China Petroleum Processing and Petrochemical Technology

Catalyst Research Volume 23, Issue 2, October 2023 Pp. 2678-2700

CHALLENGES AND FUTURE PROSPECTS OF NANOTECHNOLOGY-ENABLED QUANTUM COMMUNICATION FOR OBJECT TELEPORTATION: A SYSTEMATIC REVIEW

Dillip Kumar Mishra,1* Dr Bunil Kumar Balabantaray 2 Dr Debendra Das 3
1* Department of Computer Science and Engineering, National Institute of Technology,
Meghalaya, Shillong, 793003, India
(P22cs002@nitm.ac.in)
3 Department of Computer Science and Engineering, National Institute of Technology,
Meghalaya, Shillong, 793003, India
(bunil@nitm.ac.in)
2 Department of Mechanical Engineering, University of Alaska Fairbanks, Tanana Drive,
Fairbanks, AK 99775, United States
(dkdas@alaska.edu)

ABSTRACT

Teleportation in the quantum realm transmits quantum data between two distant quantum objects (a sender and a receiver) by exploiting a phenomenon known as quantum entanglement. Information and quantum states could be sent across great distances through Quantum Communication (QC), bypassing the constraints of classical communication. Teleportation is made possible by entanglement phenomena, which causes particles to become associated despite their spatial separation. Nanotechnology is essential because it can control and manipulate individual atoms, molecules, and particles. This Systematic Review (SR) paper presents the challenges and prospects of nanotechnology-enabled QC for object Teleportation. From a yield of 1284 studies collected, 90 empirical studies have met the eligibility criteria and were extensively analyzed. This study summarizes Quantum Teleportation's (QTs) fundamental theory and contemporary scientific and industrial applications. The findings of recent studies and the challenges that need to be solved in the future. The concluding section will discuss the evolution of QT and its envisioned future implementation possibilities.

Keywords: Quantum Communications (QCs), Quantum Teleportation (QT), Nanotechnology, Quantum Physics, Quantum Entanglement.

INTRODUCTION

Teleportation refers to the hypothetical movement of material or energetic particles from one location to another without the need to go through the intervening area. This idea is often explored in works of science fiction and other forms of popular media. Since the time it takes to teleport from one location to another is unpredictable (sometimes instantaneous), it's unsurprising that time travel is commonly combined with Teleportation. It is the apport, which is discussed in parapsychology and spiritualism. The physical mechanism required for Teleportation does not exist. Although the word "teleportation" often appears in scientific and media publications, most of these pieces focus on so-called "Quantum Teleportation (QT)," a system for information transmission that, according to the no-communication theorem, nevertheless would not provide faster-than-light communication.

QT is widely acknowledged as a key step in practically implementing quantum information [1–3]. QT, a new and unique quantum phenomenon, is also of fundamental theoretical significance because it calls for an accurate study of quantum measurement and entanglement dynamics under situations that more closely mimic those in the actual world. These basic questions must be better understood and clarified as we enter a new age of quantum sciences and engineering. It comprises quantum non-locality and relativistic locality, spacelike correlations and causality, and quantum and classical information. The investigation of these challenges in a relativistic context now falls within the scope of a new science known as relativistic quantum information [4-5]. The following procedures are required to successfully teleport a quantum state ψ from location A to location B, often called Alice and Bob.

- Quantum state entanglement between Alice's and Bob's qubits.
- Preparation of teleported state ψ
- Entanglement of Alice's qubit with ψ
- Bell measurement on two qubits possessed by Alice.
- Alice sends Bob the results from the measurements along a traditional route.
- Bob's qubit cannot be operated on until Alice has completed its measurements.

Bennett et al. [6] provide the following circuit to illustrate the procedure: Figure 1 depicts the circuit of Teleportation.

The objective of challenges and prospects of nanotechnology-enabled QC for object Teleportation would be to develop a reliable and efficient means of transporting physical objects from one location to another without needing physical movement. Some potential objectives for such a system and method could include:

- Develop a theoretical framework for QT using advanced QC and nanotechnology principles.
- Explore novel techniques to enhance the efficiency and fidelity of QT processes by integrating nanotechnology components.
- Establish secure and efficient protocols for information transfer through QT, addressing potential applications in secure communication and quantum computing.
- Develop guidelines and recommendations for future research and development in QC-enabled Teleportation and its integration with nanotechnology.
- Overall, developing a system and method for object teleportation using concepts of QC and nanotechnology would potentially revolutionize transportation and logistics, enabling rapid and efficient movement of goods and materials across the globe.
- Several prerequisites must be fulfilled for successful QT.
- The variety of possible data inputs is unlimited.

- Aside from the sender and the receiver, a third party could provide the input data and verify the result.
- A complete Bell measurement is achieved.
- It is possible to begin conditional unitary transmission before third-party verification.
- The teleportation fidelity must be greater than the required minimum of the classical protocol.

Conditions (3) and (4) are not frequently met since only a small subset of the Bell measurement is practical, and the feed-forward is either not completed or imitated in post-processing. The teleportation issue in the actual world could be somewhat different. When increasing the number of dimensions, say from 2 to N, care must be taken to ensure that the teleportation process remains unaffected by the additional dimensions. The scheme could require certain fundamental assumptions that can be used for all dimensional Teleportation in addition to certain hypotheses that are only applicable in N dimensions for there to be real N-dimensional teleportation. Other challenges to address are light propagation losses and the atomic coherence lifetime, highlighted by the classical protocol.

This Systematic Literature Review (SLR) consists of five sections and is structured as follows: Section 1 introduces QT. Section 2 presents the review methodology, the research question, and the data collection procedure. Section 3 exemplifies the relevant blockchain scalability research based on our research questions. Section 4 describes the applications of Nanotechnology. Section 5 defines the challenges of nanotechnology-enabled quantum communication for Teleportation, and Section 6 concludes the conclusion and outlook of this paper.

Quantum Teleportation

QT is one of the most intriguing predictions of quantum theory, and it has been intensively studied since its initial demonstrations over 20 years ago. It is because of its importance in developing quantum information technologies [7-10], like quantum computers and networks, and its links to more basic branches of physics. A quantum network's primary function is to facilitate the dispersion of qubits among several nodes, which is essential for implementing quantum cryptography, distributed quantum computing, and sensing. The term "quantum network" refers to a group of interconnected quantum devices (such as quantum computers, quantum sensors, or users) that could share quantum resources (such as qubits and entangled states) over physical distances [11]. QT is essential in many quantum network designs, including star-type networks that disperse entanglement from a centralized point and quantum repeaters that circumvent the rate-loss trade-off of direct transmission of qubits [12–13]. It is possible to teleport a qubit via a Bell-State Measurement (BSM) between the qubit in question and another qubit that is part of an entangled Bell state [14-15]. The quality of the Teleportation is often characterized by the fidelity $F = \psi| \rho |\psi$ of the teleported state ρ for the state $|\psi|$ accomplished by ideal generation and Teleportation [16]. This measure is becoming more important as quantum networks go beyond specialized applications like Quantum Key Distribution (QKD) and toward the quantum Internet [17]. A simplified diagram of the teleportation procedure is shown in Figure 2.

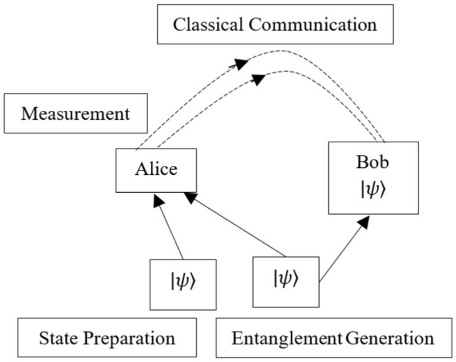


Figure 2. Each of Alice and Bob receives a part of an entangled state.

