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Ensuring a spare quantum traffic

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Abstract - In this report is examined an algorithm for ensuring a spare quantum traffic, which requires the exchange of only one pair of qubits in order to be reached to a solution of the problem related to ensuring a spare traffic. Here we show two different approaches of the unitary dynamics that can enable the directional control, enhancement, and suppression of quantum transport. This opens new prospects for more efficient methods to transport a quantum information.

Index Terms— boolen function, circuit, composition, encoding, gate, quantum.

1 Introduction

The theory of the complex networks is used in a number of abstract researches on the quantum information [31, 32]. In this research is addressed the theory of the complex networks in order to determine whether the development and use of the optimization procedures will lead to an improvement in the transport through the quantum flows in large and randomly generated quantum networks. The understanding of the quantum transport is of key importance for the development of more solid communication networks, more efficient transfer of energy, as well as improved devices for information processing.

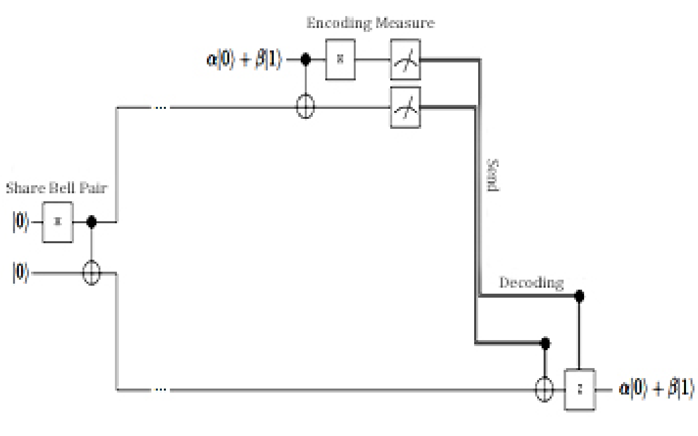
While the majority of the known quantum algorithms focus on the encoding of two classical bits into one quantum bit and its subsequent sharing, in this algorithm is used a shared qubit, which is used for the encoding of two classical bits. The usefulness of this technique allows for securing a spare quantum traffic in case of problems with the quantum channel.

2 Quantum logarithm ensuring a spare traffic

In this report is offered a simple quantum circuit, which allows to be increased the reliability of the quantum channel, as well as to be reduced its latency and could in principle be used to create larger logical circuits and future realizations of transport means, in order to be stored

Figure 1: Circuit for provision of a spare quantum traffic

and processed information. Fig. 1 presents one example for the proposed quantum circuit.



The change of the system state, as well as the operations, which are applied, from left to right are examined in the time. Initially the system is into a full zero-state. The left side *A* still has not initialized its qubit and the superposition has not yet been created. Algebraically represented, using a KET notation, the initial state is:

$|0\rangle\ |0\rangle\ |0\rangle = |000\rangle$

From this state is created a superposition, from which the left side *A* will encode its qubit, and when it receives it, the right side *B* - will decode it.

Creating a Superposition

The first thing that needs to be done is the sharing of a pair of qubits. Two qubits must be placed in a superposition, in which both values are zeros or units. This is done by applying the Hadamard operator on one of the qubits, and CNOT on the other.

The Hadamard operator (H) creates from the state $|0\rangle$ a superposition $|0\rangle\ \ |1\rangle$, and from the state $|1\rangle$ a superposition $|0\rangle$-$|1\rangle$. The proposed algorithm uses the second and third bit to create a pair, thus the Hadamard operator is applied to the second position. Its value is $|0\rangle$, therefore the resultant superposition is:

$|0\rangle\ \ |1\rangle: \rightarrow |0\rangle\ (|0\rangle\ \ |1\rangle)\ |0\rangle = |000\rangle\ \ |010\rangle$

It is possible by a supplement the multiplication to be spread vectorally, which is useful for presenting the state in more convenient ways to work. At this stage is applied a CNOT operator, an inversion of the third bit in all parts of the superposition, where the second bit is set: $\rightarrow |000\rangle\ \ |011\rangle = |0\rangle\ (|00\rangle\ \ |11\rangle)$ The superposition is allready created. *A and B* have by one paired qubit, then it is proceeded to the stage of encoding.

