United Nation Security Council in Quantum World: Experimental Realization of Quantum Anonymous Veto Protocols using IBM Quantum Computer

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November 18, 2021

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Abstract

United Nation (UN) security council has fifteen members, out of which five permanent members of the council can use their veto power against any unfavorable decision taken by the council. In certain situations, a member using the right to veto may prefer to remain anonymous. This need leads to the requirement of protocols for anonymous veto which can be viewed as a special type of voting. Recently, a few protocols for quantum anonymous veto have been designed which clearly show quantum advantages in ensuring anonymity of the veto. However, none of the efficient protocols for quantum anonymous veto have yet been experimentally realized. Here, we implement two of those protocols for quantum anonymous veto using an IBM quantum computer named IBMQ Casablanca and different quantum resources like Bell, GHZ and cluster states. In this set of proof-of-principle experiments, it's observed that using the present technology, a protocol for quantum anonymous veto can be realized experimentally if the number of people who can veto remains small as in the case of UN council. Further, it's observed that Bell state based protocol implemented here performs better than the GHZ/cluster state based implementation of the other protocol in an ideal scenario as well as in presence of different types of noise (amplitude damping, phase damping, depolarizing and bit-flip noise). In addition, it’s observed that based on diminishing impact on fidelity, different noise models studied here can be ordered in ascending order as phase damping, amplitude damping, depolarizing, bit-flip.

1 Introduction

Quantum mechanics often exposes us to phenomena or rules that are counter-intuitive to our classical minds. Interestingly, these counter-intuitive phenomena or rules having no classical analogue lead to quantum advantages. In fact, quantum advantages have already been reported in different contexts, including but not restricted to quantum metrology [1, 2], quantum computing [3, 4], and quantum communication [5]. As a result, it’s now widely believed that the civilization is ready for the second quantum revolution [6]. However, all the facets where we may be benefited from the uses of quantum resources are not equally matured at the moment. To be precise, quantum cryptography [5] which can offer unconditional security, seems to be the most mature quantum technology at the moment as various commercial solutions are already available. The primary feature of quantum cryptography is quantum key distribution (QKD) which allows generation and distribution of an unconditionally secure key between two authentic parties using quantum resources. This field started with the advent of the BB84 protocol [7] in 1984. Since then considerable progress has happened. Specifically, several schemes of QKD have been proposed and implemented [8] and generalizing the basic idea of QKD, quantum advantage of obtaining unconditional security has been extended to several new schemes for one-way and two-way secure direct quantum communication (cf. Refs. [9, 10, 11] and Chapter 8 of [12]) as well as schemes for secure multiparty quantum computation (SMQC) [13, 14]. Secure multiparty computation tasks include voting, auction, private comparison, etc. As these tasks have enormous uses in our daily life, protocols for SMQC have drawn considerable attention. Voting is one of the most important SMQC tasks as it forms an integral part of any democratic setup where decisions are taken collectively. The usefulness of quantum resources for anonymous voting was first exploited in 2006 by Hillery et al. [15] and almost simultaneously by Vaccaro et al. [16] (for a historical note see [17]). Since, then the field has grown many a times with several new protocols appearing in the last few years ([17] [18] and references therein).

Within the broad class of voting schemes, a specific subclass of interest is one in which all the decisions are taken by unanimity only, i.e., a proposal put to the vote is rejected even if just one of the members disagrees. One of the most prominent examples of this is when a proposal is put to vote in the United Nation (UN) security council, where the proposal is rejected at once if one or more permanent member(s) of the council disagrees. Such a scheme is known as the veto and
many times the situations require that the secrecy of the vote is maintained. The first quantum solution for anonymous veto was provided by Rahman and Kar by utilizing the GHZ correlations [19]. Following that Wang et al., provided a mature solution using the same GHZ states and experimentally testing it in the case of four voters on the IBM quantum computer [20]. Recently, Mishra et al. [18] proposed a set of new schemes for quantum anonymous veto and classified the schemes based on quantum resources used along with their feasibility under realistic physical implementations. Further, the schemes proposed by Mishra et al., have been classified into probabilistic, iterative and deterministic schemes. From the set of proposed schemes, two schemes (referred to as QAV-6 and QAV-7 in [18] and to be referred to as Protocol A and Protocol B, respectively in this article) are of particular interest as they have the highest efficiency. Here, we implement the two most efficient quantum anonymous veto protocols proposed by Mishra et al. [18] on the cloud-based IBM quantum computer and investigate the effect of amplitude damping, phase damping, bit flip and depolarizing noise on these protocols.