Let's assume Alice has been fed an input of an unspecified qubit state.

$$|\psi\rangle_{A_0} = \alpha|0\rangle_{A_0} + \beta|1\rangle_{A_0} \tag{1}$$

where A0 represents the subsystem, assuming Alice and Bob both own one-half of the state.

$$|\Phi^+\rangle_{A_1B} = \tfrac{1}{\sqrt{2}}(|100\rangle + |11\rangle)_{A_1B} \tag{2}$$

where A_1 is the subsystem belonging to Alice, and B is the subsystem belonging to Bob. Since it is entangled, there is no way to express this state mathematically as the sum of two separate particles' states. The total condition of the three parts could be represented as,

$$|\emptyset\rangle = |\psi\rangle_{A_0}|\emptyset\rangle$$

$$|\phi\rangle = |\psi\rangle_{A_0}|\phi^+\rangle_{A_1B} = \tfrac{1}{\sqrt{2}}(\alpha|000\rangle + \alpha|011\rangle + \beta|011\rangle + \beta|011\rangle) \tag{3}$$

Alice then measures the combined. A_0 A_1 system in the basis.

$$|\Psi^\pm\rangle_A = \frac{1}{\sqrt{2}}(|01\rangle \pm |10\rangle)_{A_0A_1}$$

$$|\phi^\pm\rangle_A = \tfrac{1}{\sqrt{2}}(|00\rangle \pm |11\rangle)_{A_0A_1} \tag{4}$$

The combined state could be described in this structure so that potential measurement results can be shown.

$$|\phi\rangle = \tfrac{1}{2}((|\Psi^\pm\rangle_A(\alpha|0\rangle_B + \beta|1\rangle_B) + |\phi^-\rangle_A)(\alpha|0\rangle_B - \beta|1\rangle_B) + |\Psi^\pm\rangle_A(\beta|0\rangle_B + \alpha|1\rangle_B) + |\Psi^-\rangle_A(-\beta|0\rangle_B + \alpha|1\rangle_B) \tag{5}$$

The possibilities for Bob's post-measurement state are,

$$\alpha|0\rangle_B + \beta|1\rangle_B$$
$$\alpha|0\rangle_B - \beta|1\rangle_B$$
$$\beta|0\rangle_B + \alpha|1\rangle_B$$
$$-\beta|0\rangle_B - \alpha|1\rangle_B$$

Each of these states is related to |ψiA0 by a unitary transformation, although in the first case, the transformation would be the identity since it is identical to the input state. Since the form of the unitary transformation depends on the outcome of Alice's measurement, Bob can recover |ψi at his location if Alice communicates the outcome of her measurement, and he can apply the correct transformation to his post-measurement state. Next, Alice used entanglement and classical communication to send Bob the input state [18].

The protocol is a straightforward representation of the strategy or algorithm that generates the Teleportation [19]. It suggests that the protocol can be modified to increase teleportation accuracy. Here, the most basic protocol is presented so readers can grasp its essence. The protocol's stages, which could be thought of as an algorithm, are as follows:

The transported qubit is one of Alice's whose state is now uncertain.

Alice and Bob both have two qubits in Bell State, but they share them. Bob and Alice have an entangled qubit but an unentangled qubit in an unknown state.

Alice does a Bell test and gets four results, where βn is an integer. This procedure eliminates the potential for identifying the qubit in an obscured state.

The protocol is a straightforward representation of the strategy or algorithm that generates the Teleportation [19]. It suggests that the protocol can be modified to increase teleportation accuracy. Here, the most basic protocol is presented so readers can grasp its essence. The protocol's stages, which could be thought of as an algorithm, are as follows:

The transported qubit is one of Alice's whose state is now uncertain.

Alice and Bob both have two qubits in Bell State, but they share them. Bob and Alice have an entangled qubit but an unentangled qubit in an unknown state.

Alice does a Bell test and gets four results, where βn is an integer. This procedure eliminates the potential for identifying the qubit in an obscured state.

$$(\alpha|\rangle+\beta|1\rangle)(00+11) = \frac{1}{2}\{\beta_0(\alpha0+\beta1)+\beta_1(\alpha1+\beta0)+\beta_2(\alpha0+\beta1)+\beta_3(-\alpha1+\beta0)\} \tag{6}$$

Each βn one with equal probability.

Alice transmits Bob the metric readings over any available classical information route.

Bob restores the original unknown state by performing the necessary modifications based on the four results of Alice's measurements. Finally, Bob returns to his initial uncertain condition [20]. Figure 3 depicts a schematic of this procedure.

Finally, Bob returns to his initial uncertain condition [21]. Figure 3 depicts a schematic of this procedure.

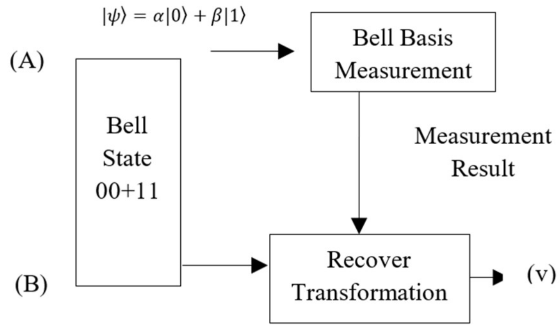


Figure 3. A simplified diagram illustrates a qubit's protocol transported between Alice and Bob [22].

Applications of Quantum Teleportation

The following applications of QT are explained in given below:

Quantum Cryptography

Hostile network settings are the norm. The information being communicated must be encrypted for data integrity and security reasons. Therefore, cryptography is essential to the operation of any Internet. QKD is widely recognized as the most popular quantum cryptography for key exchange. Its purpose is to facilitate the exchange of conventional secret keys between two entities in a quantum setting. People are putting it into practice [23-25]. It is well-known for the quantum aspect of its measurement-based intrusion detection, cf. the "unconditional security" [26]. The development and use of QKD's offshoots are also continuing. Other efforts exist to create other unique cryptographic systems apart from QKD [27-28]. Since quantum computers threaten classical encryption, post-quantum cryptography (using classical computers) has been offered as a classical alternative [29]. Finally, there would always be cryptographic goods (like blockchains) involved. Similar attention has been paid to its analogs and offshoots in quantum computing [30-32]. Figure 4 illustrates the architecture of Quantum Cryptography.

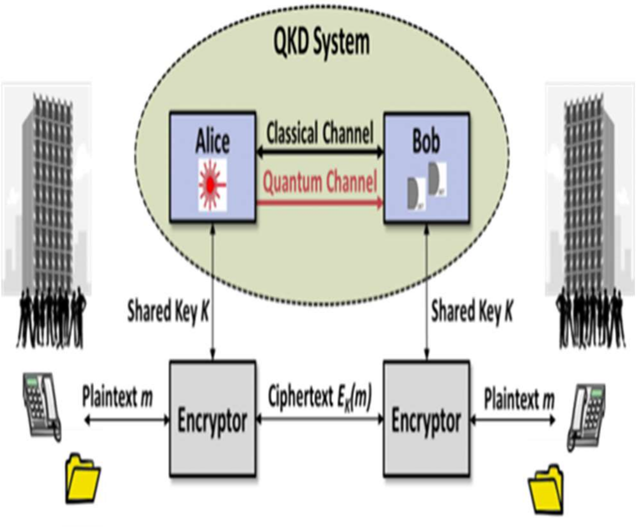


Figure 4. The architecture of Quantum Cryptography [33].

Quantum Computing

Quantum computing is based on quantum mechanics, a field more recognizable to and focused on by physicists than computer scientists or software developers [34]. Recently, however, quantum algorithms and Quantum Programming Languages (QPL) have emerged, allowing software developers to take advantage of the theory and principle of quantum mechanics to deal with information and execute computation tasks at speeds previously only achievable by classical computing systems [35-36]. The efficiency with which certain computationally difficult problems, such as those involving nature-inspired computing, financial modeling, and advanced encryption, can be solved by quantum methods is significantly higher than traditional approaches [37-38]. At the core of quantum information processing are characteristics of quantum computing (such as Qubits, superposition, entanglement, and interference) [39-40].

Quantum Communication

A branch of quantum information theory, QC addresses data transmission using quantum properties like superposition and entanglement. Specifically, it seeks to exceed classical communication protocols in efficiency and security by constructing quantum channels to exchange quantum resources, particularly quantum states, and secure classical channels [41-42]. QT is one of the most well-known QC techniques to transmit data about an unknown quantum state from one party using an entangled resource and conventional communication to a second party at a different location. It was originally developed for discrete-variable quantum states, but the protocol has also been investigated in continuous-variable contexts [43-45]. QKD, which is based on two separate protocols (BB84 and E91), is another well-known benefit of QC. According to quantum rules, these protocols enable two parties at a distance to generate a random key that is completely safe from eavesdroppers [46-47]. Quantum entanglement distribution exchanges entangled states across communication partners and are essential to several QC protocols [48]. It is also an important aspect of the well-known quantum internet concept [49]. It has been accomplished empirically [50], along with QKD [51] and QT, through optical fibers and free space. Quantum computing, quantum sensing [52], and quantum metrology [53] are all related fields that have advanced with QC. Distributed quantum computing [54-56] is one idea for facilitating the effective transport of quantum information across processing units, which are predicted to have applications in quantum computing.