Encoding

A initializes the first bit in superposition: $\alpha\ |0\rangle\ \ \beta\ |1\rangle$. Then the state of the entire system is changed to:

$\rightarrow (\alpha|0\rangle\ \ \beta|1\rangle)\ (|00\rangle\ \ |11\rangle)$
$= \alpha|000\rangle\alpha|011\rangle\beta|100\rangle\beta|111\rangle$

To encode its qubit, *A* applies a CNOT operator on its half of the pair. Thus the second bit is inverted in the parts of the superposition, where the first bit is already set:

$\rightarrow\alpha|000\rangle\alpha|011\rangle\beta|110\rangle\beta|101\rangle$

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After the CNOT operator, A applies on its bit also the Hadamard operator (bit # 1). As a consequence of the rule: 0 -> 0 1 and 1 -> 0-1, the operation changes the state:

$\rightarrow \alpha\ (| 000\rangle\ \ | 100\rangle)\ \ \alpha\ (| 011\rangle\ \ | 111\rangle)\ \ \beta\ (| 010\rangle - | 110\rangle)\ \ \beta\ (| 001\rangle - | 101\rangle)$

$= \alpha\ | 000\rangle\ \ \alpha\ | 100\rangle\ \ \alpha\ | 011\rangle\ \ \alpha\ | 111\rangle\ \ \beta\ | 010\rangle - \beta\ | 110\rangle\ \ \beta\ | 001\rangle - \beta\ | 101\rangle$

With this the process of encoding ends, and it can be proceeded to decoding.

Decoding

The receiving side *B* decodes the received qubit from the classical bits, which it receives. A CNOT operator is applied on the second bit from its part of the superposition, and conditional Z-rotation is applied on the basis of the first bit. The CNOT operator inverts the third bit of a superposition, when the second bit is set, which leads to a state:

$\rightarrow \alpha\ | 000\rangle\ \ \alpha\ | 100\rangle\ \ \alpha\ | 010\rangle\ \ \alpha\ | 110\rangle\ \ \beta\ | 011\rangle - \beta\ | 111\rangle\ \ \beta\ | 001\rangle - \beta\ | 101\rangle$

Then the Z operator is applied, conditionally from the first to the third bit. The Z operator makes the phase $|1\rangle$ negative, thus each time when the first and the third bit are set, is multiplied by -1:

$\rightarrow \alpha\ | 000\rangle\ \ \alpha\ | 100\rangle\ \ \alpha\ | 010\rangle\ \ \alpha\ | 110\rangle\ \ \beta\ | 011\rangle\ \ \beta\ | 111\rangle\ \ \beta\ | 001\rangle\ \ \beta\ | 101\rangle$

Then everything is factored again:

$= \alpha\ | 000\rangle\ \ \beta\ | 001\rangle\ \ \alpha\ | 100\rangle\ \ \beta\ | 101\rangle\ \ \alpha\ | 010\rangle\ \ \beta\ | 011\rangle\ \ \alpha\ | 110\rangle\ \ \beta\ | 111\rangle$

$=(|00\rangle | 10\rangle\ \ | 01\rangle\ \ | 11\rangle)\ (\alpha\ | 0\rangle\ \ \beta\ | 1\rangle)$

$= (| 0\rangle\ \ | 1\rangle)\ (| 0\rangle\ \ | 1\rangle)\ (\alpha\ | 0\rangle\ \ \beta\ | 1\rangle)$

The expression for the third qubit in fact represents the state, which the side *A* has sent. This qubit is received by the *B* side, using only one classical channel, thanks to the paired in advance qubits. The described algorithm similarly could be used also upon pairing of a large number of qubits. All of these applications are hypothetical. More precisely, they all rely on the possibility for storing the state of the qubits for long periods of time. It is not yet known a hardware solution that can provide this. The algorithm also could be used to be increased the reliability of the quantum channel, as well as to be reduced its latency by just sending a constant flow of paired qubits.

