Teletransporte da informação quântica

Adenilton Silva

PHYSICAL REVIEW LETTERS

VOLUME 70 29 MARCH 1993 NUMBER 13

Teleporting an Unknown Quantum State via Dual Classical and Einstein-Podolsky-Rosen Channels

Charles H. Bennett,[1] Gilles Brassard,[2] Claude Crépeau,[2],[3] Richard Jozsa,[2] Asher Peres,[4] and William K. Wootters[5]

[1] *IBM Research Division, T.J. Watson Research Center, Yorktown Heights, New York 10598*

[2] *Département IRO, Université de Montréal, C.P. 6128, Succursale "A", Montréal, Québec, Canada H3C 3J7*

[3] *Laboratoire d'Informatique de l'École Normale Supérieure, 45 rue d'Ulm, 75230 Paris CEDEX 05, France*[a]

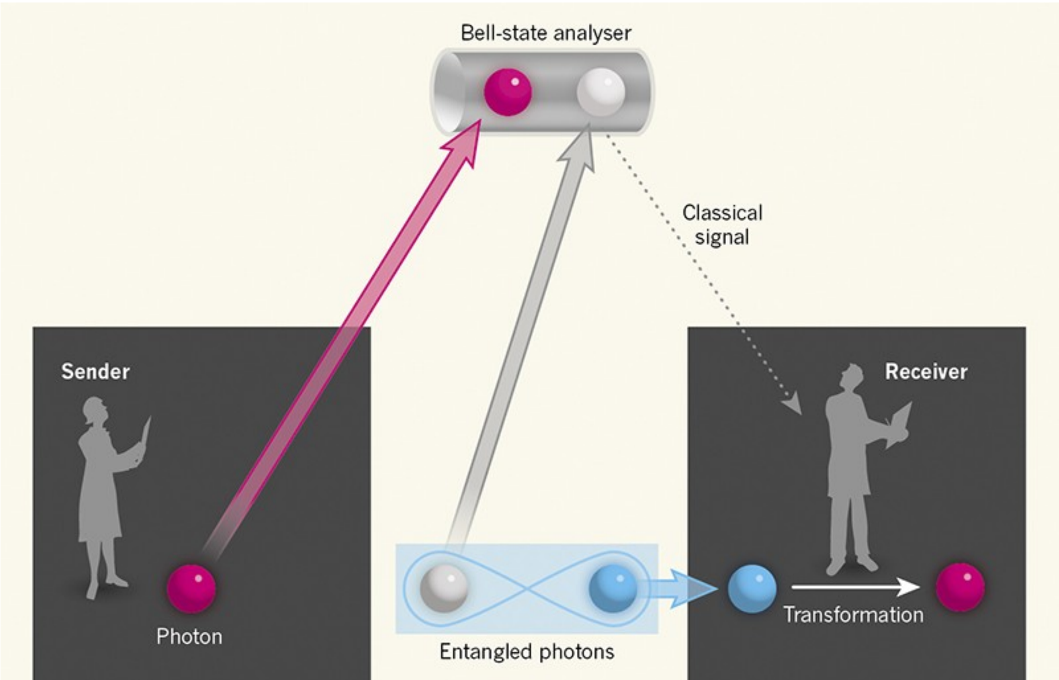
[4] *Department of Physics, Technion–Israel Institute of Technology, 32000 Haifa, Israel*

[5] *Department of Physics, Williams College, Williamstown, Massachusetts 01267*

(Received 2 December 1992)

Realização experimental

- Boschi, Danilo, et al. "Experimental realization of teleporting an unknown pure quantum state via dual classical and Einstein-Podolsky-Rosen channels." Physical Review Letters 80.6 (1998): 1121.
- Ren, Ji-Gang, et al. "Ground-to-satellite quantum teleportation." Nature 549.7670 (2017): 70-73.


Bell-state analyser
Classical signal
Sender
Receiver
Photon
Entangled photons
Transformation

Introdução

- Enviar um bit quântico $a|0\rangle + b|1\rangle$ transmitindo apenas dois bits clássicos.

Introdução

- Enviar um bit quântico $a\left|0\right\rangle + b\left|1\right\rangle$ transmitindo apenas dois bits clássicos.

$$\boxed{\text{Alice}} \xrightarrow[\text{dois bits clássicos}]{} \boxed{\text{Bob}}$$

Introdução

- Enviar um bit quântico $a|0\rangle + b|1\rangle$ transmitindo apenas dois bits clássicos.

