Quantum Files and Their Teleportation

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In classical computing, a file is a fundamental abstraction used to store, manage, and transfer the information, with access governed by permissions such as read and write. Despite the rapid development of quantum computing, an analogous notion of a file does not yet exist within the standard quantum information framework for a quantum computer. In this work, we propose a mathematical model for a quantum file, thereby extending the concept of quantum teleportation introduced by C.H. Bennett *et al.* in 1993. Further we present a unique feature of the protocol as remote amplitude cancellation, which helps for securing quantum information transfer with controlled access.

Introduction.— A file is a fundamental unit of information exchange, which encapsulates data in a structured form. Files often require a physical storage medium, such as a hard disk or memory device, and serves as the primary means by which information is stored, processed, and transmitted[2]. In the early 1960s, computers were shared by many users like students, researchers etc. These systems had almost no fine grained security once somebody got access, you could often see or modify anything and it created serious issues like: No privacy among users; Risk of data modificaion; No structured way to manage permissions.

The concept of file-level access control in classical computing was pioneered by F. J. Corbató et al. during 1963-1969 as part of the project entitled Multiplexed Information and Computing Services [3, 4]. The value of a file increases significantly when the file owner enforces access restrictions, such as read and write permissions, prior to sharing it with another party over the network. These restrictions allow the owner to control how the file may be accessed, modified, or distributed by the recipient. Such permission-based control mechanism play a crucial role in ensuring data security, privacy, and integrity during communication. Importantly, this control remains in the hands of the file owner, even while the file is being transmitted or accessed by external users[1]. The concept of a file in classical computing is fully developed and this abstraction reached to a mature form in the design philosophy of UNIX system, where the principle of "*everything is a file*" enabled and provides the unified treatment of data, devices, and communication channels[1].

By taking the motivation from the permission-aware classical file system, we introduce a quantum analogue concept of a file, i.e., a permission-aware quantum file equipped with read and write permissions. Despite the significant progress in quantum computation and information[5, 6], the notion of a quantum file is absent from the existing literature. In the absence of such an abstraction, a quantum computer lacks a fundamental organizational and information-management structure, rendering it conceptually incomplete. Over the past decades, including the developments of quantum communication protocols, quantum memories, and quantum networks[7, 8], a core and fundamental quantum communication protocol is quantum teleportation, introduced by C. H. Bennett et al. (1993)[9]. This protocol teleports an unknown quantum qubit between spatially separated parties (Alice and Bob) using shared entanglement[10] with a classical communication channel. Referring to this idea, numerous versions of this protocol have been developed, such as remote state preparation, gate teleportation, perfect state transfer for quantum communication, distributed quantum computing, and secure quantum information transfer[11–15].

Building upon the seminal work done on quantum teleportation by C.H. Bennet et al.[9], we introduce the quantum teleportation of a single qubit permission-aware quantum file with mathematical abstraction that extends the classical notion of a file into the quantum domain. This construction provides full control in the hands of Alice, who can control the read and write permissions of a quantum file at the end of Bob, even Alice has the ability to destroy the quantum file remotely by following the concept of "Remote Amplitude Cancellation". This new perspective on quantum information organization in a quantum file may serve as a building block for future secure quantum communication protocols.

Notations: The permissions associated with a classical file $\mathscr{F}_{\mathscr{R}\mathscr{W}}$, defined as an ordered pair $(\mathscr{R}, \mathscr{W}) \in \{0,1\} \times \{0,1\}$. The binary digit 0 indicates that the corresponding action (read or write) is not permitted, whereas the digit 1 indicates that the corresponding action is permitted. For example, the notation $\mathscr{F}_{00}$ indicates that the file can neither be read nor written; $\mathscr{F}_{01}$ denotes that the file cannot be read but can be written. Similarly, $\mathscr{F}_{10}$ denotes that the file can be read but cannot be written, and finally, $\mathscr{F}_{11}$ indicates that the file can be read and can be written also.

Organization.- The article is organized into six sections. Section I introduces the mathematical model of a quantum file and and further a permission-aware quantum file. Section II presents the the axiom as first action principle for a quantum file. Section III introduces the teleportation of a quantum file, which generalizes the C.H.Bennet et al. protocol, further the unfolding of a quantum file is presented. Section 1V, presents a unique feature of the protocol as remote amplitude cancellation. In Section V, the conclusion of the work is presented.

Modeling a Quantum File.- An arbitrary (unequal) superposition of n-qubit pure states can always be written as

$$|\Psi\rangle = \alpha.|0\rangle^{\otimes n} + \beta.e^{i\delta} \sum_{i\in\{0,1\}^n\setminus\{0\}^n} |i\rangle; \quad |\alpha|^2 + |\beta|^2 = 1 \tag{1}$$

where $|\Psi\rangle \in \mathcal{H}^{\otimes n}$ with $\mathcal{H} \cong \mathbb{C}^2$ denoting the single-qubit Hilbert space and $e^{i\delta}$ is the phase factor of the quantum state. We develop the concept of an n-qubit or many body quantum file by interpreting the following terms in Eq. (1) as blank $|b\rangle$ and filled portion $|f\rangle$ with the probability amplitudes α and $\beta.e^{i\delta}$ respectively,

$$|b\rangle = |0\rangle^{\otimes n} \quad \text{and} \quad |f\rangle = \sum_{i\in\{0,1\}^n\setminus\{0\}^n} |i\rangle \tag{2}$$

where the blank portion $|b\rangle$ in n-qubit quantum file refers to natural vacuum reference state in computational basis encoding, which represent logically there is zero information; whereas the filled portion $|f\rangle$ is used to keep the quantum information.

