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ARTICLES

THE GLOBAL APPROACHES TO THE REGULATION OF QUANTUM COMMUNICATION

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Abstract

In the rapidly evolving field of quantum communication, the regulatory framework plays a crucial role in ensuring security, standardization, and international cooperation. This article examines various approaches employed by countries to regulate quantum communication. The purpose of this research is to comprehensively analyze and compare different international approaches to the regulation of quantum communication to identify key features characteristic of the current stage of development and regulation of quantum communication, as well as to develop recommendations for optimizing and improving regulatory governance in this area. The methodological basis of the study consisted of general scientific and special methods. A detailed study of various legal documents, strategies, and standards related to quantum communication was conducted using the following general scientific methods: analysis, synthesis, induction, and system analysis. Among the special legal methods used was the comparative legal method, which made it possible to identify general trends, differences, and unique approaches in the regulation of quantum communication, as well as the formal-legal method for studying legal categories and legislative techniques used in various acts in the studied area. The study systematically examines legislative measures, government policies, and industry standards to determine the relationship between technological innovation and regulatory governance in the field of quantum communication. The research revealed that the regulation of quantum communication is primarily carried out at the level of strategic documents, such as national roadmaps, which contain recommendations and guidelines for regulating quantum communication. It was found that technical standards play a vital role in the development of quantum communication, with this development occurring at both national and international levels. Special groups and centers have been established for the effective implementation, development, and regulation of quantum communication, which allows for the identification of social, legal, political, and ethical issues. The main conclusions include the need to monitor administrative barriers, identify priority sectors for the implementation of quantum communication, and recognize quantum communication as a dual-use technology. It is recommended that an international certification and tracking system be created for quantum communication devices for export and import control purposes.

Keywords

quantum communication, regulation, information security, international cooperation, quantum technologies, national strategies, industry standards, government governance, regulatory frameworks

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СТАТЬИ

ГЛОБАЛЬНЫЕ ПОДХОДЫ К РЕГУЛИРОВАНИЮ КВАНТОВЫХ КОММУНИКАЦИЙ

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Аннотация

В быстро развивающейся области квантовых коммуникаций нормативно-правовая база играет решающую роль в обеспечении безопасности, стандартизации и международного сотрудничества. В этой статье рассматриваются различные способы, применяемые странами к регулированию квантовых коммуникаций. Целью данного исследования является всесторонний анализ и сравнение различных международных подходов к регулированию квантовых коммуникаций для выявления ключевых особенностей, характерных для текущего этапа развития и регулирования квантовых коммуникаций, а также разработки рекомендаций для оптимизации и совершенствования нормативного управления в данной области. Методологической основой исследования явились общенаучные и специальные методы. Детальное изучение различных правовых документов, стратегий и стандартов, связанных с квантовыми коммуникациями, проводилось с использованием следующих общенаучных методов познания: анализа, синтеза, индукции и метода системного анализа. Среди специальных юридических методов познания использовались сравнительно-правовой метод, который позволил выявить общие тенденции, различия и уникальные подходы в регулировании квантовых коммуникаций, а также формально-юридический метод для исследования правовых категорий и законодательной техники, используемых в различных актах в области квантовых коммуникаций. В рамках исследования систематически изучаются законодательные меры, правительственные политики и отраслевые стандарты для понимания взаимосвязи между технологическими инновациями и нормативным управлением в сфере квантовых коммуникаций. Было выявлено, что регулирование квантовых коммуникаций в основном осуществляется на уровне стратегических документов, таких как национальные дорожные карты, которые содержат рекомендации и руководящие принципы по регулированию квантовых коммуникаций. Обнаружено, что технические стандарты играют важнейшую роль в развитии квантовых коммуникаций, причем их разработка происходит как на национальном, так и на международном уровнях. Специальные группы и центры создаются для эффективного внедрения, разработки и регулирования квантовых коммуникаций, что позволяет выявлять социальные, правовые, политические и этические вопросы. Основные выводы включают необходимость мониторинга административных барьеров, определение приоритетных секторов для внедрения квантовых коммуникаций, а также признание квантовых коммуникаций как технологий двойного назначения. Рекомендуется создание международной системы сертификации и отслеживания квантовых коммуникационных устройств для целей экспортного и импортного контроля.

Ключевые слова

квантовые коммуникации, регулирование, информационная безопасность, международное сотрудничество, квантовые технологии, национальные стратегии, отраслевые стандарты, государственное управление, нормативное регулирование

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Introduction

In an era characterized by exponential technological growth, the realm of communication stands as a cornerstone of innovation, driving advancements across various sectors. Among the myriad emerging communication technologies, quantum communication holds exceptional promise, offering unparalleled security and efficiency in data transmission. Leveraging the principles of quantum mechanics, such as superposition and entanglement, quantum communication systems have the potential to revolutionize information exchange, rendering conventional cryptographic methods obsolete.

Despite the transformative potential of quantum communication, the regulatory landscape governing its deployment remains relatively uncharted. With the rapid proliferation of quantum communication technologies, policymakers are faced with the daunting task of crafting regulatory frameworks capable of fostering innovation while safeguarding against potential risks. Moreover, the global nature of quantum communication necessitates an understanding of the diverse regulatory approaches adopted by different countries and regions.

Against this backdrop, this research endeavors to address the pressing need for a comprehensive analysis of quantum communication regulation on a global scale. The main objective of this research is to thoroughly examine and contrast various global strategies for regulating quantum communication in order to pinpoint essential characteristics unique to the current phase of the development and regulation of quantum communication, and to formulate recommendations for enhancing and refining regulatory governance in this field. Through a comparative legal analysis of regulatory frameworks, this research seeks to uncover common trends, disparities, and emerging patterns in regulating quantum communication, thereby providing valuable insights for policymakers, researchers, and industry stakeholders alike.

To achieve these objectives, the research will be conducted in several stages. Qualitative and quantitative analyses will be employed to assess the regulatory frameworks implemented in different countries and regions. By systematically examining legislative measures, governmental policies, and industry standards, this research aims to shed light on the intricate interplay between technological innovation and regulatory governance in the realm of quantum communication.