Before proceeding further, it will be apt to note that due to the presence of decoherence a scalable quantum computer cannot be built until now. However, a set of noisy intermediate-scale quantum (NISQ) computers have been built in the recent past. Further, cloud based access of such quantum computers has also been provided by different organizations. IBM is a pioneer in this aspect as they are providing cloud-based access to NISQ computers to common researchers since 2016. IBM’s quantum computers are superconductivity based and utilizes transmon qubits. However, the available computers have different topology and number of qubits. Without going into those details, we may note that IBM quantum computers have already been used for the realization of various quantum computing and communication tasks [21, 22, 23, 24, 25]. For example, IBM quantum computers are used in: quantum part of a quantum-classical hybrid algorithm for factorization [21], nondestructive discrimination of Bell states [22], a proof-of-principle experiment for the implementation of an optimal scheme for the teleportation of an n-qubit quantum state [23], the implementation of fault-tolerant logic gates in the code space [24], modeling quantum walk [25] and various other tasks (see [26] and references therein). Extending this long list, in this paper, we aim to report experimental realization of two efficient schemes of QAV using IBM quantum computer. The motivation behind performing such an experiment is two fold, firstly anonymous veto has many applications in social life and secondly as veto usually involve a small number of voters so commercial implementation QAV would be possible if it can be successfully implemented using IBM quantum computer.

The rest of the paper is organized as follows. In Section 2, we briefly describe the two most efficient quantum anonymous veto protocols proposed by Mishra et al. [18]. Then, we discuss the results and issues associated with the experimental realization of those schemes on the IBM quantum computer in Section 3. In Section 4, performance of the experimentally realized protocols are compared in the ideal scenario as well as in the presence of noise. Finally, the paper is concluded in Section 5.

2 Quantum anonymous veto protocols

We have already mentioned that recently Mishra et al., [18] have reported a set of schemes for QAV. Two of the reported schemes are relatively more efficient (as far as qubit efficiency is concerned) compared to the existing protocols and the other protocols proposed by Mishra et al. In what follows, we briefly describe those two protocols in a step-wise manner and refer to them as Protocols A and B. Both the protocols are conducted by a semi-honest voting authority (VA) referred to as Alice who is semi-honest in the sense that she strictly (i.e., honestly) follows the protocol, but tries to obtain additional information about the inputs (say, votes in our context) of the other users (i.e, voters). Voting involves n voters \( \{V_1, V_2, \ldots, V_n\} \).

2.1 Protocol A

Protocol A is an iterative protocol and uses a Bell state for its implementation with one qubit acting as a home qubit while the other qubit acting as the travel qubit. The protocol can be described in the following steps:

**Step A1** VA prepares a maximally entangled Bell state \( |\phi^+\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle) \), and keeps the first qubit (home qubit) with herself while sends the second qubit (travel qubit) to the first voter \( V_1 \).

**Step A2** \( V_1 \) applies \( \sigma_z(t) = \begin{bmatrix} 1 & 0 \\ 0 & e^{i2\pi t} \end{bmatrix} \) with \( t = 0 \) if he wishes to perform a veto, otherwise he applies Identity operation \( I = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \). After the application of unitary on the travel qubit, \( V_1 \) sends the travel qubit to \( V_2 \), who encodes his vote in the similar manner and subsequently sends the travel qubit to \( V_3 \), and the process continues till \( V_n \) finally sends the travel qubit to VA after executing his voting right.