REVIEW METHODOLOGY

This SRs methodology follows the guidelines established by the Preferred Reporting Items for SRs and Meta-Analyses (PRISMA) statements. PRISMA is a concise, evidence-based report of SRs and meta-analyses. Its primary use is to assess interference effects, but it could also be used to document SRs whose goals differ from interference assessment (such as determining prevalence, making a diagnosis, or predicting outcomes).

Eligibility Criteria

It is also required to manually go through the bibliographies of all relevant articles and reviews. The remaining paperwork was also scrutinized extensively. To identify which studies should be included and which should be excluded from this SR, look at their supplementary information and abstracts using the criteria provided in Table 1.

Table 1. Systematic Review Criteria for Inclusion and Exclusion

Inclusion Criteria	Exclusion Criteria
I1: The paper should be peer-reviewed	E1: Papers that do not focus on the body stress-related study.
I2: The paper should be in the English language.	E2: Grey literature
I3: No time frame limit for publication	E3: Duplicate research and publications
I4: Papers should be published in research or full-article publication.	E4: Ph.D. theses, working papers, and project deliverables
I5: Standard of paper was blind to impact factor	

The subsequent phase in our study method was selecting appropriate internet sources and online databases to gather information. Eight of the most relevant texts written by scholars in domains connected to computer technology were selected. On June 6th, 2023, a last search was conducted. We mostly utilized the following databases:

- IEEE
- Springer
- Scopus
- Science Direct
- Search Strategy

An SLR focuses on the challenges and prospects of nanotechnology-enabled QC for object teleportation and appropriate case-base structure for the collected cases to enable their effective retrieval. as part of this endeavor. Science Direct, IEEE Xplore, Springer, and Scopus are the first databases used to gather information. Authors perform SLRs to gather data about recent studies important to their research question or subject.

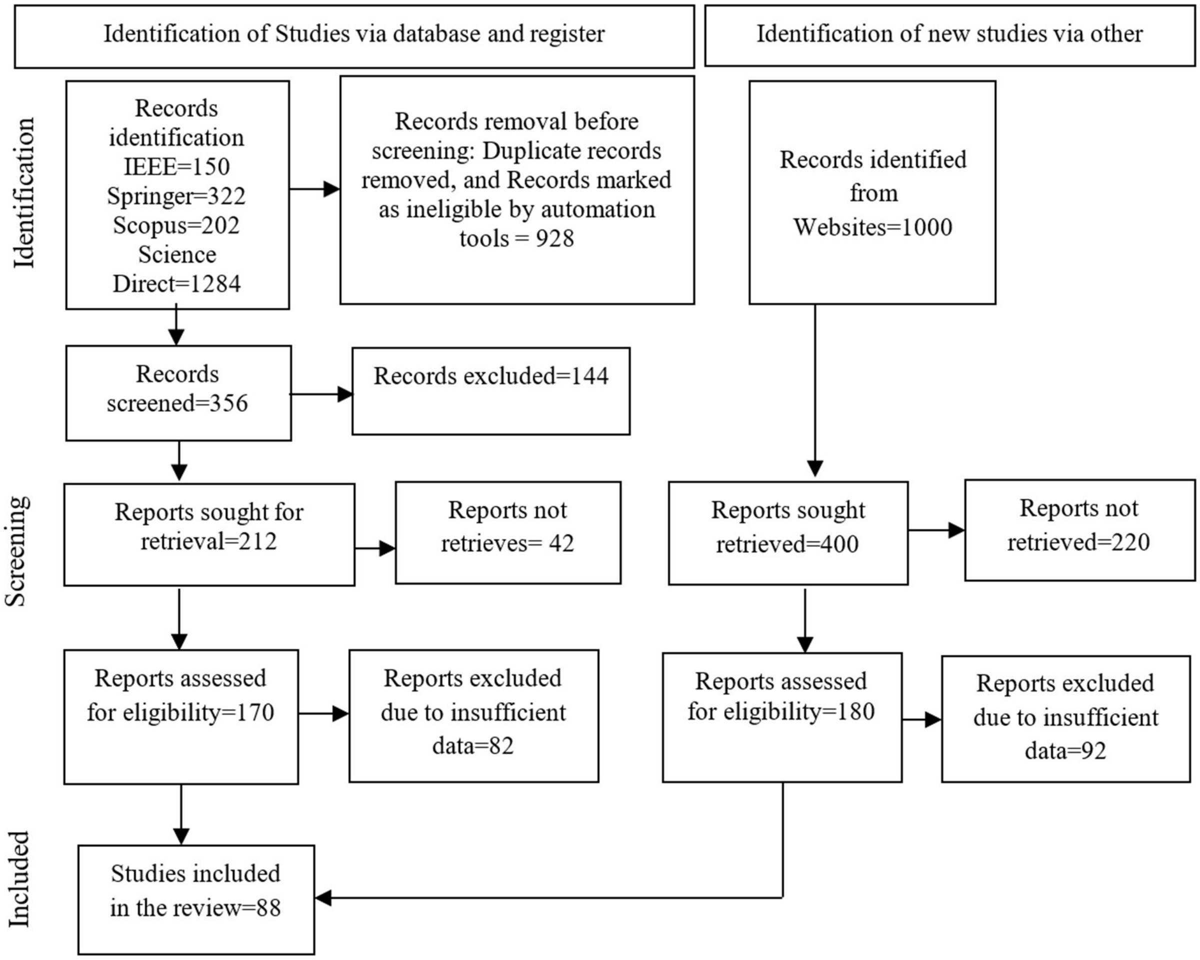
The most recent search was performed on March 25th, 2023, and extensive keyword-based database searches were performed to track down relevant scholarly literature. Scopus and other databases were searched for the relevant keywords in both the title and abstract and the title and abstract with no time limit. Only articles, reviews, proceedings papers, annotated bibliographies, and articles were accepted, along with articles, reviews, and conference proceedings. The keywords searched for in Scopus and Near are shown in Table 2. Multiple variations of the keyword's spelling were also analyzed. There were eight items altogether in this group. The keywords used in the search strategy are listed in Table 2.

Table 2. Search strategy keywords.

	Keywords
1.	What is the Quantum Teleportation?
2.	What are the fundamental principles of quantum communication and nanotechnology that can be used to enable the teleportation of objects?
3.	What is the theoretical framework for the use of quantum communication and nanotechnology in teleportation?
4.	How does the use of quantum entanglement enable the teleportation of quantum states?
5.	How can nanotechnology be used to improve the efficiency and reliability of QT systems?
6.	What is the current state of research in the field of teleportation, and what are the existing methods for teleportation of objects?

Scrutinizing of paper for study

Four steps are involved in the Primary Studies (PS) selection process: detection, admissibility, inclusion, and repeated screening. There were 2375 results from the original search. Therefore, the first step is to determine every possibly relevant paper. Conference proceedings were discovered after an exhaustive search of several online libraries and archives, including full-text papers, Science Direct, Springer, Scopus, and IEEE Xplore. After screening and analyzing all the results for duplicates, we were left with 217 studies, of which 28% were concerned with identifying emotional stress, 17% with determining scientific viability and consistency, and 33% were exploratory studies of new scientific applications and advancements. The second phase involves a preliminary review using the title, keyword, and abstract screening. Currently, 2335 records have been excluded due to failings to meet inclusion criteria, most notably regarding study scope and optimization subject. These two records were sent for further evaluation together with the ambiguous records. According to Figure 5, an SR database assessment is shown.



These SRs want to construct an open-source knowledge platform to facilitate future research by collecting and assessing key findings from previous research, summarizing, and comparing these results, and highlighting difficulties and restrictions arising from the study. Research on challenges and prospects of nanotechnology-enabled QC for object teleportation was undertaken by assessing the current level of information in the field. The three main research questions formulated at the study's conception stage provide the basis for this section's discussion and evaluation of various investigators and their methodologies. The following are the investigation questions:

RQ 1: What is Nanotechnology?

RQ 2: How can nanotechnology enhance QC for the potential of object teleportation?