In essence, this study seeks to contribute to the burgeoning field of quantum communication by offering a comprehensive exploration of its regulatory landscape. By highlighting the regulatory challenges and opportunities inherent in this rapidly evolving field, this research aims to promote evidence-based policy making and foster international collaboration in creating secure and efficient quantum communication infrastructure.

Results

Research into foreign regulation of quantum communication has yielded several key findings, not only concerning the regulation itself but also related measures:

1. Regulation of quantum communication is primarily carried out at the level of strategic planning documents. National roadmaps in the field of quantum technologies typically contain recommendations and regulatory guidelines for quantum communication, identify best practices, and list existing and planned initiatives that may receive financial support from one or more government agencies. The process of drafting a roadmap provides a valuable opportunity to engage a wide range of stakeholders in the development of national strategies. Roadmaps usually encompass all government structures and identify opportunities for inter-sectoral cooperation among stakeholders. The roadmap development process also creates opportunities for stakeholders to collaborate in developing their own strategies and policies, as well as sharing knowledge, information, and best practices. In most cases, such roadmaps are developed by government bodies and organizations, but there are also roadmaps from private quantum associations, for example, in the European Union.
2. Technical standards play a paramount role in the development of quantum communication. Their development occurs not only at the national level but also internationally. The international dimension is seen as a means of promoting protocols from individual countries and enhancing influence. However, it is essential to prevent the formation of different international standardization systems.
3. Special groups and centers are established for the effective implementation, development, and regulation of quantum communication. Their task is to identify social, legal, political, and ethical issues related to quantum communication. Such groups play a crucial role in informing society and shaping a positive image of quantum communication.
4. For effective legal regulation, it is necessary to monitor administrative barriers that hinder the implementation of quantum communication. These barriers may include complicated rules for government procurement, as well as procedures for obtaining licenses and certificates.
5. It is necessary to identify the sectors where the implementation of quantum communication is expected to occur first. These sectors may include the financial sector, healthcare, defense, and critical infrastructure.
6. Regulating and implementing quantum communication involves the use of experimental legal regimes. It is recommended to include quantum communication in the list of technologies that may be subject to experimental legal regimes.
7. The overwhelming majority of countries classify quantum communication as a dual-use technology. This means it can be used for both civilian and military purposes.
8. The classification of quantum communication as a dual-use technology is undoubtedly aimed at ensuring national security, but at the same time, it imposes significant export restrictions. A

solution to this could be the establishment of a transparent certification system and tracking of quantum communication devices. To achieve this, it is possible to create an international system for tracking and certifying quantum communication devices for the purpose of export and import control under the auspices of the United Nations.

9. Most countries encourage the use of public-private partnerships. Collaboration between public and private organizations facilitates quicker responses than traditional regulatory bodies, providing flexibility in achieving regulatory outcomes for quantum communication and addressing industry challenges (Johnson, 2019, p. 21).
10. For countries facing challenges in accessing global markets, a viable strategy could involve orientating towards regional blocs. This approach aims to position them either as local hubs for quantum technology development or as significant infrastructure players, particularly in the realm of quantum communication. This strategy is particularly relevant for countries like Australia and Russia.
11. It is crucial to pay close attention to the ethical aspects of regulating and using quantum communication. The current era necessitates efforts to initiate the development of a quantum ethics code and the establishment of an ethical and legal compliance system, both at the national and international levels.

Discussion

1. Understanding quantum communication

Quantum communication refers to a set of information technologies aimed at transmitting and protecting information, the operation of which is based on the laws of quantum physics. Quantum communication harnesses the principles of quantum mechanics, such as superposition and entanglement, to facilitate secure and efficient transmission of information (Hoofnagle & Garfinkel, 2021, p. 25). Superposition denotes the simultaneous existence of multiple states within a single object. The renowned double-slit experiment demonstrates various quantum phenomena, showcasing the dual wave-particle nature of small particles and the concept of superposition. The primary inference drawn from the experiment is that we are unable to determine which slit the individual photon traversed; instead, the photon exists as a probability wave. Unlike classical communication systems, which rely on classical bits to encode information, quantum communication employs quantum bits, or qubits, which can exist in multiple states simultaneously.

The next phenomenon under examination is quantum entanglement, wherein the quantum states of two or more entities become mutually dependent, despite being spatially distant. Entangled particles exhibit synchronized behavior, irrespective of the spatial separation between them. Empirical validation of this property was notably achieved by China in 2017 through the utilization of a quantum satellite (Juan et al., 2017, p. 4).

An additional crucial characteristic of quantum particles, exploited in quantum communication, pertains to the impossibility of cloning a quantum state (Imre, 2014, p. 139). Given that a quantum state eludes precise measurement, the act of accurately duplicating it is likewise unattainable. As a result, the replication of quantum messages inevitably introduces errors, thereby notifying the communicating parties of any observation by an external observer. Consequently, users retain the capability to consistently detect the presence of surveillance or any attempted intrusion.

Here's a simplified overview of how quantum communication works: Alice sends photons with random directions, called polarizations. Bob also randomly chooses directions to measure these photons. After Bob receives and measures the photons, Alice tells him which directions she used. Bob discards the cases where his directions didn't match Alice's and informs her where data transmission failed. Even without sharing the actual measurement results, Alice and Bob can generate the same key. Moreover, if a third party tries to interfere and measure the photons, their polarization changes, and Alice and Bob can detect errors.

The most popular application of quantum communication is quantum key distribution (QKD) (Renner, 2008, p. 9). In the process of key generation, the parties exchange photons. Due to the aforementioned quantum properties, any attempt by a third party to eavesdrop will inevitably disrupt the delicate quantum states, which the communicating parties will immediately detect (Silva et al., 2012, p. 13).

At present, the lack of regulatory frameworks governing the advancement and application of quantum technologies opens avenues for ethical and societal quandaries. Without sufficient regulations in place, these issues could arise, potentially endangering ethical norms and societal welfare (Johnson, 2019, p. 12).