The filled and blank portions of a quantum file are analogous to the classical information in a "Word Document" file. As an example one can consider a two pages word document file, in which first page has zero information (blank portion) and second page has some information (filled portion). To the scope of this work, we consider Eq (1) for $n = 1$, which represents a single-qubit quantum file,

$$|\psi\rangle = \alpha.|0\rangle + \beta.e^{i\delta}|1\rangle. \tag{3}$$

Merging of Quantum Files.- Consider mixing of two single qubit quantum files $|\psi_1\rangle$ and $|\psi_2\rangle$ with distinct phases δ_1 and δ_2:

$$|\psi_1\rangle = \alpha_0|b\rangle + \alpha_1.e^{i\delta_1}|f\rangle \tag{4}$$
$$|\psi_2\rangle = \beta_0|b\rangle + \beta_1.e^{i\delta_2}|f\rangle. \tag{5}$$

A bipartite quantum file can be obtained by using Kronecker tensor product as $|\psi_{12}\rangle = |\psi_1\rangle \otimes |\psi_2\rangle$, resulting in the following expression:

$$|\psi_{12}\rangle = g|bb\rangle + h|bf\rangle + z|fb\rangle + l|ff\rangle \tag{6}$$

where

$$|g|^2 + |h|^2 + |z|^2 + |l|^2 = 1 \tag{7}$$

with

$$g = \alpha_0\beta_0, \quad h = \alpha_0\beta_1, \quad z = \alpha_1\beta_0, \quad l = \alpha_1\beta_1 \tag{8}$$

Eq.(6) consists of four terms representing the full information in the file. However, when taking a quantum measurement, one can design a projection operator to retain the desired information. For instance, consider collapsing the cross terms (the second and third terms) in Eq. (6) with the following projection operator[16]

$$P = |bb\rangle\langle bb| + |ff\rangle\langle ff| \tag{9}$$

consisting of two orthonormal basis. Followed by a quantum state post-selection[17], one can reduce the information in a bipartite quantum file having solely the blank and filled portions expressed as

$$|\psi_{12}\rangle = \frac{g|bb\rangle + l|ff\rangle}{|g|^2 + |l|^2}. \tag{10}$$

The method can also be extended for a many-body quantum file $|\Psi\rangle$ with a carefully designed projection operator.

A Permission-Aware Quantum File.- In this section we discuss how a single qubit quantum file can be made as permission-aware by multiplying a phase factor $X_{\mathscr{R}\mathscr{W}}$, which is also called as permission factor in the context of quantum file. Consequently a permission-aware single qubit quantum file can be mathematically expressed as below,

$$\mathscr{Q}\mathscr{F}_{\mathscr{R}\mathscr{W}} = X_{\mathscr{R}\mathscr{W}}.|\psi\rangle \tag{11}$$

The permission factor $X_{\mathscr{R}\mathscr{W}}$ corresponds to a classical phase-oracle derived scalar at the end of Alice, which depends on the binary values $f(0)$ and $f(1)$. This factor plays an important role in remote amplitude cancellation and quantum information security described into the subsequent section. The values of the permission factors reads as,

$$\begin{aligned} X_{00} = X_{11} &= \frac{1}{2}\Big((-1)^{f(0)} + (-1)^{f(1)}\Big) \\ X_{01} = X_{10} &= \frac{1}{2}\Big((-1)^{f(0)} - (-1)^{f(1)}\Big) \end{aligned} \tag{12}$$

Where the condition is followed $\mathscr{R} = f(0)$ and $\mathscr{W} = f(1)$. Refereeing to the permission factors the following result can be obtained,

$$X_{\mathscr{R}\mathscr{W}} \in \{\pm 1, 0\}, \quad \text{with}\Big(f(0), f(1)\Big) \in \{0, 1\} \tag{13}$$

Eq.11, can also be interpreted by using the distributive property in the Hilbert space $\mathcal{H}$ over the scaler field $\mathbb{C}$. Assuming $X_{\mathscr{R}\mathscr{W}} \equiv (a \pm b)$ with $a = (-1)^{f(0)}, b =$

$(-1)^{f(1)}$, the following equation reads the distributive property over the addition of scalers,

$$(a \pm b)|\psi\rangle = a.|\psi\rangle \pm b.|\psi\rangle \quad \text{with} \quad (a,b) \in \mathbb{C} \tag{14}$$

The key feature of the construction of a permission aware quantum file is that the values of $X_{\mathscr{R}\mathscr{W}}$ depend on interference between phase contributions introduced by the oracle develop at the end of Alice. If Alice flips the bit $f(1)$, which consequences $\mathscr{W} = \overline{f(1)}$, then destructive interference occurs leading to $X_{\mathscr{R}\mathscr{W}} = 0$.