Note that \( (t + 1) \) is the number of iterations of the protocol. Thus, \( t = 0 \) refers to the first iteration and in the first iteration a voter would apply \( \sigma_z(n - 1) = \begin{bmatrix} 1 & 0 \\ 0 & e^{i\pi(n - 1)} \end{bmatrix} \).
Steps A1-A3 are repeated for step A4. In contrast to the previous protocol, this protocol is a deterministic protocol, where the conclusive result is obtained in a single iteration only. Further, every voter is provided with a set of unitaries, which can be used to give a veto. Specifically, as voters can encode only 1 bit of information either in favor or against the proposal. VA further makes an iteration a voter would apply \[
\begin{bmatrix}
1 & 0 \\
0 & e^{i\pi}
\end{bmatrix} = \begin{bmatrix}
1 & 0 \\
0 & -1
\end{bmatrix} = \sigma_z.
\]

**Step A3** VA performs a Bell measurement using the home qubit available with him and the travel qubit received from \(V_n\).

If the veto is applied by an odd (even including 0) number of voters, measurement of VA would yield \(|\phi^-\rangle = \frac{1}{\sqrt{2}}(|00\rangle - |11\rangle)\) \(|\phi^+\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)\) and the protocol will be accomplished (continued to the next step as the result is inconclusive).

**Step A4** Steps A1-A3 are repeated for \(t = 1\) and so on till one gets a conclusive result with each iteration increasing the value of \(t\) by one.

If \(n\) number of voters participate in the process, then the maximum number of iterations required to arrive on conclusive result would be \(1 + \log_2 n\) with every iteration eliminating half of the voting possibilities.

### 2.2 Protocol B

In contrast to the previous protocol, this protocol is a deterministic protocol, where the conclusive result is obtained in a single iteration only. Further, every voter is provided with a set of unitaries, which can be used to give a veto. Specifically, \(i\)th user possesses a unitary \(U_i\) which he can apply to register a veto. As a specific example, possible unitary operations for 4 voters and different entangled states is shown in Table 1. The steps involved in executing this protocol for \(n\) number of voters in general are as follows:

**Step B1** VA prepares a \(m\)-qubit entangled state \(|\psi_{in}\rangle\) (with \(m \geq (n-1)c\)).

Here, \(c = 1\) as voters can encode only 1 bit of information either in favor or against the proposal. VA further makes \(l\) qubits \((l < m)\) as travel qubits and keeps \((m - l)\) qubits as the home qubits with \(l\) qubits traveling to each of the voter and finally returned back to VA.

**Step B2** The voter \(V_i\) \((1 \leq i \leq n - 1)\) applies the identity operation when he is in favor and apply an operator \(U_i\) when he is in against. After the operation, the \(l\) travel qubits will be sent to voter \(V_{i+1}\). This process continues till the voter \(V_n\) who sends the travel qubits to VA after his operation.

**Step B3** VA measures the final state (say \(|\psi_{fin}\rangle\)) in the same basis in which initial state was prepared. If \(\langle\psi_{in}|\psi_{fin}\rangle = 1\) then it is concluded that either no voter has done veto or all voters have done veto. If \(\langle\psi_{in}|\psi_{fin}\rangle \neq 1\) then it is concluded that at least one voter has applied the veto. In this way, the voters can conclude if there is any consensus or not.