RQ 3: What are the main challenges in implementing nanotechnology-enabled QC for object teleportation?

RQ 4: What is Quantum Entanglement?

An extensive exploration of existing literature was undertaken to initiate the pursuit of these objectives. Utilizing resources such as Sage, Emerald, Google Scholar, MDPI, Science Direct, IEEE Xplore, and Springer Link, citation indexing databases, as well as online publication repositories, were thoroughly searched to locate relevant papers published in the past decade about the subject of the study. Additionally, a web investigation was conducted to pinpoint the foremost manufacturers of wrist-mounted technology. The conclusions drawn from this endeavor were scrutinized by incorporating insights from white papers, manufacturing manuals, and academic publications.

NANOTECHNOLOGY

RQ1: What is Nanotechnology?

Nanotechnology is the capacity to compute, operate, and arrange matter at the nanoscale level. Typically, 1-100 nm in at least one dimension is meant; However, the scale is commonly expanded to cover materials smaller than 1 nm in size [57-58]. It's not confined to any industry; rather, it's a set of enabling technologies that could be used in any field of study. To better comprehend and modify biosystems, which use biological ideas and materials in the construction of novel - nanoscale devices and systems [59-60], nanotechnology employs the philosophy and methods of the nanoscale. Nanostructures, created to exhibit unique chemical, physical, and biological properties, are among the most amazing synthetic materials [61]. Such properties enable an unprecedented breadth of uses for nanostructures across industries, including electronics, agriculture, and medicine [62]. Nanoparticles provide an ideal medium for communicating with biological systems, one of the many ways nanotechnologies bridge the gap between the macro- and microscopical worlds. As shown in Figure 6, the interdependence of the wet, dry, and computational dimensions is essential to their successful functioning.

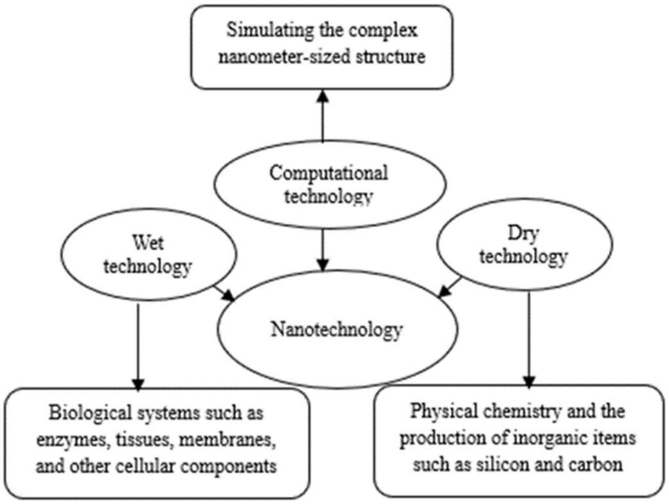


Figure 6. Some of the types of Nanotechnology [63].

Nanoparticles are distinguished from bulk materials by their unique characteristics, such as their enormous active surfaces, imaging labels, and ligands which could bind to tiny molecule medicines, peptides, and nucleic acids. They are so tiny that they can interact with cells only on the inside and outside, allowing for processes like extravasation through endothelial cells and enhanced permeability and retention in tumor tissues [64-66]. Xu J. et al., (2021) [67] showed an innovative approach to building quantum multi-hop networks that can withstand more interference while using less power. Teleportation is only conceivable in a framework where entanglement could be bought, sold, fused, and cleansed. They also develop the procedure for disinfecting the system and making it secure. Results from the simulations show how accurately entanglement was created. Cirq is used on the platform, which stands for Noisy Intermediate-Scale Quantum (NISQ), to safeguard data transmissions. The latter proves more robust when comparing the Bell states system with the fusion approach, especially as the network size expands. Energy efficiency and throughput must be optimized in a multi-hop quantum network. Daei O. et al., (2020) [68] purpose of this research is to reduce communication overhead in quantum circuits spread throughout a network.

For this reason, we provide a technique for constructing distributed quantum circuits from monolithic quantum circuits to minimize the need for information to flow back and forth between the various nodes in a distributed quantum circuit. Using these standard quantum circuits, we can evaluate the efficacy of our method and demonstrate that partitioning is a crucial stage in designing a distributed quantum circuit. Song D. et al., (2018) [69] established protocols for sending information between GHZ and W states through a quantum channel based on the Brown state. By performing a quantum Fourier transform on Alice's quantum states, it may determine the orthogonal basis onto which her states are projected. They determine the unitary operations Bob must carry out to restore the teleported states by the principle of quantum mechanics. Next, we extend our protocols to a more generic multi-qubit setting. They demonstrate that our technique could be readily applied to a network of several qubits. This approach of locating the projective basis through QFT is universal and time-efficient, and it could find usage in QC. Table 3 describes the summary of the literature review revised by different authors.

Table 3. Summary of Literature Review

Authors	Technique Used	Outcomes
Xu J. et al., (2021) [67]	NISQ	Finally, simulation results demonstrate that the offered technique is superior in balancing network performance and consumption
Daei O. et al., (2020) [68]	QKD	The authors validated the efficacy of our technique on the test circuits by comparing it to a random partitioning approach
Song D. et al., (2018) [69]	QFT	They demonstrate that our methods generalize well to a state with many qubits.

RQ2: How can nanotechnology enhance QC for the potential of object teleportation?

Nanotechnology promises to revolutionize QC, potentially paving the way for remarkable advancements such as object teleportation. By leveraging the precise control and manipulation of matter at the nanoscale, researchers can engineer materials and devices with unprecedented properties that facilitate the efficient transmission and manipulation of quantum information. One of the significant challenges in QC is maintaining the delicate quantum states of particles over long distances, often thwarted by environmental interference. Nanotechnology-enabled solutions could provide highly sensitive sensors and error-correcting mechanisms at the quantum level, enhancing the fidelity and reliability of QC channels. Furthermore, nanoscale structures could be designed to generate, store, and manipulate entanglement-a fundamental property of quantum systems— thereby enhancing the teleportation process. While the Teleportation of macroscopic objects remains speculative and far from practical implementation, nanotechnology's integration into QC lays a crucial foundation for future breakthroughs, edging us closer to harnessing the extraordinary potential of object teleportation. Ali M. et al., (2023) [70] indicated that the foundations of QC have been laid; the development of QC covering a broad range of technologies and applications; and the presentation of QKD, one of the most intriguing uses of quantum security. In addition, we look at a wide range of critical characteristics and approaches for improving the security, processing, and communication capabilities of 6G networks. Future directions have been discussed, and some problems for QC in 6G have been addressed. Paudel H. et al., (2022) [71] described the current state of quantum computing and simulators from both a mathematical and scientific perspective. Then, we focus on the many energy-related uses of this technology. Finally, they provide an evaluation of high-value application paths for resolving problems in the energy industry. Wu H. et al., (2022) [72] investigated the light-diminishing properties of seawater using a model built on chlorophyll content in seawater. Specifically, we propose using a Noiseless Linear Amplifier (NLA) to boost CVQT efficiency in a marine environment. The suggested technique outperforms the initial system in simulations measuring fidelity and maximum transmission distance. Rota M. et al., (2020) [73] described the three-photon state teleportation and four-photon entanglement teleportation tests, which both exploit the non-local features of entanglement to transfer quantum states. We analyze all the experimental findings while considering a theoretical model and create a to accommodate the quantum source's imperfections. The tight agreement between theory and practice provides a thorough grasp of how the source parameters impact teleportation fidelity and precisely identifies the need for going beyond the classical constraints. Table 4 describes the summary of the literature review revised by different authors.

Table 4. Summary of Literature Review

Authors	Technique Used	Outcomes
Ali M. et al., (2023) [70]	QKD	The results of this study could be useful to QC researchers and scientists as they design for the development of future quantum-enabled 6G networks.
Paudel H. et al., (2022) [71]	Quantum Algorithms	The time and resource efficiency with which these techniques solved several test tasks was encouraging.
Wu H. et al., (2022) [72]	NLA	Results from a simulated environment demonstrate that the NLA-based approach mitigates the impact of channel loss on the entanglement generator, resulting in better overall system performance.
Rota M. et al., (2020) [73]	Quantum Algorithm	This study indicates that QDs can produce entangled photon pairs with energy that could be tuned, indistinguishability and entanglement levels

		unmatched by any other non-classical light source, and ultra-low multiphoton emission properties

RQ3: What are the main challenges in implementing nanotechnology-enabled QC for object teleportation?