2. Regulation of quantum communication in different countries

2.1. Canadian regulation of quantum communication

This country's most recent strategy is Canada's National Quantum Strategy.[1] The document emphasizes the importance of quantum communication for ensuring the confidentiality of information. A forecast is provided which predicts that the quantum sector will become a $139 billion industry in Canada by 2045, generating over 200,000 jobs and $42 billion in revenue, potentially contributing 3% of Canada's GDP.

In the section dedicated to quantum communication, the Canadian government emphasizes the crucial role of post-quantum cryptography. It is noted that a national quantum communication network, combined with post-quantum cryptography, can enhance the security of confidential information, critical applications, and infrastructure. Such a network will encompass ground and satellite infrastructure, significantly surpassing current Canadian and international capabilities. In the future, the 'quantum internet' may also be utilized by Canadian industries, such as the financial sector, which require the transmission of confidential information and compatibility of their networks with those of reliable international partners. Consequently, there is a task to promote the adoption of post-quantum cryptography and quantum communication products in order to protect data stored by the Canadian government and Canadian industry.

Among other tasks, increasing organizations' awareness of the importance of data confidentiality and quantum communication as a means of ensuring such confidentiality is highlighted. The document indicates an understanding of the importance of quantum technology and the need to encourage the private sector to invest in this area. There are no specific standards or acts aimed at regulating quantum technology. On the contrary, the strategy emphasizes Canada's international participation in the development of standards, implying that these standards will be applied in the country.

The strategy also acknowledges that quantum communication may fall into the hands of malicious actors, leading to negative consequences for security and resilience. It is noted that the

[1] Ministry of Innovation, Science and Industry. (2022). *Canada's National Quantum Strategy*. Government of Canada. https://ised-isde.canada.ca/site/national-quantum-strategy/sites/default/files/attachments/2022/NQS-SQN-eng.pdf

regulation of quantum communication should be based on principles of security, compatibility, and neutrality.

For effective regulation, the establishment of a Quantum Advisory Council is envisaged, comprising representatives from industry, science, non-profit, and investment communities. To coordinate government bodies, the creation of an Interdepartmental Quantum Committee is proposed.

In pursuit of advancements in the quantum sphere, the Canadian government plans to achieve success by providing additional funding, offering alternative forms of support for industry and research, and developing roadmaps.

Quantum communication is classified as a dual-use technology, meaning it can be used for both civilian and military purposes. According to the Wassenaar Arrangement of 1995, quantum cryptography technology is listed as a dual-use technology, which consequently imposes export restrictions on companies wishing to participate in international trade.

Thus, there are no specialized laws applicable to quantum communication in Canada. While the country's national quantum strategy lays important foundations for the further development of quantum communication, there are no plans concerning its regulation, such as identifying administrative or bureaucratic barriers. This may hinder the development of quantum communication in Canada.

2.2. EU regulation of quantum communication

A key EU strategic planning document is the European Union Strategy for Cybersecurity in the Digital Decade.[2]

In the field of quantum communication, the importance of standardization is noted. It is stated that standards acquire significant importance in addition to traditional legal regulation.

Among the issues emphasized is the importance of preventing individual countries from exploiting international standardization for their own political objectives and the emergence of competing international standardization systems.

In 2016, the EU launched a large-scale program known as the Quantum Flagship Initiative.[3] The program is aimed at supporting the work of hundreds of quantum researchers over a period of 10 years, with an expected budget of €1 billion. It is noteworthy that in the same year, 2016, the key areas of activity in the field of quantum technologies were approved to ensure the EU's leadership in the second quantum revolution. These directions are known as the Quantum Manifesto (hereinafter referred to as the Manifesto).[4] The Manifesto calls on private companies to participate in the development of quantum technology. They are provided with opportunities to engage in the creation and advancement of quantum technology through public-private partnerships, grants, and other means. The Manifesto identifies three pillars upon which the development of quantum technology, including quantum communication, relies: science, education, and technology.

Additionally, as part of the private initiative, The European Quantum Industry Consortium (QuIC) has developed the Strategic Industry Roadmap (SIR) 2024.[5] For instance, researchers note that the

[2] European Commission Joint Communication to the European Parliament and the Council JOIN (2020) 18 final, The EU's Cybersecurity Strategy for the Digital Decade. (December 16, 2020). https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A52020JC0018

[3] European Commission. (2018, October 29). *Quantum technologies flagship kicks off with first 20 projects* [Press Release]. https://ec.europa.eu/commission/presscorner/detail/en/IP_18_6205

[4] European Commission. (2016). *Quantum manifesto for quantum technologies*. https://qt.eu/media/pdf/93056_Quantum-Manifesto_WEB.pdf

[5] The European Quantum Industry Consortium. (2024). *Strategic Industry Roadmap*. https://www.euroquic.org/wp-content/uploads/2024/02/PUBLIC-version-Strategic-Industry-Roadmap-2024.pdf

most promising approach to utilizing quantum key distribution (QKD) and quantum cryptography is their synergy. Therefore, legislators should be mindful of timelines and lay the groundwork for long-term funding and support for QKD. Alongside governmental investments, this also entails recommendations and subsequent regulatory acts regarding the use of QKD-based solutions in areas where private and public information is processed and transmitted.

Additionally, a recommendation is provided for the development of regulatory acts that could assist in the development of products, especially for systems manufactured for European organizations.

It is noted that immigration controls and export control rules often do not allow non-European specialists to work in Europe outside of academic environments, and provisions on work visas typically do not specify specialists in the field of quantum technologies. Similar proposals attracting talent and creating opportunities for specialists in quantum technology can be found in many countries, such as China, Russia, and Australia. Typically, such initiatives target quantum communication engineers and developers, but rarely encompass representatives of the humanities (lawyers, ethics specialists). For the most comprehensive and thorough development and implementation of quantum communication, from both a technical and legal perspective, the candidacy of all stakeholders should be considered.