### 3 Quantum veto protocols using IBM quantum computer

As mentioned above IBM provides cloud based access to a set of quantum computers, which are distinct from each other as far as their size (number of qubits) and topology are concerned [27]. Without loss of generality, for the experimental realization of the above described protocols, here we have considered the number of voters as four. Further, Protocol A requires Bell states only so any small quantum computer can in principle be used for proof-of-principle implementation of the Protocol A. In contrast, Protocol B can be implemented using a class of entangled states. Of course the choice of unitary operations would depend on the choice of the entangled state. In Table 1 we have already described the unitaries to be used by the voters if a 4 qubit cluster state or a 3 qubit GHZ state is to be used for the implementation of Protocol B. Here, we will restrict us to realize Protocol B using these entangled states only. Thus, any quantum computer which can perform quantum information processing involving four or more qubits will be sufficient for our purpose. Here, we have chosen IBMQ Casablanca, because of its availability at the time of performing these experiments. It may be noted that IBMQ Casablanca is a 7 qubit superconductivity-based quantum computer whose topology is shown in Fig. 1. In what follows, we briefly describe the quantum circuits used for the realization of the protocols of quantum veto and the
Table 2: Description of the relevant errors in the quantum processor used (i.e., IBMQ Casablanca). The table is prepared using the calibration data available at the website of IBM quantum services at the time of performing the experiments (on October 13, 2021). Here, $cxi_j$ represents the error in the implementation of a CNOT gate, where index $i$ denotes a control qubit and the index $j$ denotes a target qubit.

results obtained by implementing those circuits in IBMQ Casablanca. A two qubit gate (say a CNOT gate) can be directly implemented only between the qubits which are connected through an arrow. A bidirectional arrow implies that any one of the qubits shown at the end of the arrow can work as control qubit. However, every CNOT gate does not work with the same accuracy. Errors introduced by a CNOT gate depends on the choice of the pair of qubits on which the CNOT gate is applied. To be explicit on this point, in Table 2 we list the experimental parameters and errors in different gate implementation in IBMQ Casablanca that was present at the time of performing this experiment. We restrict the table to qubit 0, 1, 2, 3 shown in Fig. 1 and marked as $Q_0, Q_1, Q_2, Q_3$, respectively in Table 2 as we have only used these qubits for our experiment. In fact, to implement Protocol A we have used $Q_0$ and $Q_1$ and to implement Protocol B using GHZ states we have used qubits $Q_0, Q_1, Q_2, Q_3$, whereas to implement Protocol B using 4-qubit cluster state we have used all the four qubits $\{Q_0, Q_1, Q_2, Q_3\}$.

3.1 Experimental realization of Protocol A
To implement Protocol A, VA needs to prepare a Bell state $|\phi_{\text{int}}\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$ which can be prepared using a CNOT gate followed by a Hadamard gate (cf. leftmost block of Fig 2). Subsequently, voters as well as VA follow the protocol and to do so 4 voters need to apply unitaries in sequence, where $i$th voter $V_i$ applies $\sigma_z(t)$ and specific choice of $\sigma_z(t)$ depends on the number of iterations and whether a voter is executing his right to veto. A general circuit representation of this part is shown in the middle part of Fig 2. This step would produce a final state $|\phi_{\text{fin}}\rangle$ which is produced after all voters have applied their votes in a particular iteration round. If $\langle \phi_{\text{int}}|\phi_{\text{fin}}\rangle = 1$ then the VA remains inconclusive, otherwise she can conclude that everyone does not agree with the proposal and veto has been applied. Now, to check whether the final state satisfies $\langle \phi_{\text{int}}|\phi_{\text{fin}}\rangle = 1$ or not, one needs to measure $|\phi_{\text{fin}}\rangle$ in Bell basis, but IBM quantum computers do not allow direct measurement in any basis other than computational basis. Consequently a reverse EPR circuit comprising of a Hadamard gate followed by the CNOT gate is used for transforming Bell measurement into computational basis.
3.2 Experimental realization of Protocol B

