LOGICAL QUBIT :

Assumed to be accurate and reliable.

PHYSICAL QUBIT:

Real qubit

Cirq $\longrightarrow$ Logical Circuits $\longrightarrow$ Physical Circuit

Compiler

Select set of universal gates:

$\{ CNOT, H, X, T, T^{+} \}$

IBM: u_1, u_2, u_3, CNOT

$$u_2(\phi, \lambda) = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & -e^{i\lambda} \\ e^{i\phi} & e^{i(\lambda+\phi)} \end{pmatrix}$$

RIGETTI : $R_x(\theta), R_z(\theta)$, CZ

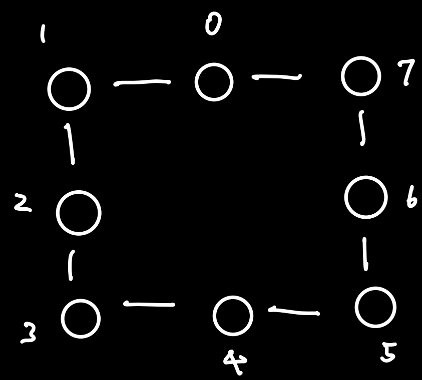
ION TRAP : R_x, R_y, R_z, XX

ISSUE 1: Different hardwares, different languages.

Another issue : 2-Qubit operations might have restrictions.

eg:

Rigetti



The qubits should be connected!

CNOT (1, 2) ✓

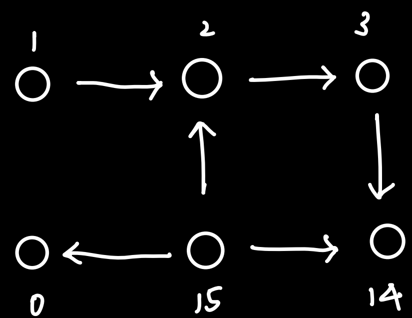
CNOT (1, 4) ✗

CZ is symmetric!

CZ (1,2) = CZ(2,1)

So edges are undirected.

IBM:



CNOT (1,2) ✓

CNOT (2,1) ✗

We have to do

$$\text{CNOT}(2,1) = (H \otimes H)\ \text{CNOT}(1,2)\ (H \otimes H)$$

$$\text{CNOT}(1,2) = (I \otimes H)\ CZ(1,2)\ (I \otimes H)$$

QUANTUM COMPILER :

Parse

↓

Build Program Representation

↓ No type Check

Optimizations

↓

Instruction Selection

Qubit Register Allocation

(Swapping!)

Source : {CNOT, H, x, T, T^+, S}

Target : {CZ, R_x, R_z}

$$\uparrow$$

$$k\pi/2$$

$$k \in \mathbb{Z}$$

$$T = \underbrace{-e^{i\pi/8}}_{\text{Phase}} R_z(-\pi/4)$$

Compiler Correctness :

Up to a global phase (This difference is fine)

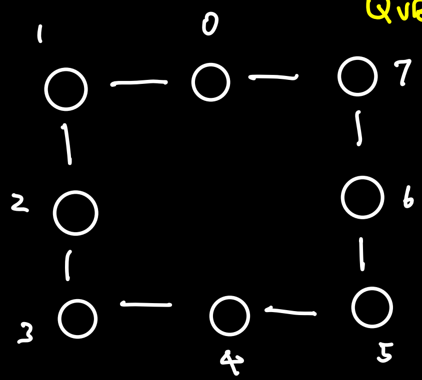
$$comp(T) = R_z(-\pi/4)$$

$$H = i\, R_y(-\pi/2)\, R_x(\pi)$$

$$S = T\,T$$

$$x = i \cdot R_x(\pi/2)\, R_x(\pi/2)$$

$$R_y(\theta) = R_z(-\pi/2)\, R_x(\theta)\, R_z(\pi/2)$$



QUBIT REGISTER ALLOCATION:

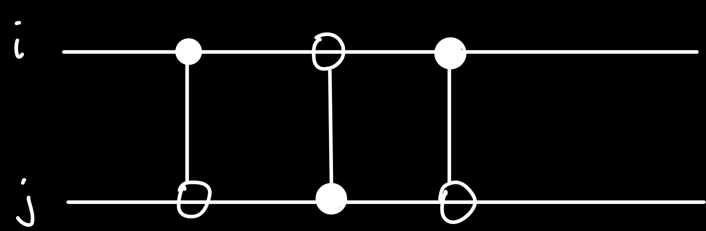
MAPPING PROBLEM.

We want to do $cz(0,2)$

SWAPPING:

$$cz(0,2) = \begin{array}{l} SWAP(1,2) \\ cz(0,1) \\ SWAP(1,2) \end{array}$$

$$SWAP(i,j) = \begin{array}{l} CNOT(i,j) \\ CNOT(j,i) \\ CNOT(i,j) \end{array}$$



$$
\begin{aligned}
CZ(0,3) = \ & SWAP(2,3) \\
& SWAP(1,2) \\
& CZ(0,1) \\
& SWAP(1,2) \\
& SWAP(2,3)
\end{aligned}
$$