Nanotechnology-enabled QC for object teleportation involves using nanoscale systems to manipulate and control individual quantum states and particles. While the field of QC and Teleportation is rapidly evolving, several challenges and considerations exist, which may include: Quantum Entanglement Generation and Preservation: Teleportation relies on establishing and maintaining entanglement between particles, ensuring that their quantum states remain correlated regardless of distance. Achieving and preserving entanglement in nanoscale systems can be challenging due to decoherence caused by environmental interactions, which can disrupt the delicate quantum states.

- Quantum State Measurement and Detection: For Teleportation, the sender must perform a joint measurement on the entangled particles and then communicate the measurement outcomes to the receiver. Achieving precise and efficient quantum state measurement and detection at the nanoscale is a significant technical challenge.
- Nanoscale Control and Manipulation: Nanotechnology is crucial in enabling precise control and manipulation of individual quantum particles, essential for generating and maintaining entanglement. Developing nanoscale devices and systems capable of reliably controlling quantum states is a complex engineering challenge.
- Decoherence and Error Correction: Quantum states are susceptible to decoherence resulting from interactions with the surrounding environment. Developing robust error correction techniques and fault-tolerant quantum systems is crucial to ensure the fidelity of quantum information transfer.
- Resource Requirements: Efficient Teleportation often requires using entangled pairs of particles as a resource, which may need to be generated and maintained. It can be particularly challenging in nanoscale systems, where suitable quantum resources might be limited.
- Integration and Scalability: Integrating nanoscale quantum devices into larger QC networks is a significant challenge. Ensuring compatibility, scalability, and efficient communication between various components is essential for building practical QT systems.
- Verification and Security: Verifying the successful Teleportation of quantum states and ensuring the communication process's security are critical. Developing methods for verifying teleportation outcomes and preventing eavesdropping or other forms of quantum information interception is essential.
- Quantum Channel Requirements: Teleportation requires the establishment of entanglement between distant particles, which often relies on quantum channels

such as optical fibers. Ensuring suitable quantum channels' availability, reliability, and efficiency for Teleportation is challenging.

It's important to note that advancements in nanotechnology, quantum physics, and quantum information science are ongoing, and researchers are continually addressing these challenges to push the boundaries of QC and Teleportation. Alfieri A. et al., (2022) [74] QISE could benefit from the potential benefits that nanomaterials and other low-dimensional materials (those with inherent quantum confinement) could offer. For each form of qubit, we detail the material's hurdles and how recent advances in nanotechnology may help us overcome them. Problems with and solutions for developing nanomaterial-based quantum devices are discussed. This study aims to facilitate communication between nanotechnology and quantum information researchers to accelerate the development of next-generation quantum devices suitable for wide-scale, real-world applications. Bhat H. et al., (2022) [75] explored the physical realizations of quantum computing and its prospective uses. Recent progress in each realization, ion traps-based quantum computing, superconducting quantum computing, Nuclear Magnetic Resonance (NMR) quantum computing, spintronics, and semiconductor-based quantum computing, has been examined within the framework of the DiVincenzo criteria. Caleff A.et al., (2019) [76] aimed to illuminate some unresolved issues and concerns associated with constructing a Quantum Internet. As a first step toward this goal, we introduce quantum physics and its concepts for recognizing the distinctions between a classical and a quantum network. Then, we provide QT as the primary method for passing on quantum data without transferring the quantum information's storage particle or otherwise going against the rules of quantum physics. The major obstacles to designing QC networks are outlined. Table 5 describes the summary of the literature review revised by different authors.

Table 5. Summary of Literature Review

Authors	Technique Used	Outcomes
Alfieri A. et al., (2022) [74]	Photonic Quantum Sensing	To conclude, low-dimensional materials like InAs and InSb nanowires are crucial to developing theoretical frameworks for topological qubits and for early practical demonstrations of these qubits' properties in the quest for non-abelian anyons.
Bhat H. et al., (2022) [75]	Generalized Fully Specified Matrix (GFSM)	We gathered the most recent research findings on the practical use of quantum computers and their potential applications by capturing their structural squares.
Caleff A.et al., (2019) [76]	Quantum Sensing	Although yet in its infancy, the Quantum Internet is an exciting novel idea requiring a wide range of creative concepts and techniques at the intersection of quantum physics, computer science, and telecoms engineering.

RQ4: What is Quantum Entanglement?

When two or more particles interact in a manner that makes it impossible to explain one particle's quantum state without describing the other particles' states, this is known as quantum entanglement77. Correlated outcomes are predicted for several entities. Distance doesn't affect the quantum states of entangled photons or atoms; measurements show strong correlations between them. It presents a viable means to make future communication more secure and reliable. Let's suppose two coins could become entangled. There are almost two times as many "heads" as there are "tails" when one person tosses a coin several times and keeps track of the results. It is impossible to know any given outcome until after it has been measured. Then they throw a second coin, yielding random but comparable outcomes. The experiment logs would then reveal a connection between the two variables. The outcome of the next coin toss is determined as soon as the first one is flipped. People could not be able to anticipate the outcome of a single coin toss, but subsequent flips would have the same probability because of the correlation between outcomes. The complete correlation could be achieved when measuring entangled photons even if an infinite distance separates the particles. Entanglement is incredibly significant and beneficial in the quantum realm, and it has many potential communications uses [78-79]. Figure 7 shows the architecture of Quantum Entanglement.

Zhang C. et al., (2023) [81] examined the feasibility of QT in a noisy environment by using GHZ and non-standard W states as quantum channels. They use a statistical approach to a master issue using Lindblad form to examine the effectiveness of QT. According to the simulations, the fidelity of Teleportation utilizing non-standard W is greater than that of the GHZ state for the identical amount of evolutionary time. They also consider how well Teleportation works with weak and reverse quantum measurements with amplitude-damping noise. According to the findings, the fidelity of Teleportation utilizing non-standard W is likewise more resistant to noise than the GHZ state under the same circumstances. Podoshvedov S.A. et al., (2019) [82] developed a theory of QT for an unnamed qubit that makes use of the interaction mechanism between DV and CV states on a Highly Transmissive Beam Splitter (HTBS). With this DV-CV interaction process, photons in the auxiliary modes are registered after the coherent components of the hybrid dislodge the DV state with displacement amplitudes that are equal in absolute value but opposite in sign.

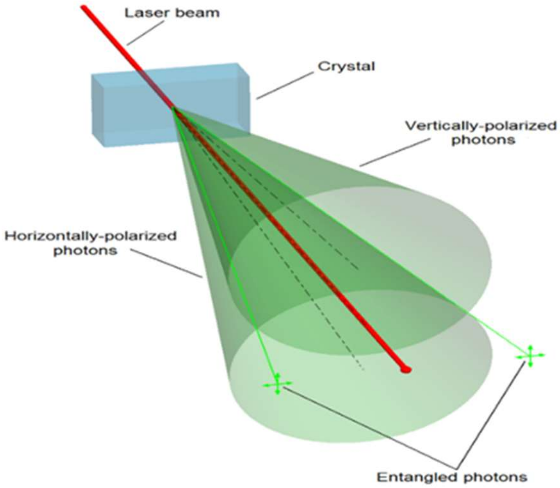


Figure 7. Quantum Entanglement [80].

There are two options suggested for eliminating the variables. QT could be interpreted in several ways; here, we provide an unnamed qubit with a method for increasing processing speed. Alshowkan M. et al., (2014) [83] presents an innovative way to transmit private information between several parties using quantum entanglement switching. Quantum Entanglement swapping is a method for entangling incompatible quantum systems. Mutual authentication via a neutral third party would be required to further increase security and validate the users. An independent third party validates the sender's and receiver's identities and helps them generate a common secret key. In addition, the suggested approach involves an entanglement swap between the sender and the receiver. Without an entanglement exchange between the transmitter and receiver, an Einstein-Podolsky-Rosen (EPR) pair might be produced and sent as the secret key. Afzali R. et al., (2014) [84] calculated QT and quantum entanglement by considering the interaction between neighboring sites and the interaction existing in each site in a QDs system arranged one-dimensionally. After considering this system's spin and space entanglement, we survey Teleportation. The effect of prime neighbors' interaction concerning not considering the interaction on quantum entanglement and QT is compared and determined. Table 6 describes the summary of the literature review revised by different authors.