Similar to Protocol A, we consider that there are 4 voters and the circuits to be implemented in IBMQ Casablanca to have three parts. Leftmost part to be used for preparation of the entangled state (see the leftmost blocks of Fig.|\textbf{2} (a) and (b), which are used to produce 4-qubit cluster state \(\psi_c = \frac{1}{\sqrt{2}}((0000) + (0011) + (1100) - (1111))\) and 3-qubit GHZ state \(\psi_{GHZ} = \frac{1}{\sqrt{2}}((000) + (111))\), respectively). The middle block is to be used for voting in accordance with the rules described in Table |\textbf{1}. The protocol is followed by all voters and finally the travel qubits are returned back to VA. Now, in
| Case | Initial state | Number of veto | Which voter(s) has (have) vetoed | Iteration No. | Final state | Result | Simulator result (or expected measurement outcome) | Probability of obtaining the expected result on real device | Fidelity (%) |
|------|---------------|----------------|---------------------------------|---------------|------------|--------|---------------------------------------------------|------------------------------------------------------|------------|
| 1    | $|\phi^+\rangle$ | 0              | No one                          | Iteration 1   | $|\phi^+\rangle$ | Inconclusive | 00 | 0.985 | 99.41 |
| 2    | $|\phi^+\rangle$ | 1              | Any one voter among the 4 voters | Iteration 1   | $|\phi^-\rangle$ | Conclusive   | 10 | 0.878 | 96.50 |
| 3    | $|\phi^+\rangle$ | 2              | Any two of the 4 voters (e.g., $1^{st}$ & $3^{rd}$ or $3^{rd}$ & $4^{th}$) | Iteration 1   | $|\phi^+\rangle$ | Inconclusive | 00 | 0.981 | 98.65 |
|      |               |                |                                 | Iteration 2   | $|\phi^-\rangle$ | Conclusive   | 10 | 0.911 | 96.23 |
| 4    | $|\phi^+\rangle$ | 3              | Any three of the 4 voters (e.g., $1^{st}$, $2^{nd}$ & $4^{th}$ or $1^{st}$, $3^{rd}$ & $4^{th}$) | Iteration 1   | $|\phi^-\rangle$ | Conclusive   | 10 | 0.915 | 98.44 |
|      |               |                |                                 | Iteration 2   | $|\phi^+\rangle$ | Inconclusive | 00 | 0.980 | 98.98 |
|      |               |                |                                 | Iteration 3   | $|\phi^-\rangle$ | Conclusive   | 10 | 0.964 | 95.19 |

Table 3: Comparison of the theoretically expected results for the realization of quantum veto using Bell state (Protocol A) with the corresponding results obtained experimentally. Here, $|\phi^\pm\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$ and simulator result corresponds to the measurement outcome obtained on execution of the circuit shown in Fig. 2 in IBM Qasm.

Figure 3: (Color online) Simulator and real device results for Protocol A using Bell state for the (a) inconclusive and (b) conclusive results.
the rightmost block VA needs to perform measurement in the same basis in which the initial entangled state was prepared. However, such a measurement is not directly allowed in IBM quantum computers, so we need a circuit which may be viewed as the inverse of the circuit used in the preparation stage to transform the measurement into a computational basis measurement. The same is done in the rightmost block of Fig 4 (a) and (b), for the cluster state based implementation and GHZ state based implementation, respectively. Expected results for 5 different possibilities of voting pattern using cluster (GHZ) states are summarized in the first seven columns of Table 4 (Table 5). As expected these results of ideal scenario are consistent with the IBM Qasm results. However, the actual experimental realization led to results which are slightly different from the ideal results and those are listed in the last two columns of Table 4 and Table 5 and also illustrated in Fig. 5.

Results depicted in Fig. 6 (a, b) (Fig. 5 (c, d) for cluster state (GHZ state) based implementation of the Protocol B using the IBMQ Casablanca along with the expected results of ideal scenario clearly show that proof-of-principle realization of quantum anonymous veto protocol (Protocol B) has happened successfully in IBMQ Casablanca for 8192 repetitions (shots) of the experiment.