Applications

What makes the proposed quantum circuit useful is its ability to improve the characteristics of the quantum channels by storing a quantum traffic.

The proposed quantum circuit can be used to be increased the reliability of the quantum channel. The quantum circuit allows to be used the available bandwidth to be shared paired qubits, and then these shared pairs, can be used to maintain the quantum communication during the interruption of the connection. The proposed quantum circuit allows to be converted a quantum channel with high-latency, which only works in one way and with frequent interruptions, into a bidirectional quantum channel with low latency, which works even if there is an interruption.

3. Usage of swaps instead of the consuming Bell Pairs

If the pre-shared pairs of qubits instead of being used directly are processed on the go, then it will be obtained a doubling of the information flow of classical information in one of the directions by sending the quantum information in the opposite direction.

If we use quantum circuit, who's upper and lower part are divided by a harmonious area of alternating swap operators all data, entered at the beginning will be exchanged downwards until the lower limit of the circuit is reached. On the other hand, the data, which are entered in the lower part of the circuit are exchanged upwards, until the upper limit is reached:

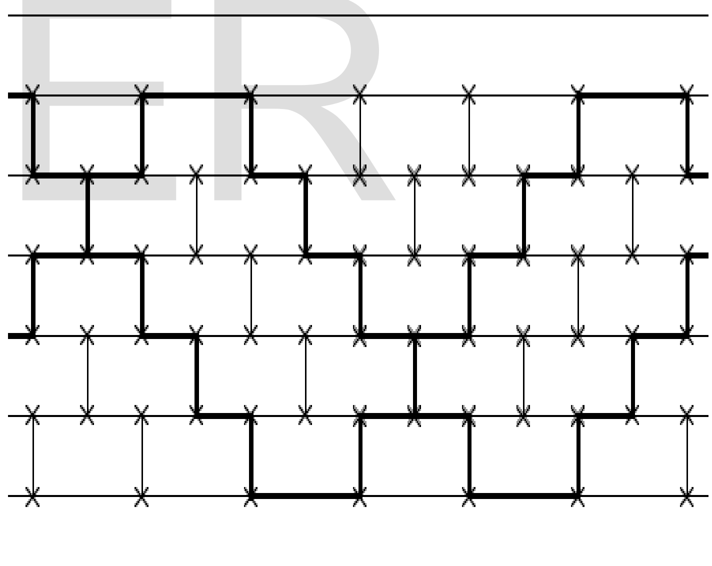

Figure 2: Diagram of the transitions

On figure 2 can be seen the movements backwards and forward of two values, the transitions pass upwards and downwards, between the outer limits of the circuit. This allows the upper zone to communicate with the lower part. The circuit with the swap operators is used as a quantum channel, on which can be sent unidirectionally a classical information. Conditionally can be accepted that the sender is the upper part of the circuit, and the receiver is the zone above the circuit.

The simplest way for sending the classical information can be realized as the submitter shifts its communication line to 1 in

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order to send data, while the receiver periodically reads the message and reset the line. The sent bits gradually swap from the lower to the upper limit, where they are read.

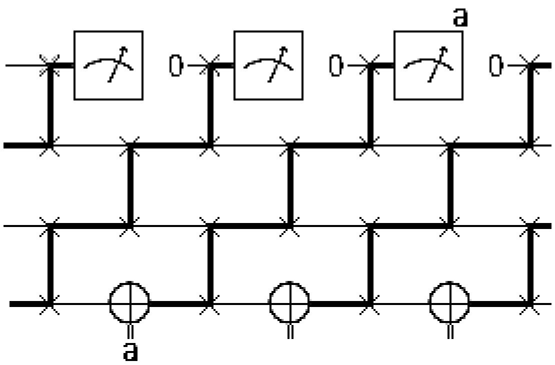

Figure 3: Measurement

On figure 3 can be seen that the classical bit *a* determines whether the lower conductor should switch from 1 to 0 in the second time stage. Then the swap operators move the data upwards to the upper line. There the data are read from the receiver. The receiver also resets the line to avoid further interference with the next sent bits. In the proposed model the return path of the information is used to generate paired qubits, which can then be used for superdense encoding.