Table 6. Summary of Literature Review

Authors	Technique Used	Outcomes
Zhang C. et al., (2023) [81]	Lindblad Master Equation	Compared to the GHZ state, the findings demonstrate that when utilizing W1 for Teleportation, higher amplitude damping noise could be sustained.
Podoshvedov S.A. et al., (2019) [82]	DV and CV	The efficiency of quantum mechanical Teleportation of an unidentified qubit has been explored
Alshowkan M. et al., (2014) [83]	Quantum Entanglement Swapping	According to the lack of a quantum channel, the sender and receiver would be forced to depend only on a classical channel while evaluating the basis and keeping their results to themselves.
Afzali R. et al., (2014) [84]	Quantum Entanglement	The best result for teleporting is when the system's entanglement is maximum.

Nanotechnology has been the buzz of the scientific community since its inception in the early 2000s. Nanotechnology has already discovered several uses in everyday life and industry, and many key applications are yet in the research and development stages. It is not incorrect to state that nanotechnology has taken the technical world by storm. Here are the primary sectors in which nanotechnology is employed and the ones under R&D out of all the applications mentioned throughout the globe. Figure 8 shows the applications of nanotechnology.

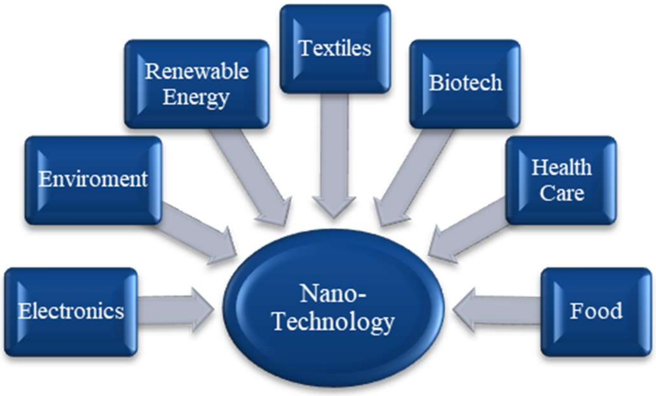


Figure 8. Applications of Nanotechnology [85].

Nanotechnology has emerged as a key factor in recent years, helping to meet every need. Adaptability and potential mean that it could be used in many contexts. Different uses for nanoparticles are described.

Medicine: The field of medicine benefits greatly from nanotechnology's use. Its small size means it could be used as a medicine in the infected cell of our body without affecting healthy cells. Vaccines could be administered using this method, which helps produce a healthy immunological response. Indirectly, it is used to combat viruses by stimulating the production of enzymes.

Food: It's utilized for improving food safety, quality, and flavor at every stage of the food production process, from planting through storage. It has the potential to serve as a sensor for spoiled food. Antimicrobial zinc nanoparticles may also defend against UV radiation in plastic packaging [86]. Using a nano-sensor to detect vitamin deficiencies in the human body is also the subject of active research. It is also employed in agriculture to detect whether seeds or plants lack water or nutrients.

Cleaner water: Nanotechnology is also used to address water quality and environmental issues. The first step in reducing industrial waste pollution is to collect the trash that causes it. Nanoparticles could purify the water, making it safe for consumption and other purposes. The second step is purifying water by reducing its sodium and metal content. The third issue is detecting the virus in water using nanoparticles since regular filters are ineffective. Nanoparticles of graphene and palladium oxides are employed [87].

Space Nanotechnology: It might be the key to making space travel feasible. The development of nanomaterials allows for spacecraft that are both lightweight and capable of using a space elevator.

Solar cell: Nanotechnology allows the production of long-lasting solar cells for a fraction of the cost.

Batteries: The creation of batteries now makes use of nanotechnology. The battery constructed from nanoparticles is expected to last longer.

Electronics: Nanotechnology is also employed in the production of electrical devices. Nanoparticle-based equipment uses less energy and electricity while performing at peak efficiency.

Fuel cells: Reduced pollution and increased efficiency in fuel production are the results of using nanotechnology. Producing hydrogen from water, which is frequently utilized to make fuel, could be greatly aided by using nanogold particles. The impact of nanotechnology extends to a wide variety of other industries. However, this is all there is to know about the most important uses of nanoparticles in many industries [88].

CONCLUSION

Teleportation, which is possible because of the combination of QC and nanotechnology, is a major technological leap forward in transportation and communication. This system and approach, which draws on quantum physics and the properties of nanoscale materials and devices, open previously unimaginable prospects for items' instantaneous, long-distance movement. Teleportation relies heavily on nanotechnology, which provides the means to alter and control individual atoms, molecules, or particles. Teleportation's complex procedures may be handled accurately because of nanoscale equipment like quantum computers, sensors, and memory. This paper demonstrates the challenges and prospects of nanotechnology-enabled QC for object teleportation. Following the PRISMA guidelines, 1284 published studies were reviewed, and 90 studies were found valid and included in the statistical analysis. Finally, a few of the most salient advantages and disadvantages of the current teleportation hypothesis are discussed, along with the challenges that future researchers need to solve.

In the future, teleporting items using QC and nanotechnology will have vast potential throughout various fields. Technology might be in its infancy right now, but with time and work, it can make enormous advances in the future.

ACKNOWLEDGMENTS

The author would like to express her sincere gratitude to " Dr Bunil Kumar Balabantaray" from the "Department of Computer Science and Engineering " and “Dr Debendra Das” from “Department of Mechanical Engineering” for their invaluable contributions to this research paper. Their expertise and insights have been instrumental in shaping the direction of this study. The author is also grateful for the support and resources provided by the "Department of Computer Science and Engineering” of "National Institute of Technology". The author extends our heartfelt thanks to all those who have contributed to the successful completion of this research.

REFERENCES AND NOTES

1. Nielsen, M.A. and Chuang, I.L., 2010. Quantum computation and quantum information. Cambridge university press.
2. Bouwmeester, D., Pan, J.W., Mattle, K., Eibl, M., Weinfurter, H. and Zeilinger, A., 1997. Experimental quantum teleportation. Nature, 390(6660), pp.575-579.
3. Furusawa, A., Sørensen, J.L., Braunstein, S.L., Fuchs, C.A., Kimble, H.J. and Polzik, E.S., 1998. Unconditional quantum teleportation. science, 282(5389), pp.706-709.
4. Patterson, E.A., 2023. Analysis of the Thermal Fisher Information in 2+ 1 Dimensional Black Hole Spacetimes (Master's thesis, University of Waterloo).
5. Lin, S.Y., Chou, C.H. and Hu, B.L., 2015. Quantum teleportation between moving detectors. Physical Review D, 91(8), p.084063.
6. Bennett, C.H., Brassard, G., Crépeau, C., Jozsa, R., Peres, A. and Wootters, W.K., 1993. Teleporting an unknown quantum state via dual classical and Einstein-Podolsky-Rosen channels. Physical review letters, 70(13), p.1895.
7. Satsangi, S. and Patvardhan, C., 2015. Evolution of Quantum Teleportation Circuits with Improved Genetic Algorithm. International Journal of Computer Applications, 975, p.8887.
8. Hensen, B., Bernien, H., Dréau, A.E., Reiserer, A., Kalb, N., Blok, M.S., Ruitenberg, J., Vermeulen, R.F., Schouten, R.N., Abellán, C. and Amaya, W., 2015. Loophole-free Bell inequality violation using electron spins separated by 1.3 kilometres. Nature, 526(7575), pp.682-686.

9. Shalm, L.K., Meyer-Scott, E., Christensen, B.G., Bierhorst, P., Wayne, M.A., Stevens, M.J., Gerrits, T., Glancy, S., Hamel, D.R., Allman, M.S. and Coakley, K.J., 2015. Strong loophole-free test of local realism. Physical review letters, 115(25), p.250402.

10. Giustina, M., Versteegh, M.A., Wengerowsky, S., Handsteiner, J., Hochrainer, A., Phelan, K., Steinlechner, F., Kofler, J., Larsson, J.Å., Abellán, C. and Amaya, W., 2015. Significant-loophole-free test of Bell's theorem with entangled photons. Physical review letters, 115(25), p.250401.