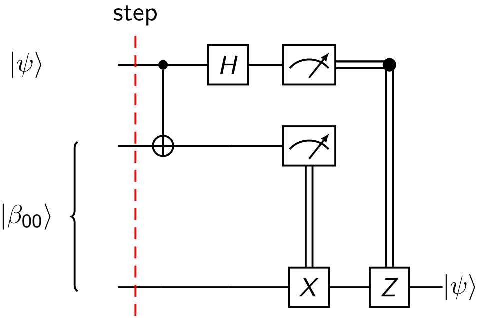
$$\boxed{\text{Alice}} \xrightarrow[\text{dois bits clássicos}]{} \boxed{\text{Bob}}$$

- A tarefa é possível se Alice e Bob compartilharem qubits emaranhados no estado

$$\frac{1}{\sqrt{2}}\left(|00\rangle + |11\rangle\right).$$

Teletransporte

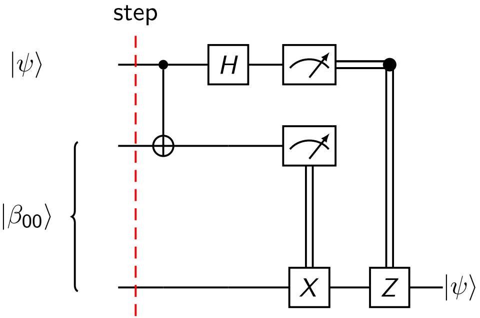
Estado inicial



- $|\psi\rangle = a\,|0\rangle + b\,|1\rangle$.
- $|\beta_{00}\rangle = \frac{|00\rangle + |11\rangle}{\sqrt{2}}$

Teletransporte

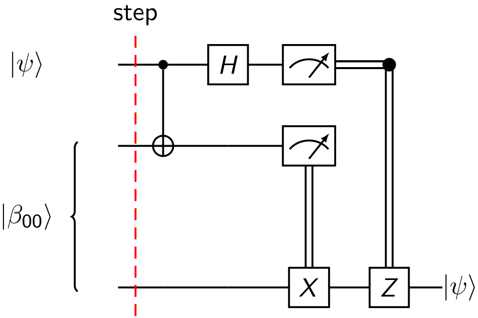
Estado inicial



- $|\psi\rangle = a\,|0\rangle + b\,|1\rangle$.
- $|\beta_{00}\rangle = \frac{|00\rangle + |11\rangle}{\sqrt{2}}$
- $|\psi\rangle \otimes |\beta_{00}\rangle =$

Teletransporte

Estado inicial

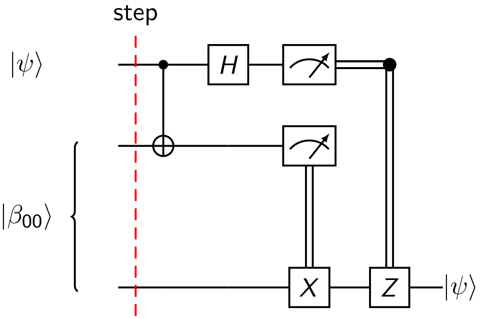


- $|\psi\rangle = a\,|0\rangle + b\,|1\rangle$.
- $|\beta_{00}\rangle = \frac{|00\rangle+|11\rangle}{\sqrt{2}}$
- $|\psi\rangle \otimes |\beta_{00}\rangle =$

$$(a\,|0\rangle + b\,|1\rangle)\left(\frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)\right) =$$

Teletransporte

Estado inicial



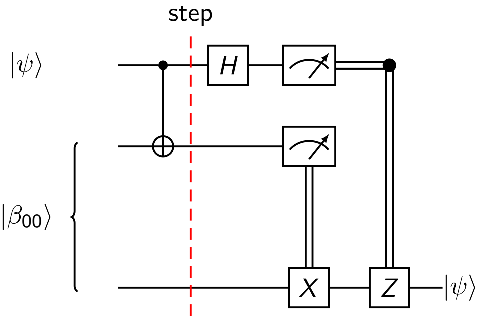
- $|\psi\rangle = a\,|0\rangle + b\,|1\rangle$.
- $|\beta_{00}\rangle = \frac{|00\rangle+|11\rangle}{\sqrt{2}}$
- $|\psi\rangle \otimes |\beta_{00}\rangle =$

$$(a\,|0\rangle + b\,|1\rangle)\left(\frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)\right) =$$

$$\frac{1}{\sqrt{2}}(a\,|000\rangle + a\,|011\rangle + b\,|100\rangle + b\,|111\rangle)$$