2.3. German regulation of quantum communication

In Germany, the primary act dedicated to quantum technologies, including quantum communication, is the German Government's Action Plan for Quantum Technologies.[6]

Germany views quantum communication as a technology for ensuring confidential communication.

The characteristic shortage of personnel in the field of quantum technology is noted, which is typical for many countries. Therefore, there is a need to develop a program both for educating new specialists and attracting experts from abroad.

Just like QuIC, the German government is considering a scenario involving the use of quantum communication alongside post-quantum cryptography. When combined with post-quantum cryptography based on mathematical principles, the confidentiality of sensitive information can be maintained in the long term. However, continuous monitoring of risks in the field of information security and data protection is imperative.

To coordinate government agencies, the creation of a special interdepartmental group is envisaged. Such initiatives deserve attention as they are found in many countries and are primarily aimed at overcoming bureaucratic hurdles that could significantly hinder the development of quantum communication.

Besides supporting pan-European initiatives, Germany will collaborate with national institutions, which also indicates a public-private approach.

In addition, the federal government has adopted a framework program titled 'Quantum Technologies — From Basics to Market' which outlines the following goals of the federal government:

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[6] Quantum Computing Lab. (n.d.) *Germany's action plan for quantum technologies*. Retrieved November 25, 2023, from https://www.quantumcomputinglab.cineca.it/en/2023/05/09/germanys-action-plan-for-quantum-technologies/; Bundesministerium für Bildung und Forschung [Federal Ministry of Education and Research]. (2023). *Handlungskonzept Quantentechnologien der Bundesregierung* [Federal Government's quantum technology action plan]. Bundesregierung [Federal Government]. https://qbn.world/wp-content/uploads/2023/04/Action-Plan-Quantum-Technologies-by-German-Government-2023-2026.pdf

strengthening Germany's strong positions in quantum physics research and paving the way for applications using quantum technology; creating a framework of conditions to prepare for new economic opportunities and markets; establishing a solid foundation for Germany's leading role in developing industrial applications for quantum technology; fostering international collaboration in the development of quantum technologies; informing the German population and involving them in the advancement of this new key technology.[7]

It is noted that, from the federal government's perspective, there is a particular need to develop quantum-resistant cryptographic systems that are secure against both quantum and classical computers and can operate with existing communication protocols and networks. The federal government aims to take measures in this area to maintain Germany's place as the number one encryption country. Here, arises the challenge of transitioning to new cryptographic infrastructures while also focusing on a degree of encryption flexibility.

In general, though Germany lacks specialized laws dedicated to quantum communication, it has a general strategy for quantum technology that sets the right direction for future development and regulation of quantum communication.

2.4. British regulation of quantum communication

On March 23, 2015, the United Kingdom adopted a National Quantum Technologies Strategy[8] that sets various goals and identifies actions that the British government must take. For example, one task is the development of regulatory acts and standards. It is noted that standards are a useful tool for the future development of technology, as they provide confidence and uniformity in an evolving market that can be recognized internationally by all links in the supply chain. The aim is to ensure that standards are developed at an appropriate pace and used properly to facilitate the planned development of quantum technology.

Similarly, existing regulatory acts can often be revised to unlock opportunities in the emerging market. Developing effective regulation that covers innovations in quantum technology will contribute to advancing the shared vision.

Special attention is given to the necessity of creating dialogue among all stakeholders. For instance, one of the principles for implementing standards is named as consultation with relevant stakeholders to better understand the need for standard implementation. It should be noted that such initiatives should not only pertain to standards but also to the regulation of any technology.

'Quantum communication' is also mentioned in the 2021 National Security and Investment Act, where it is defined as:[9]

(a) The transmission of information utilizing the properties of quantum mechanics, including superposition, entanglement, single-photon technology, the utilization of conjugate variables, or their combination;

(b) The utilization of communication networks (quantum or otherwise) for the distribution of quantum states or information about quantum states;

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[7] Bundesministerium für Bildung und Forschung [Federal Ministry of Education and Research]. *Quantum technologies — from basics to market*. Bundesregierung [Federal Government]. https://www.bmbf.de/SharedDocs/Publikationen/de/bmbf/5/31432_Rahmenprogramm_Quantentechnologien.pdf?__blob=publicationFile&v=3

[8] UK National Quantum Technologies Programme. (2020). *Strategic Intent*. https://uknqt.ukri.org/wp-content/uploads/2021/10/UKNQTP-Strategic-Intent-2020.pdf

[9] National Security and Investment Act 2021/1264, schedule 13 (UK). https://www.legislation.gov.uk/uksi/2021/1264/schedule/13

(c) The creation of cryptographic keys or the generation of provably random numbers using a quantum physical process.

The purpose of the mentioned law is to grant the UK government powers to scrutinize and intervene in certain acquisitions, including those made by enterprises or investors, that may pose a threat to the United Kingdom's national security. Under this law, any entity intending to acquire a company developing quantum technology is required to notify the UK government

It is also important to mention the theoretical approach to regulating quantum technology proposed by the Regulatory Horizons Council (RHC) in the 'Regulating Quantum Technology Application' report in February of 2024.[10] The main principle of this approach lies in regulating the specific application of the technology rather than the technology itself. For instance, instead of attempting to regulate quantum communication as a whole, the focus is on regulating its applications, such as in quantum key distribution. A similar approach is outlined in the German government's Quantum Technology Action Plan.

Thus, the British government views public-private partnerships as the most rational mechanism for developing and implementing quantum communication, while it is simultaneously developing national standards and participating in international standardization bodies.

2.5. Dutch regulation of quantum communication

Another prominent player in the quantum communication market is the Netherlands with its National Program on Quantum Technologies.[11] The program is a comprehensive document providing an overview of all kinds of quantum technology, their practical applications, and descriptions of the main challenges inherent in developing quantum technology. It is worth noting that the program places special emphasis on forming and utilizing the quantum internet for quantum communication. A technical challenge is highlighted concerning the deployment of the quantum internet on a large scale, which involves overcoming various issues such as achieving entanglement over long distances and enhancing the functionality of quantum networks. The program concludes that the quantum internet will operate fundamentally differently from the modern internet, requiring a new network stack architecture capable of interacting with the current internet stack and fully leveraging the specific advantages of quantum communication. The program highlights the international aspects of quantum communication.