In order to be formalized the logic of the circuit, is defined a complex oracle operator which encapsulates the logic of the most of the operations carried out by the receiver:

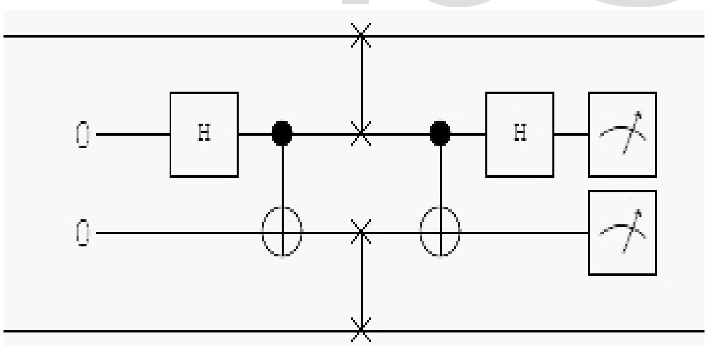

Figure 4: Oracle operator

The operator from Fig.4 consumes a certain entropy for initialization of two zero qubits and entangles them in a paired couple, swaps the paired couple for the input paired couple of qubits, then through superdense - decoding extracts the classical information which is stored in the Bell pair.

Important in this case is that each paired couple of qubits at the end are matched again together. If the data are not in the designated order or are excluded from one of the sides due to a loss of one part at the traffic to the sender and vice versa, and are matched with wrong corresponding part, the message is considered as inaccurate. In order to be preserved the compliance of the data: The swap operator is positioned above the receiver! So the signals from the paired couple will be redirected forward, will reach to the other side, the operations with them will be carried out, and at the same time will be returned backwards to the middle of the circuit, because a field with the same number of swap operators is used.