Teletransporte

Passo 1

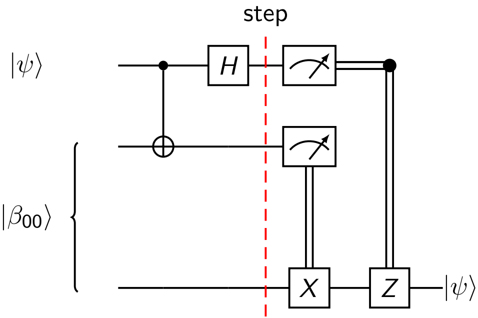


$$CNOT_{01}\left(\frac{a|000\rangle+a|011\rangle+b|100\rangle+b|111\rangle}{\sqrt{2}}\right)$$

$$=\frac{a|000\rangle+a|011\rangle+b|110\rangle+b|101\rangle}{\sqrt{2}}$$

Teletransporte

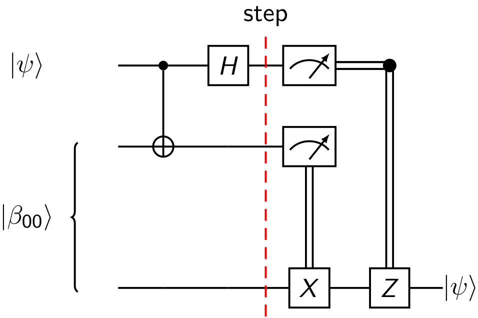
Passo 2



$$H_0\left(\frac{a|000\rangle + a|011\rangle + b|110\rangle + b|101\rangle}{\sqrt{2}}\right) =$$

Teletransporte

Passo 2

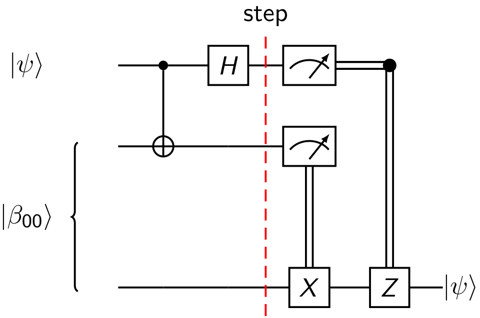


$$H_0\left(\frac{a|000\rangle+a|011\rangle+b|110\rangle+b|101\rangle}{\sqrt{2}}\right) =$$

$$\frac{1}{\sqrt{2}}\left(a\frac{|0\rangle+|1\rangle}{\sqrt{2}}|00\rangle + a\frac{|0\rangle+|1\rangle}{\sqrt{2}}|11\rangle + \right.$$
$$\left. b\frac{|0\rangle-|1\rangle}{\sqrt{2}}|10\rangle + b\frac{|0\rangle-|1\rangle}{\sqrt{2}}|01\rangle\right)$$

Teletransporte

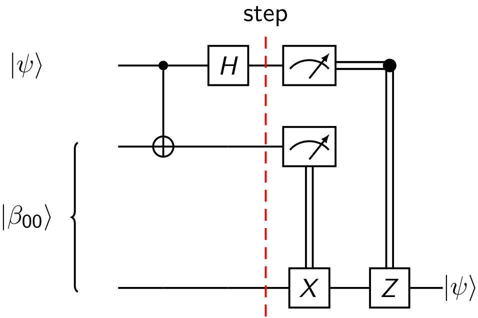
Passo 2



$$\frac{1}{\sqrt{2}}\left(a\frac{|0\rangle+|1\rangle}{\sqrt{2}}|00\rangle + a\frac{|0\rangle+|1\rangle}{\sqrt{2}}|11\rangle + \right.$$
$$\left. b\frac{|0\rangle-|1\rangle}{\sqrt{2}}|10\rangle + b\frac{|0\rangle-|1\rangle}{\sqrt{2}}|01\rangle\right)$$

Teletransporte

Passo 2

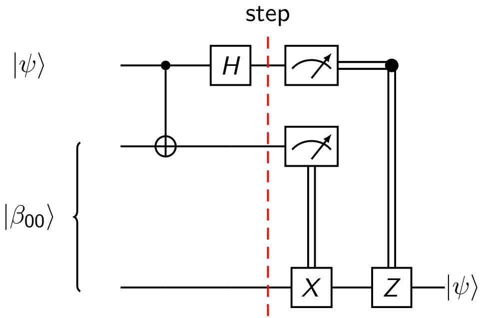


$$\frac{1}{\sqrt{2}}\left(a\frac{|0\rangle+|1\rangle}{\sqrt{2}}|00\rangle + a\frac{|0\rangle+|1\rangle}{\sqrt{2}}|11\rangle + b\frac{|0\rangle-|1\rangle}{\sqrt{2}}|10\rangle + b\frac{|0\rangle-|1\rangle}{\sqrt{2}}|01\rangle\right)$$

$$\frac{1}{2}(a|000\rangle + a|100\rangle + a|011\rangle + a|111\rangle + b|010\rangle - b|110\rangle + b|001\rangle - b|101\rangle)$$

