" such as sensors and intelligent terminals have become new information communicators. During the 2024 Yangtze River flood season, the "5G + hydrological sensor" network deployed by Xinhua News Agency in collaboration with the water conservancy department is a typical example: these sensors can collect water level and flow rate data in real time, automatically generate "flood situation alerts", which are not only pushed to the public through the Xinhua News Agency client but also transmitted to emergency management departments simultaneously. The entire process of "information collection - communication - application" requires no manual intervention [15]. On the other hand, it integrates channels—forming an integrated "cloud-network-edge-device" network: information is first transmitted to edge nodes through mMTC for preprocessing, then pushed to terminals via eMBB or uRLLC, and finally realizing "real-time collection - intelligent analysis - accurate communication" [18].

A survey conducted by Tencent Research Institute on residents in sensor-covered areas (sample size: 1,200) shows that 78% of residents believe that flood situation alerts are pushed in a timely manner, helping them prepare for flood prevention in advance; 72% of residents indicate that sensor data is more intuitive than traditional news; and 15% of residents hope to receive more life-related sensor information such as air quality and water quality in the future [16]. From a theoretical perspective, mMTC promotes communication into the "post-anthropocentric" stage: communicators are no longer limited to human subjects, and channels have evolved from "single transmission pipelines" to "intelligent networks

with multi-node interconnection". Communication activities have gradually shifted from "human-dominated" to "human-machine-thing collaborative" [3, 22].

4 5G Communication model reconstruction: the intelligent networked model

The innovation of 5G on Lasswell's 5W Model lies in the "synergistic upgrading of all elements". The real-time interaction of uRLLC blurs the boundary between communicators and audiences, the high bandwidth of eMBB promotes the continuous iteration of information forms, and the massive connections of mMTC expand the dimensions of channels and effect evaluation. Together, they form a "human-machine-thing collaborative" communication ecosystem [3, 22]. The specific innovations are shown in Table 1.

Table 1 Innovation of 5G on lasswell's 5W model

Communication Element	Characteristics of Traditional Model	Characteristics of 5G Model	Core Driving Characteristics	Empirical Support (Authoritative Data)
Communicator (Who)	Human-dominated (media/individuals)	Collaborative communicators of humans + machines + AI	mMTC + AI	72% of users recognize the value of sensor information (Tencent Research Institute, 2024) [16]
Information (Says What)	Symbolic content (text/ordinary video)	Experiential + data-driven content (8K/VR/real-time data)	eMBB	83.3% of users recognize that VR enhances sense of participation (CAICT, 2024) [16]
Channel (In Which Channel)	Single pipeline (TV/ mobile network)	Integrated "cloud-network-edge-device" channel	mMTC + uRLLC	78% of users recognize the timeliness of sensor pushes (Tencent Research Institute, 2024) [16]
Audience (To Whom)	Passive human audience	Active prosumers + intelligent devices	uRLLC + mMTC	92.5% of doctors recognize the effect of remote interaction (Chinese Hospital Association, 2023) [14]
Effect (With What Effect)	Delayed statistics (viewership rate)	Real-time multi-dimensional evaluation (sentiment analysis/behavior tracking)	Synergy of the three characteristics	76.7% of users recognize that 8K improves efficiency (CAICT, 2024) [16]

Data Sources: CAICT, 5G Application Development White Paper (2024)[16]; Chinese Hospital Association, 5G Telemedicine Application Practice Report (2023) [14]; Tencent Research Institute, 5G IoT Communication Ecosystem Report (2024)[16].

Based on these innovations, this study proposes the "5G Intelligent Networked Communication Model". This model has four core characteristics: first, it takes a "cloud-based intelligent platform" as the core but does not rely on a single node—human, machine, and AI nodes can be directly connected to form a multi-node interactive network. For example, traffic cameras can push real-time traffic information directly to drivers' mobile phones without going through traditional media; second, information flow realizes two-way real-time circulation—eMBB ensures high-speed information transmission, and uRLLC realizes the immediacy of feedback, avoiding the one-way linear limitation of traditional communication; third, communication elements can switch roles dynamically—for example, smart home devices can transmit environmental data (as communicators) and receive user instructions (as audiences), with role switching automatically completed by 5G networks and AI algorithms; fourth, it relies on AI to realize intelligent decision-making—the cloud platform can optimize content recommendation (e.g., adjusting VR perspectives according to user behavior) and resource allocation (e.g., allocating more bandwidth to live broadcasts through network slicing) by analyzing real-time data [18, 22].