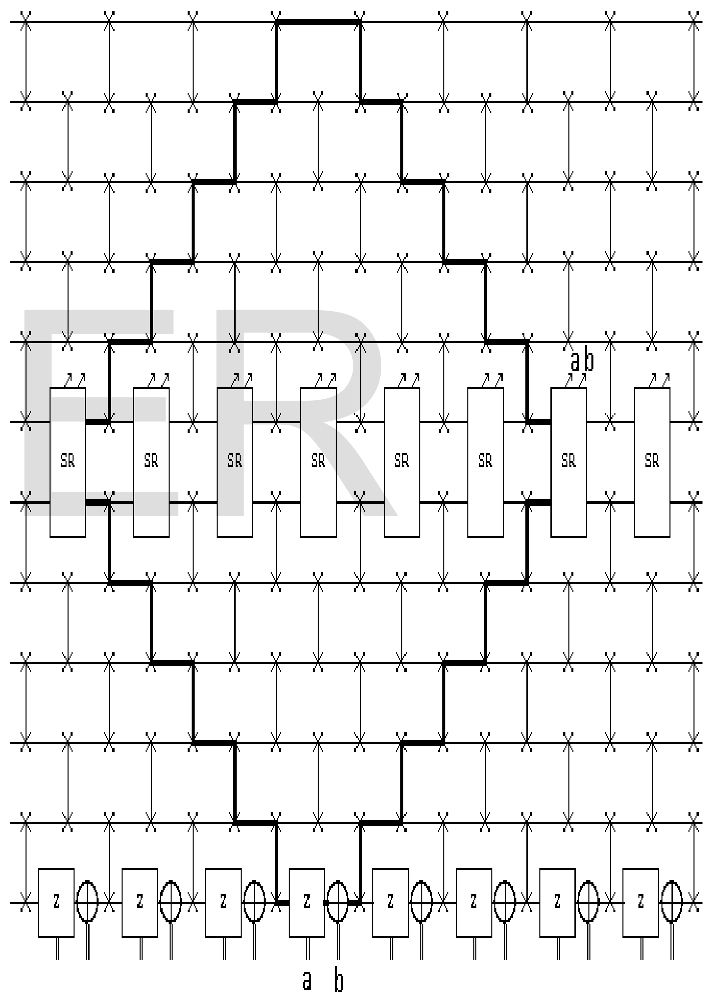

Figure 5: Superdense encoding

On Fig.5 it can be seen that the generated at the second step Bell pair is the one which is used for sending the classical bits *a and b*. The diagram contains two quantum channels between the sender and receiver. The one of the quantum channels is used only for delay of the queue:

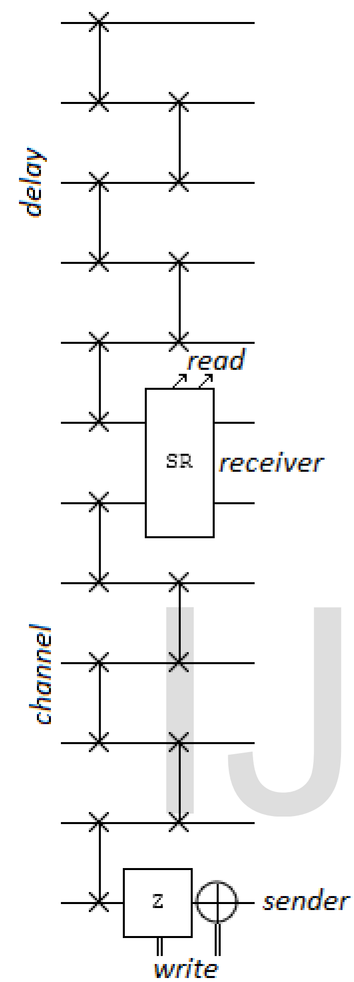

Figure 6: Two quantum channels

The proposed on Fig.6 components of the quantum circuit, could be interpreted as hardware components.

For the practical realization of the proposed circuit the hardware components will have to be able to perform subsequently a measurement of entangled photons, to retain the photons in a coherent state for tens of milliseconds, to carry out a circulation with them, to be measured with a great precision the time of reading the data.

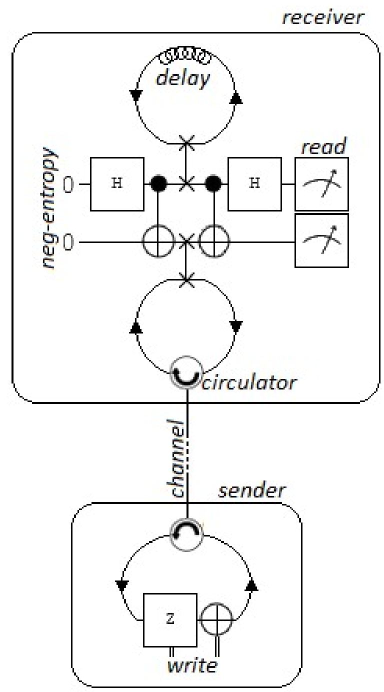

Figure 7: Full diagram

3 Conclusion

The quantum logarithm for securing a spare traffic uses pre-shared pairs entangled qubits in order to send quantum information on a classical channel. The proposed circuit can be used to improve the reliability and the latency of the quantum channel, when a stable classical channel is available.

Through the use of swap operators instead of Bell pairs the classical capacity can be doubled in one of the directions, on a bidirectional quantum channel with the help of another direction. Unfortunately the same technique does not work with a quantum circuit, which uses a teleportation.

The proposed in this research two different approaches give a possibility for significant improvement of the control in the engineering of the quantum transport. The fact that, through these simple quantum logic circuits can be optimized and control the transport adds an additional optimism for the authenticity of this approach.

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