11. Rosenfeld, W., Burchardt, D., Garthoff, R., Redeker, K., Ortegel, N., Rau, M. and Weinfurter, H., 2017. Event-ready Bell test using entangled atoms simultaneously closing detection and locality loopholes. Physical review letters, 119(1), p.010402.

12. Simon, C., 2017. Towards a global quantum network. Nature Photonics, 11(11), pp.678-680.

13. Bhaskar, M.K., Riedinger, R., Machielse, B., Levonian, D.S., Nguyen, C.T., Knall, E.N., Park, H., Englund, D., Lončar, M., Sukachev, D.D. and Lukin, M.D., 2020. Experimental demonstration of memory-enhanced quantum communication. Nature, 580(7801), pp.60-64.

14. Wehner, S., Elkouss, D. and Hanson, R., 2018. Quantum internet: A vision for the road ahead. Science, 362(6412), p.eaam9288.

15. Pirandola, S., Eisert, J., Weedbrook, C., Furusawa, A. and Braunstein, S.L., 2015. Advances in quantum teleportation. Nature photonics, 9(10), pp.641-652.

16. Xia, X.X., Sun, Q.C., Zhang, Q. and Pan, J.W., 2017. Long distance quantum teleportation. Quantum Science and Technology, 3(1), p.014012.

17. Nielsen, M.A. and Chuang, I.L., 2001. Quantum computation and quantum information. Phys. Today, 54(2), p.60.

18. Valivarthi, R., Davis, S.I., Peña, C., Xie, S., Lauk, N., Narváez, L., Allmaras, J.P., Beyer, A.D., Gim, Y., Hussein, M. and Iskander, G., 2020. Teleportation systems toward a quantum internet. PRX Quantum, 1(2), p.020317.

19. Olofsson, E., Samuelsson, P., Brunner, N. and Potts, P.P., 2020. Quantum teleportation of single-electron states. Physical Review B, 101(19), p.195403.

20. Barrett, M.D., Chiaverini, J., Schaetz, T., Britton, J., Itano, W.M., Jost, J.D., Knill, E., Langer, C., Leibfried, D., Ozeri, R. and Wineland, D.J., 2004. Deterministic quantum teleportation of atomic qubits. Nature, 429(6993), pp.737-739.

21. Manoukian, E.B., 2020. 100 years of fundamental theoretical physics in the palm of your hand: integrated technical treatment. Springer Nature.

22. Catota, J.P.A., Quantum teleportation, features, experiments and the possible revolution on computer communication.

23. Xu, F., Ma, X., Zhang, Q., Lo, H.K. and Pan, J.W., 2020. Secure quantum key distribution with realistic devices. Reviews of Modern Physics, 92(2), p.025002.

24. Lopez-Leyva, J.A., Talamantes-Alvarez, A., Ponce-Camacho, M.A., Garcia-Cardenas, E. and Alvarez-Guzman, E., 2018. Free-space-optical quantum key distribution systems: Challenges and trends. Quantum Cryptography in Advanced Networks.

25. Liao, S.K., Cai, W.Q., Liu, W.Y., Zhang, L., Li, Y., Ren, J.G., Yin, J., Shen, Q., Cao, Y., Li, Z.P. and Li, F.Z., 2017. Satellite-to-ground quantum key distribution. Nature, 549(7670), pp.43-47.

26. Barz, S., Kashefi, E., Broadbent, A., Fitzsimons, J.F., Zeilinger, A. and Walther, P., 2012. Demonstration of blind quantum computing. science, 335(6066), pp.303-308.

27. Nadeem, M., 2014. Quantum non-locality, causality and mistrustful cryptography. arXiv preprint arXiv:1407.7025.

28. Broadbent, A. and Schaffner, C., 2016. Quantum cryptography beyond quantum key distribution. Designs, Codes and Cryptography, 78, pp.351-382.

29. Bernstein, D.J. and Lange, T., 2017. Post-quantum cryptography. Nature, 549(7671), pp.188-194.

30. Rajan, D. and Visser, M., 2019. Quantum blockchain using entanglement in time. Quantum Reports, 1(1), pp.3-11.

31. Gao, Y.L., Chen, X.B., Chen, Y.L., Sun, Y., Niu, X.X. and Yang, Y.X., 2018. A secure cryptocurrency scheme based on post-quantum blockchain. Ieee Access, 6, pp.27205-27213.

32. Yang, Z., Zolanvari, M. and Jain, R., 2023. A Survey of Important Issues in Quantum Computing and Communications. IEEE Communications Surveys & Tutorials.

33. https://www.insightsonindia.com/science-technology/communication-and-it-technology/quantum-cryptography/.

34. Zhao, J., 2020. Quantum software engineering: Landscapes and horizons. arXiv preprint arXiv:2007.07047.

35. Chong, F.T., Franklin, D. and Martonosi, M., 2017. Programming languages and compiler design for realistic quantum hardware. Nature, 549(7671), pp.180-187.

36. Ying, M., 2016. Foundations of quantum programming. Morgan Kaufmann.

37. Montanaro, A. and de Wolf, R., 2013. A survey of quantum property testing. arXiv preprint arXiv:1310.2035.

38. Grimsley, H.R., Economou, S.E., Barnes, E. and Mayhall, N.J., 2019. An adaptive variational algorithm for exact molecular simulations on a quantum computer. Nature communications, 10(1), p.3007.

39. Gay, S.J., 2006. Quantum programming languages: Survey and bibliography. Mathematical Structures in Computer Science, 16(4), pp.581-600.

40. Khan, A.A., Ahmad, A., Waseem, M., Liang, P., Fahmideh, M., Mikkonen, T. and Abrahamsson, P., 2023. Software architecture for quantum computing systems—A systematic review. Journal of Systems and Software, 201, p.111682.

41. Yuan, Z.S., Bao, X.H., Lu, C.Y., Zhang, J., Peng, C.Z. and Pan, J.W., 2010. Entangled photons and quantum communication. Physics Reports, 497(1), pp.1-40.

42. Krenn, M., Malik, M., Scheidl, T., Ursin, R. and Zeilinger, A., 2016. Quantum communication with photons. Optics in our Time, 18, p.455.

43. Baur, M., Fedorov, A., Steffen, L., Filipp, S., Da Silva, M.P. and Wallraff, A., 2012. Benchmarking a quantum teleportation protocol in superconducting circuits using tomography and an entanglement witness. Physical review letters, 108(4), p.040502.

44. Pirandola, S. and Mancini, S., 2006. Quantum teleportation with continuous variables: A survey. Laser Physics, 16, pp.1418-1438.

45. Fedorov, K.G., Renger, M., Pogorzalek, S., Di Candia, R., Chen, Q., Nojiri, Y., Inomata, K., Nakamura, Y., Partanen, M., Marx, A. and Gross, R., 2021. Experimental quantum teleportation of propagating microwaves. Science advances, 7(52), p.eabk0891.

46. Diamanti, E., Lo, H.K., Qi, B. and Yuan, Z., 2016. Practical challenges in quantum key distribution. npj Quantum Information, 2(1), pp.1-12.

47. Wang, L.J., Zhang, K.Y., Wang, J.Y., Cheng, J., Yang, Y.H., Tang, S.B., Yan, D., Tang, Y.L., Liu, Z., Yu, Y. and Zhang, Q., 2021. Experimental authentication of quantum key distribution with post-quantum cryptography. npj quantum information, 7(1), p.67.

48. Dias, J., Winnel, M.S., Hosseinidehaj, N. and Ralph, T.C., 2020. Quantum repeater for continuous-variable entanglement distribution. Physical Review A, 102(5), p.052425.

49. Wehner, S., Elkouss, D. and Hanson, R., 2018. Quantum internet: A vision for the road ahead. Science, 362(6412), p.eaam9288.

50. Herbst, T., Scheidl, T., Fink, M., Handsteiner, J., Wittmann, B., Ursin, R. and Zeilinger, A., 2015. Teleportation of entanglement over 143 km. Proceedings of the National Academy of Sciences, 112(46), pp.14202-14205.

51. Minder, M., Pittaluga, M., Roberts, G.L., Lucamarini, M., Dynes, J.F., Yuan, Z.L. and Shields, A.J., 2019. Experimental quantum key distribution beyond the repeaterless secret key capacity. Nature Photonics, 13(5), pp.334-338.