Lemma (**Phase Induced Interference**). *If $\mathscr{R} = f(0)$ and $\mathscr{W} = \overline{f(1)}$, the association of relative phase leads to destructive interference in specific branch, yielding $X_{\mathscr{R}\mathscr{W}} = 0$.*

Proof: The proof is an immediate consequence of Eq.12 as follows,

$$\begin{aligned} X_{00} = X_{11} &= \frac{1}{2}\Big((-1)^{f(0)} + (-1)^{\overline{f(1)}}\Big) = 0 \\ X_{01} = X_{10} &= \frac{1}{2}\Big((-1)^{f(0)} - (-1)^{\overline{f(1)}}\Big) = 0. \end{aligned} \tag{15}$$

If $X_{\mathscr{R}\mathscr{W}} = 0$, the quantum file turns as $\mathscr{QF}_{\mathscr{R}\mathscr{W}} = 0.|\psi\rangle$. It means the underline quantum file can neither go through unitary transformation nor it can be measured, since it violate the normalization condition in quantum mechnaics; for this case the quantum file is unavailable to the receiver. While on the other hand with $X_{\mathscr{R}\mathscr{W}} = \{\pm 1\}$, the quantum file is available to the receiver with read and write access semantics. Alice can use four distinct permission factors corresponding to all possible read-write configurations over the permission space $(\mathscr{R}, \mathscr{W}) = \{0,1\} \times \{0,1\}$, summarized in Table I.

$\mathscr{R}$	$\mathscr{W}$	$\mathscr{QF}_{\mathscr{R}\mathscr{W}}$	$X_{\mathscr{R}\mathscr{W}}\|\psi\rangle$
0	0	$\mathscr{QF}_{00}$	$X_{00}\|\psi\rangle$
0	1	$\mathscr{QF}_{01}$	$X_{01}\|\psi\rangle$
1	0	$\mathscr{QF}_{10}$	$X_{10}\|\psi\rangle$
1	1	$\mathscr{QF}_{11}$	$X_{11}\|\psi\rangle$

TABLE I. Quantum File with Permission Factors

The notation $\mathscr{QF}_{00}$ denotes that the quantum file cannot be read nor written, while the notion $\mathscr{QF}_{01}$ means; the quantum file cannot be read but can be written. Further $\mathscr{QF}_{10}$ stands for the action that quantum file can be read but can not be written and finally $\mathscr{QF}_{11}$ described as quantum file can be read and can also be written. To understand the access semantics such as read and write in quantum domain, it is important to understand the first action principle, which is provided in the next section.

First Action Principle.- In this section we present the *first action principle* for a quantum file. Once a quantum file $\mathscr{QF}_{\mathscr{R}\mathscr{W}}$ has been teleport by Alice, an important paradigm comes into picture such that, which must be the nature of the first admissible operation on $\mathscr{QF}_{\mathscr{R}\mathscr{W}}$ by Bob ? For a classical file, the first action by a recipient is always a read operation and further a write operation comes into picture; mathematcally we can express first action on a classical file as an ordered pair of read and write permissions i.e. $A^c = (\mathscr{R}, \mathscr{W})$.

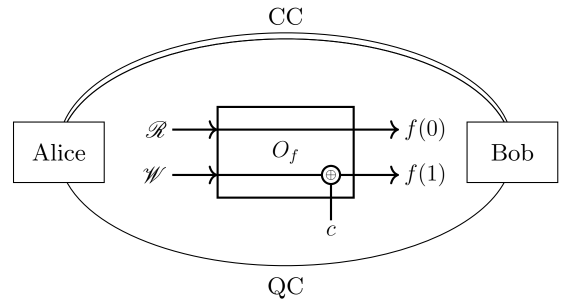

FIG. 1. Schematic of the quantum file protocol showing classical (CC) and quantum (QC) channels with an oracle O_f implemented by Alice with $f(1) = c \oplus \mathscr{W}$, where c is a classical control bit.

But for quantum files, however, the situation is fundamentally different due to the measurement postulate of quantum mechanics. To start with, let we define read and write operations in quantum domain as:

$$\mathscr{R} \equiv M, \qquad \mathscr{W} \equiv U$$

where M represents the quantum measurement and U denotes the reversible unitary operation. Suppose recipient i.e. Bob attempts first action as read $\mathscr{R}$, after receiving the quantum file; to perform this action he apply corresponding quantum measurement operator M on $\mathscr{QF}_{\mathscr{R}\mathscr{W}}$. The quantum measurement action collapse the quantum file as given below,

$$|\widetilde{\psi}\rangle = \frac{M|\mathscr{QF}_{\mathscr{R}\mathscr{W}}\rangle}{\sqrt{\langle \mathscr{QF}_{\mathscr{R}\mathscr{W}}|M|\mathscr{QF}_{\mathscr{R}\mathscr{W}}\rangle}} \tag{16}$$