The Netherlands considers itself a potential international leader in developing the regulatory and ethical aspects of quantum communication.

2.6. Russian regulation of quantum communication

In Russia, quantum communication is defined as a key end–to-end technology, the development of which is determined by the Roadmap for the Development of End-to-End Digital Technology, dubbed 'Quantum Technologies' (hereinafter — the Roadmap)[12] and the Passport of the Roadmap

[10] Department for Science, Innovation and Technology & Regulatory Horizons Council. (2024). *Regulating quantum technology applications*. https://assets.publishing.service.gov.uk/media/65ddc83bcf7eb10015f57f9f/RHC_regulation_of_quantum_technology_applications.pdf

[11] Quantum Delta Nederland. (2019). *National agenda for quantum technology*. https://gutech.nl/wp-content/uploads/2019/09/NAQT-2019-EN.pdf

[12] Ministry of Digital Development, Communications and Mass Media of the Russian Federation. (2019). *The roadmap for the development of "end-to-end" digital technology "quantum technologies"*. The Government of the Russian Federation. https://digital.gov.ru/uploaded/files/07102019kvantyi.pdf

for the development of the high-tech field of 'Quantum Communication' for the period up to 2024 (approved by the Ministry of Digital Development of Russia on 08/27/2020 No. 17) (hereinafter — the Passport).[13]

In the Roadmap, one of the initiatives for developing quantum communication is 'Regulatory Regulation'. As part of this initiative, the preparation and consolidation of proposals for amending existing regulations are planned, as well as consideration of proposals and preparation of draft amendments to regulations by the responsible executive authorities.

According to Federal Law No. 258-FZ of July 31, 2020, 'On Experimental Legal Regimes in the Field of Digital Innovations in the Russian Federation,' this regime can be applied to a number of technologies, the list of which is established by the resolution of the Government.[14] In the Resolution of the Government of the Russian Federation No. 1750 of October 28, 2020, 'On Approval of the List of Technologies Applied within the Framework of Experimental Legal Regimes in the Field of Digital Innovations,' that quantum technologies are among such technologies, including in the areas of quantum computing, quantum communication, quantum sensors, and metrology.[15]

In the Government of the Russian Federation's Order No. 1484-r of July 8, 2019, 'On the Signing of Agreements of Intent between the Government of the Russian Federation and State Corporations and State-Owned Companies for the Development of Certain High-Tech Directions,' Article 2 states that the implementation of the Roadmap is ensured by creating a comfortable regulatory environment, including the removal of administrative barriers, improving standardization and technical regulation, and establishing experimental legal regimes.[16]

Quantum cryptography is designated as a dual-use technology in the Resolution of the Government of the Russian Federation No. 1299 of July 19, 2022, 'On the Approval of the List of Goods and Dual-Use Technologies That Can Be Used in the Development of Weapons and Military Equipment and on Which Export Control Is Implemented'.[17]

As part of the establishment of specialized organizations, the Quantum Valley Innovation Science and Technology Center, established in accordance with the Resolution of the Government of the

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13 Passport of the «roadmap» for the development of the high-tech field «quantum communications» for the period up to 2024" (approved by the Ministry of Digital Development of Russia, Aug. 27, 2020, No. 17 (Russ.).

14 Federal'ny Zakon RF ob eksperimental'nykh pravovykh rezhimakh v sfere cifrovykh innovacij v Rossijskoj Federacii [Federal Law on Experimental Legal Regimes in the Field of Digital Innovations in the Russian Federation], Sobranie Zakonodatel'stva Rossiyskoy Federatsii [SZ RF] [Russian Federation Collection of Legislation] 2020, No. 31 (Part I), Item 5017.

15 Postanovlenie Pravitel'stva RF ob utverzhdenii perechnya tekhnologij, primenyaemykh v ramkakh eksperimental'nykh pravovykh rezhimov v sfere cifrovykh innovacij [Decree of the Government of the Russian Federation on approval of the list of technologies used within the framework of experimental legal regimes in the field of digital innovations] Oct. 28, 2020, No. 1750.

16 Rasporyazhenie Pravitel'stva RF o podpisanii Soglashenij o namereniyakh mezhdu Pravitel'stvom Rossijskoj Federacii i gosudarstvennymi korporaciyami i gosudarstvennymi kompaniyami po razvitiyu otdel'nykh napravlenij vysokikh tekhnologij» [Order No. 1484-r of July 8, 2019, 'On the Signing of Agreements of Intent between the Government of the Russian Federation and State Corporations and State-Owned Companies for the Development of Certain High-Tech Directions], Sobranie Zakonodatel'stva Rossiyskoiy Federatsii [SZ RF] [Russian Federation Collection of Legislation] 2019, No 28, Item 3824.

17 Postanovlenie Pravitel'stva Rossijskoj Federacii ob utverzhdenii perechnya tovarov i tekhnologij dvojnogo naznacheniya, kotorye mogut byt' ispol'zovany pri razrabotke vooruzheniya i voennoj tekhniki i v otnoshenii kotoryh osushchestvlyaetsya eksportnyj kontrol [Decree of the Government of the Russian Federation on the Approval of the List of Goods and Dual-Use Technologies that can be used in the Development of Weapons and Military Equipment and on which Export Control is implemented], Sobranie Zakonodatel'stva Rossiyskoiy Federatsii [SZ RF] [Russian Federation Collection of Legislation] 2022, No 30, Item 5630.

Russian Federation No. 2133 of November 30, 2021, 'On the Establishment of the Quantum Valley Innovation Science and Technology Center' (hereinafter referred to as Quantum Valley), has been created.[18] One of Quantum Valley's areas of activity is advanced digital technologies, including quantum technology and artificial intelligence. Operations within this center offer significant tax incentives (0% corporate income tax, 0% VAT, 0% property tax), which will have a positive impact on the industry's condition.