Teletransporte

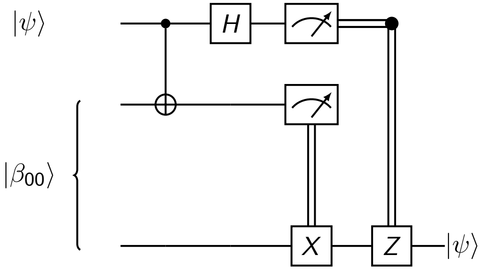
Passo 2



$$\frac{1}{2}(a|000\rangle + a|100\rangle + a|011\rangle + a|111\rangle + b|010\rangle - b|110\rangle + b|001\rangle - b|101\rangle)$$

Teletransporte

Estado após a medição



$$\frac{1}{2}(a\,|000\rangle + a\,|100\rangle + a\,|011\rangle + a\,|111\rangle + b\,|010\rangle - b\,|110\rangle + b\,|001\rangle - b\,|101\rangle)$$

Teletransporte

Estado após a medição

$$\frac{1}{2}(a\,|000\rangle + a\,|100\rangle + a\,|011\rangle + a\,|111\rangle + b\,|010\rangle - b\,|110\rangle + b\,|001\rangle - b\,|101\rangle)$$

Resultado	Probababilidade	Estado após medição
00		
01		
10		
11		

Teletransporte

Estado após a medição

$$\frac{1}{2}(a\,|000\rangle + a\,|100\rangle + a\,|011\rangle + a\,|111\rangle + b\,|010\rangle - b\,|110\rangle + b\,|001\rangle - b\,|101\rangle)$$

Resultado	Probababilidade	Estado após medição
00	25%	
01		
10		
11		

$$P(00) = \frac{|a|^2+|b|^2}{4} = 0.25$$

Teletransporte

Estado após a medição

$$\frac{1}{2}(a\,|000\rangle + a\,|100\rangle + a\,|011\rangle + a\,|111\rangle + b\,|010\rangle - b\,|110\rangle + b\,|001\rangle - b\,|101\rangle)$$

Resultado	Probababilidade	Estado após medição
00	25%	$|00\rangle\,(a\,|0\rangle + b\,|1\rangle)$
01		
10		
11		

Teletransporte

Estado após a medição

$$\frac{1}{2}(a\,|000\rangle + a\,|100\rangle + a\,|011\rangle + a\,|111\rangle + b\,|010\rangle - b\,|110\rangle + b\,|001\rangle - b\,|101\rangle)$$

Resultado	Probababilidade	Estado após medição
00	25%	$\|00\rangle\,(a\,\|0\rangle + b\,\|1\rangle)$
01	25%	$\|01\rangle\,(a\,\|1\rangle + b\,\|0\rangle)$
10		
11		

Teletransporte

Estado após a medição

$$\frac{1}{2}(a\left|000\right\rangle + a\left|100\right\rangle + a\left|011\right\rangle + a\left|111\right\rangle + b\left|010\right\rangle - b\left|110\right\rangle + b\left|001\right\rangle - b\left|101\right\rangle)$$

Resultado	Probababilidade	Estado após medição
00	25%	$\left|00\right\rangle(a\left|0\right\rangle + b\left|1\right\rangle)$
01	25%	$\left|01\right\rangle(a\left|1\right\rangle + b\left|0\right\rangle)$
10	25%	$\left|10\right\rangle(a\left|0\right\rangle - b\left|1\right\rangle)$
11		

Teletransporte

Estado após a medição

$$\frac{1}{2}(a\left|000\right\rangle + a\left|100\right\rangle + a\left|011\right\rangle + a\left|111\right\rangle + b\left|010\right\rangle - b\left|110\right\rangle + b\left|001\right\rangle - b\left|101\right\rangle)$$

Resultado	Probababilidade	Estado após medição
00	25%	$\left\|00\right\rangle (a\left\|0\right\rangle + b\left\|1\right\rangle)$
01	25%	$\left\|01\right\rangle (a\left\|1\right\rangle + b\left\|0\right\rangle)$
10	25%	$\left\|10\right\rangle (a\left\|0\right\rangle - b\left\|1\right\rangle)$
11	25%	$\left\|11\right\rangle (a\left\|1\right\rangle - b\left\|0\right\rangle)$

Teletransporte

Resultado	Probabibilidade	Estado após medição	
00	25%	$\|00\rangle (a\|0\rangle + b\|1\rangle) =$	$\|00\rangle \|\psi\rangle$
01	25%	$\|01\rangle (a\|1\rangle + b\|0\rangle) =$	$\|01\rangle (X\|\psi\rangle)$
10	25%	$\|10\rangle (a\|0\rangle - b\|1\rangle) =$	$\|10\rangle (Z\|\psi\rangle)$
11	25%	$\|11\rangle (a\|1\rangle - b\|0\rangle) =$	$\|11\rangle (XZ\|\psi\rangle)$

Teletransporte