Such a irreversible quantum measurement operation disturbs the original state and destroys the coherent superposition that encodes the quantum information within the quantum file. Consequently, the quantum measurement ie. $M \equiv \mathscr{R}$ can never serve as a first action on a quantum file, since it looses the original information from the file. Hence as a consequence, it is natural to choose Bob's first action on $\mathscr{QF}_{\mathscr{R}\mathscr{W}}$ a unitary operation. Mathematically, for a quantum file the first action is an ordered pair of write and read permissions i.e. $A^q \in (\mathscr{W}, \mathscr{R})$. The first action principle can be frame as an axiom given below,

Axiom (**First action principle**). *For a quantum file, the first action is always a write operation ie. $\mathscr{W} \equiv U$ rather a read operation ie. $\mathscr{R} \equiv M$ and hence the actions* *on a quantum file is an ordered pair $A^q \in (\mathscr{W}, \mathscr{R})$, which has mirror symmetry to the actions on a classical file as an ordered pair $A^c \in (\mathscr{R}, \mathscr{W})$.*

By introducing the first action principle on the quantum file the notation given in Eq.11 can be restructured as,

$$\mathscr{Q}\mathscr{F}_{\overleftarrow{\mathscr{R}\mathscr{W}}} = X_{\overleftarrow{\mathscr{R}\mathscr{W}}}.|\psi\rangle \tag{17}$$

The notion of arrow sign from right to left, denotes that the first action is write ($\mathscr{W} \equiv U$) and next action is read ($\mathscr{R} \equiv M$). In the present work our goal is to teleport $\mathscr{Q}\mathscr{F}_{\overleftarrow{\mathscr{R}\mathscr{W}}}$ to Bob. Before discussing the teleportation protocol, we first look at unfolding a quantum file in next section.

Unfolding the Quantum File.- The process of unfolding a quantum file refers to the controlled extraction and manipulation of quantum information encoded within a permission-aware quantum file, in accordance with the first action principle. In the previous section, we have seen that Bob is supposed to receive a single qubit quantum file $\mathscr{Q}\mathscr{F}_{\overleftarrow{\mathscr{R}\mathscr{W}}}$. The permission factors involve two binary variables $f(0)$ and $f(1)$, which are unknown to Bob and without knowing these binary variables, Bob is not able to unfold the semantics and information from a quantum file. Here we mention that Alice has full control in generating the desired values of these binary variables and to grant the desired permissions to Bob. The values of the parameters $f(0)$ and $f(1)$ are supplied by the Alice through the classical channel to Bob by using a classical oracle O_f as shown in the Fig.1. Before completing the teleportatiin protocol, at the end of Alice, one can write the state vector in compact form as,

$$|\phi\rangle = \sum_{\mathscr{R},\mathscr{W}} |\mathscr{R}, \mathscr{W}\rangle \otimes \mathscr{Q}\mathscr{F}_{\overleftarrow{\mathscr{R}\mathscr{W}}}, \quad \mathscr{Q}\mathscr{F}_{\overleftarrow{\mathscr{R}\mathscr{W}}} = X_{\overleftarrow{\mathscr{R}\mathscr{W}}}|\psi\rangle, \tag{18}$$

where $(\mathscr{R}, \mathscr{W})$ denotes the computational basis states encoding read–write permissions and each term in Eq.18 represents a distinct branch of the superposition. The set of classical bits $(\mathscr{R}, \mathscr{W})$ serve as the input to the oracle O_f to generate the binary values $f(0)$ and $f(1)$ by the Alice. Here we formulate the unfolding map, which reads,

Definition (Unfolding Map)**.** *Let $f : \{\mathscr{R}, \mathscr{W}\} \to \{0, 1\}$ be a function specified by Alice through a classical oracle O_f. The unfolding of a quantum file is defined as a classically controlled quantum operation*

$$\mathscr{U}^f = \mathscr{R}^{f(0)} \circ \mathscr{W}^{f(1)} \equiv M^{f(0)} \circ U^{f(1)}, \tag{19}$$

acting on a quantum file $\mathscr{Q}\mathscr{F}_{\overleftarrow{\mathscr{R}\mathscr{W}}}$.

To unfoled the quantum file, Bob develop the sequence of function-controlled operators $M^{f(0)}.U^{f(1)}$, which transform the quantum file, the action reads as follows,

$$\widetilde{\mathscr{Q}\mathscr{F}}_{\overleftarrow{\mathscr{R}\mathscr{W}}} \equiv M^{f(0)} \cdot U^{f(1)} \cdot \mathscr{Q}\mathscr{F}_{\overleftarrow{\mathscr{R}\mathscr{W}}} \tag{20}$$

Using the Eq. 17, the final form of the unfolded quantum file at the end of Bob can be written as,

$$\widetilde{\mathscr{Q}\mathscr{F}}_{\overleftarrow{\mathscr{R}\mathscr{W}}} \equiv M^{f(0)} \cdot U^{f(1)} \cdot X_{\overleftarrow{\mathscr{R}\mathscr{W}}}\,|\psi\rangle \tag{21}$$

In the follwing table II, we show the unfolding operation at the end of Bob. Following the row wise table entries,