The Concept of Regulation of the Quantum Communication Industry in the Russian Federation until 2030 (hereinafter referred to as the Concept) was adopted in 2023. Among its regulatory tasks are to identify legal barriers hindering the development and application of quantum communication in various sectors of the economy and society; to shape a legal framework for the market for goods, works, and services in the quantum communication industry which is based on the national standardization and conformity assessment system; and to harmonize legal acts.

One of the regulatory initiatives involves developing legal acts in the field of quantum communication at the international level.

The first step in regulating quantum communication is to establish and define a conceptual framework. Subsequently, the goal will be to establish a legal institution to regulate the use of quantum communication within existing communication networks through the application of regulatory sandboxes.

Of particular interest is the preliminary 'Quantum Communication: Terms and Definitions' national standard (hereinafter referred to as the Standard), which identifies promising directions for developing quantum communication not only in Russia but also in other countries.

The Standard defines the term 'quantum signature' as quantum information associated with other information in electronic form (the information being signed) and used to identify the entity signing the information. Quantum signature is likely to become an additional option for remote document signing, used optionally for enhancing security or in compliance with legislation, such as in the transmission of electronic documents among critical infrastructure entities.

The term 'quantum internet' refers to a global information network based on quantum technology, where quantum information is generated, processed, and stored in nodes interconnected by quantum channels. The development of a quantum internet will raise issues related to governmental control and identification to a new level. For instance, in the EU, the Quantum Internet Alliance is engaged in the development and implementation of the quantum internet.[19]

One of the promising scenarios for the use of the quantum internet is the implementation of quantum currency, which is protected against counterfeiting due to the no-cloning theorem of quantum states. This could lead to changes in the regulation of monetary transactions. Just like for quantum communication, the development of standards will be required for the quantum internet, as noted in the Japanese Strategy for Creating the Quantum Future Industry.[20]

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[18] Postanovlenie Pravitel'stva Rossijskoj Federacii o sozdanii innovacionnogo nauchno-tekhnicheskogo centra "Kvantovaya dolina" [Resolution of the Government of the Russian Federation on the Establishment of the Quantum Valley Innovation Science and Technology Center] Sobranie Zakonodatel'stva Rossiyskoiy Federatsii [SZ RF] [Russian Federation Collection of Legislation] 2021, No 49 (Part II), Item 8318.

[19] Quantum Internet Alliance. (n.d.). *The QIA Story*. Retrieved October 23, 2023 from https://quantuminternetalliance.org/qia-story/

[20] Quantum Research Promotion Office. (n.d.). *Quantum Future Industry Creation Strategy.* Ministry of Education, Culture, Sports, Science and Technology of Japan. Retrieved October 23, 2023 from www.mext.go.jp/a_menu/shinkou/ryoushi/mext_02468.html

Thus, in Russia, there are several strategic acts that define areas for regulation and set specific tasks for improving such regulation. However, there are no specialized laws that specifically address quantum communication, nor are there laws similar to those in the United States and Korea, which establish an organizational framework for the development and implementation of quantum communication. Unlike the approach in the US and Korea, Russia tends to rely on state-oriented partnerships, as state-owned companies are involved in the development of quantum communication. In other words, Russia has adopted a state-oriented approach instead of a softer approach or co-regulation.

2.7. US regulation of quantum communication

The United States' National Quantum Initiative Act was signed into law in 2018. Its aim is to ensure the United States' continued leadership in the field of quantum technology. It emphasizes the need for international quantum security standards, thereby assigning responsibility to relevant authorities and organizations to develop and implement national standards.

Additionally, the Act provides for the establishment of special bodies and committees whose primary goal will be to conduct research in the field of quantum technology.

Additionally, in accordance with Sec. 109 of the Export Control Reform Act of 2018, the Bureau of Industry and Security classified quantum information technologies, including quantum encryption, as critical technologies for export control purposes.[21]

In 2022, the National Institute of Standards and Technology (NIST) selected the non-profit research institute SRI International to develop the first roadmap for the production of quantum technologies, which is crucial for establishing reliable and high-quality supply chains.[22]

2.8. Australian regulation of quantum communication

An Australian government corporation, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), published a roadmap for quantum technologies in 2020, (CSIRO, 2020).[23] One of the key tasks it identified was to introduce certainty in the rules governing the control of trade in defense goods, as well as to support dialogue among stakeholders to foster trust in the industry and ensure the protection of intellectual property and Australia's security.

Moreover, Australia has adopted a National Quantum Strategy.[24] The structure of the National Quantum Strategy consists of 7 objectives with proposed policy initiatives to:

1. Create a conducive environment for the development, commercialization, and utilization of quantum research, including by raising awareness and demand;
2. Strengthen Australia's global leadership in quantum research by stimulating the next wave of quantum discoveries and technological breakthroughs;
3. Make Australia a primary destination for attracting talent in the field of quantum technology and stimulate the growth of a skilled workforce to enable industry scalability;

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[21] Export Control Reform Act of 2018, H.R.5040, 115th Cong., s. 109 (2018), https://www.congress.gov/bill/115th-congress/house-bill/5040/text.

[22] SRI. (2022, September 19). *Quantum Technology Manufacturing Roadmap*. https://www.sri.com/press/story/quantum-technology-manufacturing-roadmap/

[23] Australia's National Science Agency. (2022, October 12). *Growing Australia's Quantum Technology Industry*. https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/CSIRO-futures/Future-Industries/Quantum

[24] Department of Industry, Science and Resources. (n.d.). National Quantum Strategy. Australian Government. Retrieved October 23, 2023 from https://consult.industry.gov.au/national-quantum-strategy

4. Remove barriers in the supply chain;
5. Strengthen domestic and international partnerships;
6. Create the right conditions to strengthen trust, ensure inclusivity, and balance national interests with economic opportunities.