52. Pirandola, S., Bardhan, B.R., Gehring, T., Weedbrook, C. and Lloyd, S., 2018. Advances in photonic quantum sensing. Nature Photonics, 12(12), pp.724-733.

53. Polino, E., Valeri, M., Spagnolo, N. and Sciarrino, F., 2020. Photonic quantum metrology. AVS Quantum Science, 2(2).

54. Rodrigo, S., Abadal, S., Alarcón, E. and Almudever, C.G., 2020, November. Will quantum computers scale without inter-chip comms? a structured design exploration to the monolithic vs distributed architectures quest. In 2020 XXXV Conference on Design of Circuits and Integrated Systems (DCIS) (pp. 1-6). IEEE.

55. Wendin, G., 2023. Quantum information processing with superconducting circuits: a perspective. arXiv preprint arXiv:2302.04558.

56. Gonzalez-Raya, T., Casariego, M., Fesquet, F., Renger, M., Salari, V., Möttönen, M., Omar, Y., Deppe, F., Fedorov, K.G. and Sanz, M., 2022. Open-air microwave entanglement distribution for quantum teleportation. Physical Review Applied, 18(4), p.044002.

57. Jeevanandam, J., Barhoum, A., Chan, Y.S., Dufresne, A. and Danquah, M.K., 2018. Review on nanoparticles and nanostructured materials: history, sources, toxicity and regulations. Beilstein journal of nanotechnology, 9(1), pp.1050-1074.

58. Boulaiz, H., Alvarez, P.J., Ramirez, A., Marchal, J.A., Prados, J., Rodríguez-Serrano, F., Perán, M., Melguizo, C. and Aranega, A., 2011. Nanomedicine: application areas and development prospects. International journal of molecular sciences, 12(5), pp.3303-3321.

59. Chauhan, R.S., Sharma, G. and Rana, J.M.S., 2010. Nanotechnology in health and disease. Bytes and Bytes, Bareilly, UP, India, pp.1-11.

60. Bentolila, L.A., Ebenstein, Y. and Weiss, S., 2009. Quantum dots for in vivo small-animal imaging. Journal of nuclear medicine, 50(4), pp.493-496.

61. Albanese, A., Tang, P.S. and Chan, W.C., 2012. The effect of nanoparticle size, shape, and surface chemistry on biological systems. Annual review of biomedical engineering, 14, pp.1-16.

62. Chung, I.M., Park, I., Seung-Hyun, K., Thiruvengadam, M. and Rajakumar, G., 2016. Plant-mediated synthesis of silver nanoparticles: their characteristic properties and therapeutic applications. Nanoscale research letters, 11, pp.1-14.

63. Khan, F., Shariq, M., Asif, M., Siddiqui, M.A., Malan, P. and Ahmad, F., 2022. Green nanotechnology: plant-mediated nanoparticle synthesis and application. Nanomaterials, 12(4), p.673.

64. Chakravarty, Rubel, G. O. E. L. Shreya, D. A. S. H. Ashutosh, and C. A. I. Weibo. "Radiolabeled inorganic nanoparticles for positron emission tomography imaging of cancer: an overview." The quarterly journal of nuclear medicine and molecular imaging: official publication of the Italian Association of Nuclear Medicine (AIMN)[and] the International Association of Radiopharmacology (IAR),[and] Section of the Society of... 61, no. 2 (2017): 181.

65. Goel, S., England, C.G., Chen, F. and Cai, W., 2017. Positron emission tomography and nanotechnology: A dynamic duo for cancer theranostics. Advanced drug delivery reviews, 113, pp.157-176.

66. Woldeamanuel, K.M., Kurra, F.A. and Roba, Y.T., 2021. A review on nanotechnology and its application in modern veterinary science. International Journal of Nanomaterials, Nanotechnology and Nanomedicine, 7(1), pp.026-031.

67. Xu, J., Chen, X., Xiao, H., Wang, P. and Ma, M., 2021. A Performance–Consumption Balanced Scheme of Multi-Hop Quantum Networks for Teleportation. Applied Sciences, 11(22), p.10869.

68. Daei, O., Navi, K. and Zomorodi-Moghadam, M., 2020. Optimized quantum circuit partitioning. International Journal of Theoretical Physics, 59(12), pp.3804-3820.

69. Song, D., He, C., Cao, Z. and Chai, G., 2018. Quantum teleportation of multiple qubits based on quantum Fourier transform. IEEE Communications Letters, 22(12), pp.2427-2430.

70. Ali, M.Z., Abohmra, A., Usman, M., Zahid, A., Heidari, H., Imran, M.A. and Abbasi, Q.H., 2023. Quantum for 6G communication: A perspective. IET Quantum Communication.

71. Paudel, H.P., Syamlal, M., Crawford, S.E., Lee, Y.L., Shugayev, R.A., Lu, P., Ohodnicki, P.R., Mollot, D. and Duan, Y., 2022. Quantum computing and simulations for energy applications: Review and perspective. ACS Engineering Au, 2(3), pp.151-196.

72. Wu, H., Liu, X., Zhang, H., Ruan, X. and Guo, Y., 2022. Performance Analysis of Continuous Variable Quantum Teleportation with Noiseless Linear Amplifier in Seawater Channel. Symmetry, 14(5), p.997.

73. Rota, M.B., Basset, F.B., Tedeschi, D. and Trotta, R., 2020. Entanglement teleportation with photons from quantum dots: toward a solid-state based quantum network. IEEE Journal of Selected Topics in Quantum Electronics, 26(3), pp.1-16.

74. Alfieri, A., Anantharaman, S.B., Zhang, H. and Jariwala, D., 2023. Nanomaterials for quantum information science and engineering. Advanced Materials, 35(27), p.2109621.

75. Bhat, H.A., Khanday, F.A., Kaushik, B.K., Bashir, F. and Shah, K.A., 2022. Quantum computing: fundamentals, implementations and applications. IEEE Open Journal of Nanotechnology, 3, pp.61-77.

76. Cacciapuoti, A.S., Caleffi, M., Tafuri, F., Cataliotti, F.S., Gherardini, S. and Bianchi, G., 2019. Quantum internet: Networking challenges in distributed quantum computing. IEEE Network, 34(1), pp.137-143.

77. Horodecki, R., Horodecki, P., Horodecki, M. and Horodecki, K., 2009. Quantum entanglement. Reviews of modern physics, 81(2), p.865.

78. Imre, S., 2014. Quantum computing and communications–Introduction and challenges. Computers & Electrical Engineering, 40(1), pp.134-141.

79. Chen, J., 2021, April. Review on quantum communication and quantum computation. In Journal of Physics: Conference Series (Vol. 1865, No. 2, p. 022008). IOP Publishing.

80. https://en.wikipedia.org/wiki/Quantum_entanglement.

81. Zhang, C.Y., Zheng, Z.J., Fan, Z.B. and Ma, H.T., 2023. The efficiency of quantum teleportation with three-qubit entangled state in a noisy environment. Scientific Reports, 13(1), p.3756.

82. Podoshvedov, S.A., 2019. Efficient quantum teleportation of unknown qubit based on DV-CV interaction mechanism. Entropy, 21(2), p.150.

83. Alshowkan, M. and Elleithy, K., 2014, April. Authenticated multiparty secret key sharing using quantum entanglement swapping. In Proceedings of the 2014 Zone 1 Conference of the American Society for Engineering Education (pp. 1-6). IEEE.

84. Afzalia, R., Salehkoutahia, M. and Abdolia, M., Quantum teleportation and entanglement in interacting quantum dots system.

85. Singh, A., Suki, M., Sharma, R. and Ingle, P., 2020. Applications of Nanotechnology: A Review. IJARCS, 7, pp.16-32.

86. Sirelkhatim, A., Mahmud, S., Seeni, A., Kaus, N.H.M., Ann, L.C., Bakhori, S.K.M., Hasan, H. and Mohamad, D., 2015. Review on zinc oxide nanoparticles: antibacterial activity and toxicity mechanism. Nano-micro letters, 7, pp.219-242.

87. Huang, Y.X., Xie, J.F., Zhang, X., Xiong, L. and Yu, H.Q., 2014. Reduced graphene oxide supported palladium nanoparticles via photoassisted citrate reduction for enhanced electrocatalytic activities. ACS applied materials & interfaces, 6(18), pp.15795-15801.

88. https://www.ijesi.org/papers/Vol(8)i1/Version-3/O08010399101.pdf.