$(f(0), f(1))$	$M^{f(0)}.U^{f(1)}$	$X_{\overleftarrow{\mathscr{R}\mathscr{W}}}$	$\widetilde{\mathscr{Q}\mathscr{F}}_{\overleftarrow{\mathscr{R}\mathscr{W}}}$
$(0, 0)$	$M^0.U^0 = I$	$X_{00} = 1$	$\widetilde{\mathscr{Q}\mathscr{F}}_{00} = I\|\psi\rangle$
$(0, 1)$	$M^0.U^1 = U$	$X_{01} = 1$	$\widetilde{\mathscr{Q}\mathscr{F}}_{01} = U\|\psi\rangle$
$(1, 0)$	$M^1.U^0 = M$	$X_{10} = -1$	$\widetilde{\mathscr{Q}\mathscr{F}}_{10} = -M\|\psi\rangle$
$(1, 1)$	$M^1.U^1 = M.U$	$X_{11} = -1$	$\widetilde{\mathscr{Q}\mathscr{F}}_{11} = -MU\|\psi\rangle$

TABLE II. Unfolding the Quantum File.

the case $\widetilde{\mathscr{Q}\mathscr{F}}_{00} = I.|\psi\rangle$ implies that the quantum file remian same at the and of Bob and hence Bob can neither read nor write the file and it remains same as teleported by the Alice. While the second case $\widetilde{\mathscr{Q}\mathscr{F}}_{01} = U|\psi\rangle$ stands the meaning such that Bob can only write the file, but can not read. The case $\widetilde{\mathscr{Q}\mathscr{F}}_{10} = -M|\psi\rangle$ handles that Bob only can read the file, while he can never write the file, here the global phase does not matter. The last case of quantum file $\widetilde{\mathscr{Q}\mathscr{F}}_{11} = -MU|\psi\rangle$ exhibit that Bob can write as well can read the file, again the global phase does not matter here. Here we mention that Bob can never unfold the quantum file until he don't receive the binary values $f(0)$ and $f(1)$ from Alice through classical channel, and hence the unfolding operation is controlled by Alice at the end of Bob.

Remote Amplitude Cancellation.- In this section we discuss the concept of remote amplitude cancellation, which can play an important role in quantum information security. Following the Eq.18, the second term in the expression satisfy the condition,

$$\mathscr{Q}\mathscr{F}_{\overleftarrow{\mathscr{R}\mathscr{W}}} \propto X_{\overleftarrow{\mathscr{R}\mathscr{W}}}. \tag{22}$$

The accessibility of a quantum file is determined by the interference factor $X_{\mathscr{R}\mathscr{W}} \equiv X_{\overleftarrow{\mathscr{R}\mathscr{W}}}$ given in Eq.12. The factor $X_{\overleftarrow{\mathscr{R}\mathscr{W}}}$ arise from interference between computational paths and are given by combinations of the oracle-induced phases $(-1)^{f(0)}$ and $(-1)^{f(1)}$. Following the Fig.1, since Alice controls the function $f(\mathscr{R}, \mathscr{W})$ by using the control bit c, and determines the interference pattern governing these amplitudes. The control bit c is used to flip the value of $f(1)$ following the XOR operation i.e. $f(1) = c \oplus \mathscr{W}$, if $c = 1$, the output $f(1)$ is flipped i.e.

$\overline{f(1)}$. Alice send the tuple $\left(\mathscr{R}, \mathscr{W}, f(0), \overline{f(1)}\right)$ through classical channel to Bob; as per the Lemma , the value $\overline{f(1)}$ turns the factor $X_{\overleftarrow{\mathscr{R}\mathscr{W}}}$ to zero and corresponding branch is completely suppressed, it directly consequence the following result,

$$\mathscr{Q}\mathscr{F}_{\overleftarrow{\mathscr{R}\mathscr{W}}} \propto 0. \tag{23}$$

Following the Eq.18, we conclude that one can not write or read anything from the quantum file, since it is physically unavailable to the receiver. This mechanism, termed as *Remote Amplitude Cancellation*, which enables intrinsic and physically remote enforced revocation of quantum information through phase induced interference; it can be useful in securing remote quantum information.

Teleportation of a single qubit Quantum File.- Instead of teleporting only an unknown qubit, the proposed protocol jointly teleport the quantum file and its access semantics, embedding read–write permissions giving into Eq. (17). Unlike Bennett's protocol, this approach allows Alice to have control over the teleportation of a quantum file through the permission factors specified in Table I. It is also important to note that in Bennet et al. protocol there are two unknowns, which are probability amplitudes of a qubit; but in quantum file protocol there there are two more additional binary variables $f(0)$ and $f(1)$, which comprising four unknowns.

The recovery of a quantum file at Bob's side is conditional not only on Alice's classical measurement outcomes but also on the permission factor, which is the function of binary variables $f(0)$ and $f(1)$. The composite action of a permission factor along with unfolding map $\mathscr{U}^f$ selectively enables or disables read and write operations on a quantum file. This introduces a controlled and fine-grained access mechanism at quantum level. The framework thus generalizes Bennett's protocol from unknown qubit teleportation to permission-aware quantum file teleportation. In the successive subsections we discuss the initial resources required and important steps of the protocol which corresponds to the quantum circuit provided in Fig.2. Alice first develop a quantum file at her end and later she teleport the same to Bob.