Similar objectives are embedded in many other strategies, such as those in Russia. It is worth taking note of the initiatives aimed at removing barriers in the supply chain, such as identifying and eliminating procurement barriers within the quantum ecosystem that restrict the commercialization of quantum technology. Of interest is the attention paid to reducing the high dependency of the quantum industry on imports, including through the accumulation of reserves and expanding domestic production capacity, as well as raw material production.

Australia's vision for the development of its regulatory framework is intriguing. In its creation, a holistic approach is planned to ensure the achievement of a proper balance and to prevent unforeseen consequences of regulatory enactments. Achieving national interests in the field of quantum technologies will also require an active balance between:

- Commercial opportunities;
- The transformative impact of quantum technologies;
- National security requirements (including proper control over technologies to protect intellectual property and national interests).

Therefore, the most appropriate legal mechanisms for achieving the above-mentioned objectives may involve the piloting of experimental legal regimes.

In addition to the points mentioned, Australia has also adopted an Army Quantum Technology Roadmap.[25] It is asserted that widespread adoption of quantum networks in the near future is unlikely. Quantum communication will be limited to a few high-priority channels.

2.9. Japanese regulation of quantum communication

Japan stands out with a significant number of strategic initiatives in the field of quantum technology. There are three: Innovation Strategy in Quantum Technologies, Vision of the Quantum Society of the Future, and Strategy for Creating the Quantum Future Industry, as well as a Roadmap for Innovation strategy in the field of quantum technologies.

In the Strategy for Creating the Quantum Future Industry, it is noted that for the widespread use and dissemination of quantum communication, it will be recommended to incorporate quantum communication into rules, guidelines, etc. Additionally, the government will support the use of quantum technologies in public institutions and local government bodies. There is already a recognized need to develop new standards for the quantum internet of the future.

To expand and popularize the use of quantum cryptography communication devices, there are plans to develop a certification system for these devices by a third-party organization. It is expected that this system will be autonomous, where private companies will serve as evaluation institutions, and the responsibility will be placed on these companies and their executives.

In collaboration with industry and academic circles, the Japanese government has committed to forming a venture ecosystem in order to attract investment. This system will include mechanisms for discovering and generating new ideas (such as pitch competitions, idea/hackathons, etc.), collaboration with existing companies, cooperation between startup companies, and dissemination

[25] The Australian Army. (2021). *Army Quantum Technology Roadmap*. The Australian Government. https://researchcentre.army.gov.au/sites/default/files/RD5734_Quantum%20Roadmap%20WEB.pdf

of information about business activities, both domestically and internationally. As a result, a comprehensive innovation platform will be formed that will create and support startups through close collaboration between industry, academic circles, and the government, including support for accessing foreign markets. In other words, the emphasis is placed on public-private partnerships.

The Vision Strategy for the Quantum Future is particularly interested in addressing issues related to intellectual property, standardization, and international norm-setting, primarily for quantum computers and quantum communication. It is noted that quantum computers and quantum cryptographic communication represent complex systems that integrate various technologies, including quantum and traditional (classical) technologies, and it is expected that they will encompass diverse intellectual property in the future.

In light of this, a strategy of openness/closure is envisaged to protect intellectual property related to quantum technologies. Furthermore, issues are being considered related to mandating the licensing of inventions. For this reason, in collaboration with private companies, the government will promote an 'open-closed' strategy and encourage initiatives from the private sector. The Japanese government expects the formation of a patent pool led by the private sector in the future and the creation of a private management organization based on the 'open-closed' strategy. Furthermore, the formation of an international patent pool led by the private sector is expected to enable simultaneous licensing of multiple intellectual property assets.

In the field of investment, there is a plan to expand the use of government funds for particularly risky projects. To promote the development of the quantum market, the government and related organizations are expected to be obliged to actively procure new products for early adoption in order to stimulate demand.

A similar proposal is present in the Innovation Strategy in Quantum Technologies. Additionally, based on an agreement on an international export control regime, Japan will advocate strict control of secure trade and management systems based on its Foreign Exchange and Foreign Trade Act.

Thus, Japan offers the most comprehensive and holistic approach to the vision and future regulation of quantum technology. The government places significant emphasis on public-private partnerships in developing and financing quantum technology. There is a focus on the development of quantum computers and quantum communication. Changes in intellectual property legislation are expected to create a mechanism for compulsory licensing of inventions. Certification legislation will change to transfer this procedure into private hands, with the responsibility placed on the certifying bodies. There will be comprehensive changes in investment legislation aimed at facilitating investment and expediting the adoption and formation of the quantum technology market.

2.10. South Korean regulation of quantum communication

In 2023, amendments were added to South Korea's Special Law on Promotion of Information and Communication and Activation of Fusion. These changes allocate certain rights to the Minister of Information and Communication Technology (hereinafter referred to as the ICT Minister) and the government regarding the development of quantum communication.[26]

The ICT Minister is empowered to support and promote activities related to the standardization and certification of quantum information and communication technologies, facilitate international

[26] Special Act on Promotion of Information and Communication and Activation of Convergence, amended by Act. No. 19240, March 21, 2023 (S. Kor.).

cooperation in the field of quantum information and communication technologies, and appoint a specialized institution for the effective implementation of projects in the field of quantum communication (Article 27.2). In coordination with the governor of the city, the ICT Minister may designate areas for the development and dissemination of new quantum information and communication technology, as well as for workforce training and enhancing the competitiveness of the industry (Article 27.4).

The government is empowered to determine the priority of support measures for high-tech and venture enterprises utilizing quantum information and communication technology, as well as for enterprises initiating entrepreneurial activities using quantum information and communication technology (Article 27.3).

On October 6, 2023, the Quantum Scientific Technology Development and Industry Act (hereafter referred to as the Quantum Technology Industry Act) was enacted. The main content of this act revolves around establishing an institutional framework to provide various forms of support for developing quantum scientific technology and industry.[27]

The aim of the Act is to promote scientific and technological innovation, national security, and the development of the national economy by establishing a research base in the field of quantum science and technology and systematically developing the quantum industry.