4 Comparison of Protocol A and Protocol B

In the previous sections, we have shown that both Protocol A and Protocol B can be experimentally realized using the IBMQ Casablanca with some experimental errors. However, no analysis of the relative performance of these protocols has yet been made. A comparative idea can be obtained by comparing the range of fidelity as reported in the last columns of Tables 3, 4 and 5. We can easily observe that for Bell state based implementation of Protocol A fidelity varies between 95.19 and 99.44, whereas the same for cluster (GHZ) state based implementation of Protocol B is found to vary between 88.79 and 97.63 (89.99 and 97.67). The obtained ranges of fidelity clearly shows that Bell state based protocol performs better than GHZ state based protocol and that in turn works better than cluster state based protocol. This is not surprising as with the increase in the number of qubits in the initial entangled state, difficulties associated with the creation and maintenance of the entangled state increases. This straightforward fidelity based analysis of the performance of the protocols under ideal scenario can also be extended to a more realistic situation involving noise. The same is done in the next section.

4.1 Effect of noise

In realistic situations, quantum systems can never be perfectly isolated from the surrounding environment and this leads to the degrading of the unique quantum mechanical features. Hence, the practical implementations of any quantum state based protocol necessarily involve the effects of unwanted noise. So, any protocol is considered as practically useful only if it is robust in the presence of noise (for details see [28, 29, 30, 31]). Some of the most relevant noises that are usually considered in any physical implementation are amplitude damping, phase damping, depolarizing and bit flip noise. Further, the effect of the underlying noise on the protocol can be studied in terms of the corresponding change in the
| Case | Initial State | Number of veto | Which voter(s) has (have) vetoed | Final State | Is the result conclusive? | Simulator result (or expected measurement outcome) | Probability of getting expected result on real device | Fidelity (%) |
|------|---------------|----------------|-------------------------------|-------------|--------------------------|---------------------------------|-------------------------------------------------|-------------|
| 1    | | 0 | No one | $\frac{1}{\sqrt{2}}((0000) + (0011) + | 1100) - | 1111)$ | No | 0000 | 0.970 | 97.63 |
| 2    | | | 1                  | $\frac{1}{\sqrt{2}}((0101) - | 0110) + | 1001) - | 1010)$ | Yes | 1111 | 0.873 | 99.06 |
| 3    | | | 2                  | $\frac{1}{\sqrt{2}}((0100) - | 0111) + | 1000) + | 1011)$ | Yes | 0110 | 0.887 | 93.23 |
| 4    | | | 3                  | $\frac{1}{\sqrt{2}}((-0101) + | 0111) + | 1000) + | 1011)$ | Yes | 1110 | 0.779 | 91.17 |
| 5    | | | 4                  | $\frac{1}{\sqrt{2}}((-0101) + | 0110) - | 1001) - | 1010)$ | Yes | 0111 | 0.819 | 88.79 |

Table 4: Results for the realization of quantum veto using the cluster state (Protocol B). Here, $|\psi_c\rangle = \frac{1}{\sqrt{2}}((0000) + (0011) + | 1100) - | 1111)$

| Case | Initial State | Number of veto | Which voter(s) has (have) vetoed | Final State | Is the result conclusive? | Simulator result (or expected measurement outcome) | Probability of getting expected result on real device | Fidelity (%) |
|------|---------------|----------------|-------------------------------|-------------|--------------------------|---------------------------------|-------------------------------------------------|-------------|
| 1    | $|\psi_{\text{GHZ}}\rangle$ | 0 | No one | $|\frac{1}{\sqrt{2}}((0000) + | 111)\rangle$ | No | 0000 | 0.972 | 97.67 |
| 2    | $|\psi_{\text{GHZ}}\rangle$ | 1 | 1                          | $|\frac{1}{\sqrt{2}}((0100) + | 101)\rangle$ | Yes | 0100 | 0.916 | 94.79 |
| 3    | $|\psi_{\text{GHZ}}\rangle$ | 2 | 2                          | $|\frac{1}{\sqrt{2}}((-0111) + | 100)\rangle$ | Yes | 1110 | 0.934 | 91.96 |
| 4    | $|\psi_{\text{GHZ}}\rangle$ | 3 | 3                          | $|\frac{1}{\sqrt{2}}((-0111) - | 1001)\rangle$ | Yes | 0111 | 0.850 | 90.72 |
| 5    | $|\psi_{\text{GHZ}}\rangle$ | 4 | 4                          | $|\frac{1}{\sqrt{2}}((0001) + | 1111)\rangle$ | No | 0000 | 0.964 | 96.85 |