Initial resources.- To start with, Alice has an unknown qubit, $|\psi\rangle = a_0|0\rangle + a_1|1\rangle$ with $|a_0^2| + |a_1|^2 = 1$ and a shared entangled Bell pair $|\xi\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$. Alice also has an ancilla qubit $|1\rangle$ and a classical oracle O_f. Ancilla qubit is used to introduce the permission factor $X_{\overleftarrow{\mathscr{R}\mathscr{W}}}$, while oracle is used to produce the values of the binary values $f(0)$ and $f(1)$; which are further utilized to calculate the value of the permission factor and an unfolding map $\mathscr{U}^f$.

The protocol.- The quantum file teleportation protocol is provided in the following steps followed by the standard notation $|\pm\rangle = (|0\rangle \pm |1\rangle)/\sqrt{2}$, which can be obtained with the Hadamard action as $H|0\rangle = |+\rangle$ and $H|1\rangle = |-\rangle$.

Alice Procedure.-

Step 1: State Preparation Alice prepare the composite state $|1\rangle \otimes |\psi\rangle \otimes |\xi\rangle$, which is expressed in compact form,

$$|\psi\rangle = \frac{1}{\sqrt{2}} \sum_{i=0}^{1} a_i(|1i00\rangle + |1i11\rangle) \tag{24}$$

Step 2: Swap operation: Alice apply the swap gate between first and second qubit, further the swap gate is applied between first and third qubit. After both the actions, the equation reads,

$$|\psi\rangle = \frac{1}{\sqrt{2}} \sum_{i=0}^{1} a_i(|01i0\rangle + |11i1\rangle) \tag{25}$$

Step 3: Hadamard Transformation: Alice apply Hadamard gate to the second qubit, the following equation is obtained,

$$|\psi\rangle = \frac{1}{\sqrt{2}} \sum_{i=0}^{1} a_i \left(|0\rangle|-\rangle|i0\rangle + |1\rangle|-\rangle|i1\rangle\right) \tag{26}$$

Step 4: Oracle Query: Alice apply the quantum phase oracle by assuming Ist qubit as a controller qubit and 2nd qubit as a target qubit. The quantum phase oracle is defined as below,

$$O_f\left(|x\rangle \otimes |-\rangle\right) = (-1)^{f(x)}|x\rangle \otimes |-\rangle \tag{27}$$

Following the Eq.26, after applying the quantum oracle O_f, the equation reads,

$$|\psi\rangle = \frac{1}{\sqrt{2}} \sum_{i,j\in\{0,1\}} a_i(-1)^{f(j)}|j\rangle|-\rangle|ij\rangle \tag{28}$$

We noticed that ancilla qubit is used to introduce the phase factor in the equation.

Step 5: Hadamard and swap action: Alice apply the Hadamard gate on 2nd qubit and next she swap Ist and 2nd qubit; after completing the step, ancilla qubit can be pulled out from the equation and finally the following equation is obtained,

$$|\psi\rangle = \frac{1}{\sqrt{2}}|1\rangle \otimes \sum_{i,j\in\{0,1\}} c_{ij}|iji\rangle \tag{29}$$

$$\text{with, } c_{00} = p,\ c_{01} = s,\ c_{10} = r,\ c_{11} = q.$$

Satisfying the condition,

$$|p|^2 + |q|^2 + |r|^2 + |s|^2 = 2 \tag{30}$$

$$\text{with, } p = a_0(-1)^{f(0)},\ q = a_1(-1)^{f(1)}$$

$$r = a_0(-1)^{f(1)},\ s = a_1(-1)^{f(0)} \tag{31}$$

Step 6: Quantum State Expansion: Alice expands the state vector given in Eq.29 in 16×16 dimensions by applying the Hadmard gate on 2nd and 3rd qubit; the state is expanded as,

$$|\psi\rangle = \frac{1}{2\sqrt{2}}(|1\rangle \otimes |\omega\rangle) \tag{32}$$

with,

$$|\omega\rangle = (p+s)|000\rangle + (q+r)|001\rangle + (p-s)|010\rangle$$
$$+(r-q)|011\rangle + (p+s)|100\rangle + (-r-q)|101\rangle$$
$$+(p-s)|110\rangle + (q-r)|111\rangle \quad (33)$$

Step 7: Quantum State Post-Selection:

Alice apply a global unitary action U in (8×8) dimensional subspace on $|\psi\rangle$ given in Eq.32, the unitary action embeds a non unitary matrix M. The mapping is performed as follows[17],

$$U|\psi\rangle = \frac{1}{2\sqrt{2}}\Big(|1\rangle \otimes M.|\omega\rangle + |0\rangle \otimes \sqrt{(I-M^{\dagger}.M)}.|\omega\rangle\Big) \quad (34)$$