5 Ethical risks and governance strategies of 5G communication

From the perspectives of digital justice, data sovereignty, and attention economics theories, 5G communication currently faces three types of core ethical risks. The first is the dualization of the digital divide: in terms of technical accessibility, the density of 5G base stations in western China is only 1/3 of that in eastern China, and the average price of 5G packages is 30% higher than that of 4G [1, 16]. Some groups find it difficult to access the 5G communication ecosystem due to insufficient network coverage or high costs; in terms of ability adaptability, among users over 60 years old, 45% cannot operate VR devices, and 38% find 5G application interfaces complicated, making it impossible for them to effectively enjoy immersive services [16]. The second is the contextualization of privacy leakage: intelligent devices have the problem of "over-range data collection". For example, smart speakers with cameras collect family scenario data without perception, and health bracelets over-collect physiological data such as heart rate and sleep [11, 19]; moreover, the abuse of data by third-party institutions is prominent. Scholars such as Wang Sixin found in their 2022 research that the number of cases of personal data abuse in 5G IoT scenarios has increased by 2.3 times compared with the 4G era [24]. The third is the normalization of information overload: supported by eMBB, 500 hours of video content are added to the Internet every minute, and users spend 3.5 hours per day screening effective information [16]; real-time pushes driven by mMTC also cause attention fragmentation—for example, smart watches push 10-15 notifications per hour, and 72% of

users report that this affects their work and life [16]. To address these risks, governance strategies can be formulated from three levels. At the policy and technical level, it is necessary to implement the requirements of the 14th Five-Year Plan for Digital Economy Development, providing a subsidy of 20,000-30,000 yuan per 5G base station for the construction of 5G base stations in western China, and launching "5G inclusive packages" to reduce usage costs [1, 8]; technically, it is necessary to develop elderly-friendly versions of 5G applications, adding functions such as voice control and large font display, and realizing encrypted transmission and traceability of sensor data through blockchain technology [11, 16, 19]. At the legal and regulatory level, it is necessary to refine the provisions related to "IoT data" in the Personal Information Protection Law of the People's Republic of China, classifying data into three levels: core sensitive (e.g., physiological data), generally sensitive (e.g., location data), and non-sensitive (e.g., device status), and implementing differentiated protection; at the same time, establishing a "5G data supervision platform" to monitor the entire process of data collection, transmission, and use, and imposing fines of no less than 5 million yuan on non-compliant enterprises [23]. At the content and user level, media institutions should extract core information from VR/8K content—for example, marking "key scenarios" in VR news to facilitate users to quickly obtain key points; the alerts pushed by sensors should be controlled within 100 words, highlighting core data [20]; it is also necessary to carry out digital literacy education to guide users to set information reception limits, such as controlling the daily usage time of 5G content to 2 hours [12, 16].

6 Conclusion and outlook

Through the differentiated empowerment of communication elements by the three 5G characteristics (eMBB, uRLLC, mMTC), traditional linear communication has been jointly promoted to evolve toward the "intelligent networked model of human-machine-thing collaboration". This transformation not only reshapes the information form, the communicator-audience relationship, and the channel ecosystem but also provides new immersive, real-time, and intelligent paths for communication practice. Future research can be deepened in three directions: first, exploring the impact of "5G + generative AI" on content production, such as the feasibility of AI automatically generating VR news scenarios; second, conducting empirical research on segmented scenarios, quantitatively analyzing the role of VR classrooms in improving learning efficiency in "5G + education" and the value of remote surgery in knowledge transmission in "5G + medical care"; third, comparing the differences in 5G communication ethical regulations among China, the United States, and Europe, to provide references for China to construct an international governance framework.

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