Table 5: Theoretically expected results for the realization of quantum veto using the GHZ state (Protocol B). Here, $|\psi_{\text{GHZ}}\rangle = \frac{1}{\sqrt{2}}((0000) + | 111))$.
Figure 5: (Color online) Simulator and real device results for Protocol B using cluster state and GHZ state for the (a,c) inconclusive and (b,d) conclusive result.
fidelity with respect to their noiseless implementations. The effect of amplitude damping and phase damping noise on the quantum anonymous veto protocols realized here has already been studied in Ref. [18] from a different perspective. Here, we have studied the effect of noise using noise model building technique introduced on qiskit [32], an open source software for working with quantum computer. Specifically, we have used the error function available on qiskit to see the effect of different types of noise. Effects of amplitude damping, phase damping, depolarizing and bit flip noise on Protocol A and Protocol B (using both cluster state and GHZ state) are illustrated in Fig. 6 (a)-(c). Each plot describes effect of 4 different types of noise on a particular protocol. The plots are consistent with the earlier result of Ref. [18] and clearly show that the effect of different noise models can be arranged in an ascending order (based on the diminishing effect of noise on Fidelity) as phase damping, amplitude damping, depolarizing, bit-flip noise. Further, it’s observed that independent of the nature of noise, Bell state based schemes always perform better than the other two schemes studied here. As an example, effect of phase damping noise on Protocol A and two implementations of Protocol B (using GHZ or cluster state) are illustrated in Fig. 6 (d). Similar characteristics are observed for other noise models, too (not shown here).

5 Conclusion

The different types of voting strengthens democracy in different manners. However, designing quantum protocols for voting is not easy. Still, a set of protocols for quantum voting have been proposed and analyzed since 2006. Recently, a special type of quantum voting called quantum anonymous veto has drawn considerable attention of the community. As the name suggests, such a scheme would allow a set of voters to execute the right to veto in an anonymous manner. We have already mentioned that such a situation where protocol for quantum anonymous veto is useful exist in UN security council. Some of the present authors have already designed a set of protocols for quantum anonymous veto. Here, we have implemented two of those protocols (which are more efficient) using a superconductivity based quantum computer named IBMQ Casablanca. The protocols that we have selected for the present study are referred to as Protocol A and Protocol B. In the above, we have reported Bell state based experimental realization of Protocol A whereas Protocol B has been experimentally realized using GHZ state and cluster state. The protocols are realized with high success probability, and
it’s understood that using the present technology, a protocol for quantum anonymous veto can be realized experimentally if the number of people who can veto remains small as is the case of UN security council. Further, it’s observed that Bell state based Protocol A implemented here performs better than the GHZ/cluster state based implementation of the Protocol B in ideal scenario as well as in the presence of different types of noise (amplitude damping, phase damping, depolarizing and bit-flip noise). Further, it’s observed that based on diminishing impact on fidelity, different noise models studied here can be ordered in ascending order as phase damping, amplitude damping, depolarizing, bit-flip.

Acknowledgment

Authors acknowledge the support from the QUEST scheme of Interdisciplinary Cyber Physical Systems (ICPS) program of the Department of Science and Technology (DST), India (Grant No.: DST/ICPS/QuST/Theme-1/2019/14 (Q80)). They also thank Sandeep Mishra and Kishore Thapliyal for their interest in the work.

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