The structure of the matrix M is given in the Appendix and the unitary matrix U in (8×8) dimensional subspace is given as below,

$$U = \begin{pmatrix} M & -\sqrt{I-M^{\dagger}.M} \\ \sqrt{I-M^{\dagger}.M} & M^{\dagger} \end{pmatrix} \quad (35)$$

with $||M|| \leq 1$ and $M^{\dagger}.M \leq I$. The matrix U can be extended in terms of basis $|0\rangle = [1,0]^T$ and $|1\rangle = [0,1]^T$ as given below,

$$U = (|0\rangle\langle 0|) \otimes M^{\dagger} + (|0\rangle\langle 1|) \otimes (-\sqrt{I-M^{\dagger}.M})$$
$$+(|1\rangle\langle 0|) \otimes (\sqrt{I-M^{\dagger}.M}) + (|1\rangle\langle 1|) \otimes M. \quad (36)$$

The quantum sate vector after the unitary action given in Eq.34 carry the first qubit as an ancilla qubit, Alice assume this ancilla qubit as a flag qubit and perform the projective measurements in the basis $\{0,1\}$ on this flag qubit, the projective measurements given as follows,

$$P_0 = |0\rangle\langle 0| \otimes I$$
$$P_1 = |1\rangle\langle 1| \otimes I \quad (37)$$

After applying the projective measurement on flag qubit, Alice record the measurement result iff the flag qubit is $|1\rangle$, if the measurement result is $|0\rangle$, Alice discard the state $\sqrt{(I-M^{\dagger}.M)}.|\omega\rangle$. Hence after the quantum state post selection process, the quantum state $|\psi\rangle$ is transformed as,

$$|\phi\rangle = \frac{1}{2\sqrt{2}}\Big(|1\rangle \otimes |\Omega\rangle\Big) \quad (38)$$

Where $|\Omega\rangle = M.|\omega\rangle$. The simplificaiton of the quantum state vector $|\Omega\rangle$ leads as,

$$|\Omega\rangle = (p+r)|000\rangle + (s+q)|001\rangle$$
$$+(p-r)|010\rangle + (s-q)|011\rangle$$
$$-(p-r)|100\rangle - (s-q)|101\rangle$$
$$+(p+r)|110\rangle + (s+q)|111\rangle \quad (39)$$

After performing the projective measurement and post selection; the post selection success probability can be obtained as,

$$P_s = \langle\omega|M^{\dagger}.M|\omega\rangle = \Big(\frac{1}{2\sqrt{2}}\Big)^2.\Big[4(|p|^2+|q|^2+|r|^2+|s|^2)\Big] \quad (40)$$

Putting the value from the Eq.30 in the above expression we obtain,

$$P_s = 1 \quad (41)$$

Hence we conclude that the Post selection is perfectly done with success probability 1.

Step 8: Quantum file development: We put the values of the parameters (p,q,r,s) from Eq.31, in Eq.38 and using the Eq.12, the quantum state vector reads as,

$$|\phi\rangle = \frac{1}{\sqrt{2}}|1\rangle\Big[|00\rangle X_{00}(a_0|0\rangle + a_1|1\rangle)$$
$$+|01\rangle X_{01}(a_0|0\rangle + a_1|1\rangle)$$
$$-|10\rangle X_{10}(a_0|0\rangle + a_1|1\rangle)$$
$$+|11\rangle X_{11}(a_0|0\rangle + a_1|1\rangle)\Big] \quad (42)$$

Here we observed that a qubit is revealed at the 4th position, which belongs to Bob. Supplying the corresponding state vector of a qubit in the equation; we obtain,

$$|\phi\rangle = \frac{1}{\sqrt{2}}|1\rangle\Big[|00\rangle X_{00}|\psi\rangle + |01\rangle X_{01}|\psi\rangle$$
$$-|10\rangle X_{10}|\psi\rangle + |11\rangle X_{11}|\psi\rangle\Big] \quad (43)$$

Taking the Table I into account, the quantum state vector can be written as,

$$|\phi\rangle = \frac{1}{\sqrt{2}}|1\rangle\Big[|00\rangle\mathscr{QF}_{00} + |01\rangle\mathscr{QF}_{01}$$
$$-|10\rangle\mathscr{QF}_{10} + |11\rangle\mathscr{QF}_{11}\Big] \quad (44)$$

Here we observe that Alice develop the quantum file in superposition state at her possession, which is ready to teleport to Bob.