The government's Ministry of Science and Information Technology is specifically tasked with creating a plan for the development of quantum science and technology every five years. This plan must address issues related to standardization and the protection of intellectual property rights.

Article 13 of the Quantum Technology Industry Act specifically establishes the right of patent holders to present the results of intellectual activities under an exclusive license. Apparently, this measure is aimed at combating potential illegal dissemination of quantum technology.

Additionally, the government is tasked with supporting startups related to quantum technology by providing them with workspace and conference rooms to foster the development of the quantum industry.

South Korea is actively engaged in standardizing quantum communication technology both at the national level and internationally.[28]

Thus, the regulation of quantum communication in South Korea resembles that in the United States. There are laws establishing an institutional framework for organizing, financing, developing, and applying quantum technology. Responsible bodies are designated or created to carry out relevant duties. Alongside this, there is parallel development of quantum communication standards both at the national and international levels.

2.11. Chinese regulation of quantum communication

China's primary strategic document is the 'Made in China 2025' National Plan (hereinafter referred to as the National Plan),[29] and also the current 14th Five-Year Plan for China's Social and Economic Development (2021-2025). In these documents, there are declarations of "major breakthroughs," including in the field of quantum technology.

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27 Quantum Science and Technology and Quantum Industry Fostering Act (S. Kor.).

28 Quantum Information and Communication Research Association. (2018). *Standardization for Quantum Key Distribution*. Ministry of Science and ICT. https://scienceon.kisti.re.kr/srch/selectPORSrchReport.do?cn=TRKO202100006406

29 FDI China. (2022, June 22). *Made In China 2025: The Plan to Dominate Manufacturing and High-Tech Industries*. https://fdichina.com/blog/made-in-china-2025-plan-to-dominate-manufacturing/

According to the National Plan, the development of quantum technology will be driven by systematic education in the field of quantum technology, the advancement of numerous national innovation projects, and the establishment of laboratories. Significant state funding is expected to contribute to substantial achievements in the development of quantum technology. The funding is primarily directed towards the commercialization of quantum communication technology.

In 2018, a draft of a national standard dubbed 'Terminology and Definitions of Quantum Communication' was introduced.[30] This document provides definitions of concepts and terms in the field of quantum communication, including quantum communication technology, in both a broad and narrow sense, as well as terms related to the quantum information processing technology involved in quantum communication. The project focuses on defining terms related to current practical quantum key distribution technology, standardizing the description of quantum key distribution technology in industries related to quantum communication, and providing reference materials for the application of this technology in existing networks, as well as its evaluation and testing.

China enacted an Encryption Law in 2020, which regulates the use and development of cryptographic technologies, including those used in quantum communication. Additionally, there is a Cybersecurity Law enacted in 2016, which requires network operators to take measures to protect the security of their networks and the information they handle, including quantum communication networks.[31]

3. Ethical regulation

Ethical regulation could indeed emerge as a promising approach for guiding the development and deployment of quantum technology. It has the potential to influence all other forms of regulation and could serve as a foundation for governing quantum technology. There are already proposals in Europe for conducting Quantum Impact Assessments (QIA) to evaluate the legality, ethics, social implications, and technical reliability of quantum technologies throughout their lifecycle. This holistic approach could help ensure that quantum technologies are developed and used in a responsible and socially beneficial manner.[32] The following rules are proposed:

1. Ensuring the integrity of quantum systems storing and transmitting information, as well as auditing information processing by quantum systems;
2. Providing traceability, testability, and predictability of actions performed by the quantum system;
3. Compliance with the intellectual property rights of third parties;
4. Respecting individuals' privacy, confidentiality of information, fundamental ethical principles, and industry laws and regulations related to the application of quantum technology;
5. Clarifying and delineating responsibilities within the chain of development — component application — service provision.

As part of the quantum technology and quantum communication impact assessment, interdisciplinary groups are envisaged to be established. These groups will formulate future implementation plans for Quantum Impact Assessment (QIA) within each sector (such as healthcare, agriculture,

[30] Ministry of Industry and Information Technology. (2018). *Quantum Communication Terminologies and Definitions*. National public service platform for standards unformation. https://std.samr.gov.cn/gb/search/gbDetailed?id=61FF4F6132FD4278E05397BE0A0A893B

[31] Network Security Law of the People's Republic of China (promulgated by the Standing Comm. Nat'l People's Cong., Nov. 7, 2016, effective June 1, 2017) (China).

[32] Kop, M. (2021, March 30). *Establishing a legal-ethical framework for quantum technology.* Yale Journal of Law & Technology Blog. https://yjolt.org/blog/establishing-legal-ethical-framework-quantum-technology

energy, finance, transportation, education, media, arts and entertainment, defense) with the aim of monitoring and influencing the social consequences of deploying quantum technology.[33]

Here are the proposed principles for the responsible implementation of quantum communication by some authors (Kop et al., 2023, p. 12):

1. Consideration of information security as an integral part of quantum communication aimed at eliminating security threats;
2. Prevention of the malicious use of quantum technology and mitigation of risks of dual-use;
3. Pursuit of international cooperation based on shared values, guided by the 'winner-takes-all' principle;
4. Balance between transparency and secrecy;
5. Establish an ecosystem for studying the potential uses and consequences of quantum technologies, expanding our understanding of responsible quantum technology usage;

Conclusion

Quantum communication is already part of the market in many countries. However, the regulation of quantum communication is still in its infancy and consists of a scattered array of acts, with a focus on strategic planning documents and roadmaps. A projected scenario for the development of quantum communication regulation may involve an increase in the number of laws establishing the organizational framework for the implementation, testing, and development of quantum communication. Subsequently, targeted amendments to laws concerning critical infrastructure, information security, telecommunications, and electronic signatures are expected. Anticipated changes may become subjects for further research and investigation.

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[33] Kop, M. (2023, April 20). *Quantum Technology Impact Assessment*. European Commission. https://futurium.ec.europa.eu/en/european-ai-alliance/best-practices/quantum-technology-impact-assessment

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