Step 9: Teleportation of quantum file: Now Alice perform the projective quantum measurement over the space $I\otimes P_{\mathscr{RW}}\otimes I$ with $\{P_{\mathscr{RW}} = |\mathscr{R}\rangle\langle\mathscr{W}| : (\mathscr{R},\mathscr{W}) \in (0,1)\}$, this projective measurement collapse the whole quantum state with the normalization factor,

$$\sqrt{\langle\phi|(I\otimes P_{\mathscr{RW}}\otimes I)|\phi\rangle} = \frac{1}{\sqrt{2}} \quad (45)$$

this collapse teleport the quantum file at the end of Bob as $|B\rangle$ and Alice is left with the state $|A\rangle$, this collapse phenomena corresponding to the projection operators is shown below in the table, In the table we have used the

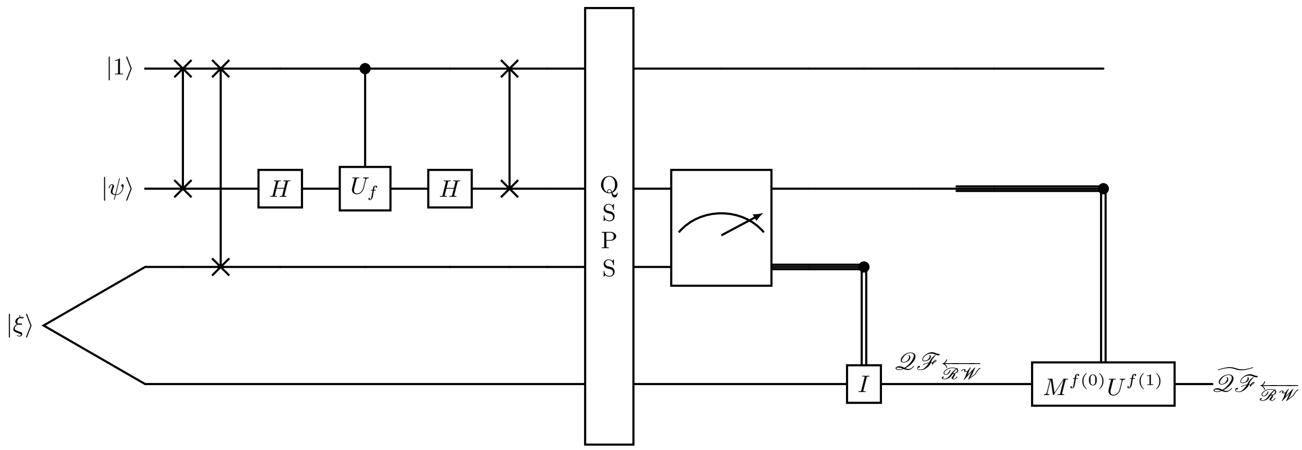

FIG. 2. Quantum circuit for single qubit permission-ware quantum file teleportation

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P_{ij}	$\|A\rangle$	$\|B\rangle$
$\|00\rangle\langle 00\|$	$\|1\rangle$	$\mathscr{QF}_{00}$
$\|01\rangle\langle 01\|$	$\|1\rangle$	$\mathscr{QF}_{01}$
$\|10\rangle\langle 10\|$	$\|1\rangle$	$-\mathscr{QF}_{10} \equiv \mathscr{QF}_{10}$
$\|11\rangle\langle 11\|)$	$\|1\rangle$	$\mathscr{QF}_{10}$

TABLE III. Projective Measurement and Quantum State Collapse.

relation $-\mathscr{QF}_{10} \equiv \mathscr{QF}_{10}$, which is because of the fact that global phase in quantum mechnaics does not matter.

Step 10: Classical Communication: Alice sends the informaion of measurement basis $(\mathscr{R}, \mathscr{W})$ along with binary values $f(0)$ and $f(1)$ to Bob through classical channel.

Bob Procedure.-

Step 11: State reconstruction: Bob apply the identity operator and receive the quantum file $\mathscr{QF}_{\overleftarrow{\mathscr{RW}}}$.

Step 12: Unfolding action: Further Bob unfold the quantum file by using the unfolding map $M^{f(0)}U^{f(1)}$, elaborated in Table II and explore the read write semantics imposed by the Alice embedded in binary values $f(0)$ and $f(1)$ and hence in permission factor $X_{\mathscr{RW}}$.

CONCLUSION

We introduced the concept of a quantum file, further the protocol of quantum teleportation has been developed of a single qubit quantum file with read and write semantics. This protocol generalize the single qubit quantum teleportation protocol developed by C.H. Bennet et al. In the context of quantum files we also introduced the first action principle, which clearly state the axiom that first action on a quantum file can never be a read operation. This protocol provide the fine grain control to Alice to grant the write and read permission to Bob and provides the control mechanism embedded in the quantum teleportation protocol. The concept of Remote Amplitude Cancellation is also developed, which assists to kill the quantum file remotely. This approach provides a new paradigm for organizing and securing quantum information in quantum file systems.

APPENDIX-A

A Non-Unitary Matrix M

The non-unitary matrix M is (8×8) dimensional, and in block form it reads as,

$$M = \frac{1}{4}\left(\begin{array}{c|c} A & B \\ \hline C & D \end{array}\right) \tag{46}$$

Each block is 4×4 dimensional and acquire the form given below,

$$A = \begin{pmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & 1 & -1 \\ 1 & -1 & -1 & 1 \end{pmatrix}, \quad B = \begin{pmatrix} 1 & -1 & 1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \end{pmatrix},$$

$$C = \begin{pmatrix} -1 & 1 & -1 & 1 \\ -1 & 1 & 1 & -1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \end{pmatrix}, \quad D = \begin{pmatrix} -1 & -1 & -1 & -1 \\ -1 & -1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & -1 & -1 & 1 \end{pmatrix}.$$

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