Challenges and Possibilities

Application of QC in Telecommunication Environment

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National Research, Development and Innovation Office
Hungary
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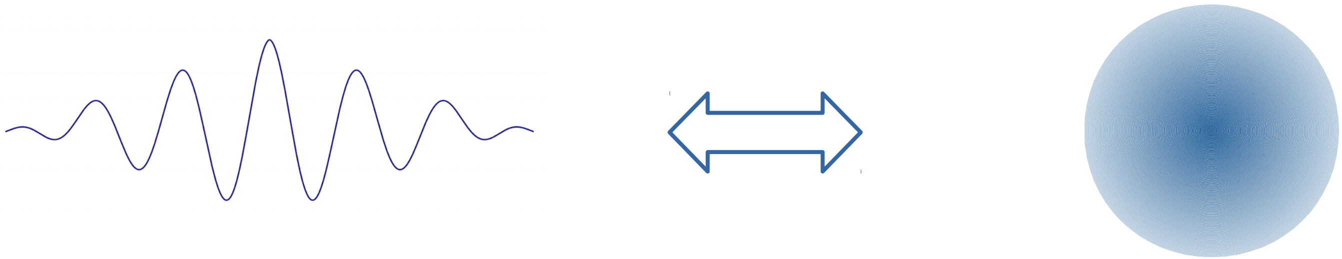
Wave–particle duality

Double-slit experiment: interference of individual particles



Schrödinger-equation: state function of a quantum-mechanical system

$$\left(-\frac{\hbar^2}{2m}\Delta + V(x,y,z)\hat{I}\right)|\psi\rangle = E\,|\psi\rangle$$

$$|\psi\rangle \in \mathrm{H}$$

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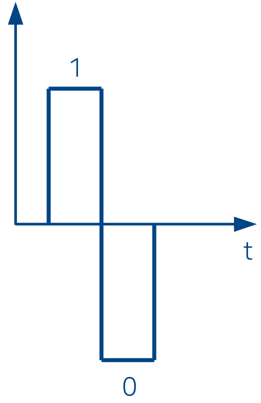
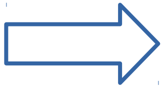
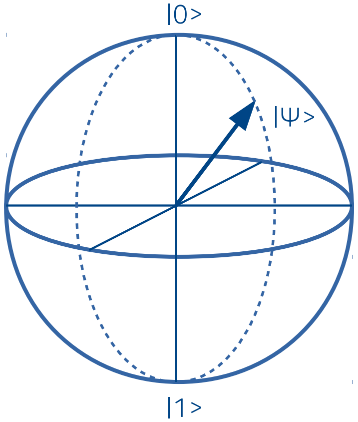
The Quantum Toolbox – Postulates, Mathematical Model and Qubit







Bloch Sphere

$|\Psi\rangle = \alpha_0 |0\rangle + \alpha_1 |1\rangle$

Computational basis

$|0\rangle = [1\ 0]^T$

$|1\rangle = [0\ 1]^T$

α_0, α_1 are complex scalar amplitudes

$|\alpha_0|^2 + |\alpha_1|^2 = 1$

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The Quantum Toolbox – Quantum Registers

Quantum register is made up multiple qubits

$$|\psi_n\rangle = \sum_{i=0}^{2^n-1} a_i |i\rangle \qquad \sum_{i=0}^{2^n-1} |a_i|^2 = 1$$

$$|\psi_3\rangle = a_0|000\rangle + a_1|000\rangle + a_2|000\rangle + a_3|000\rangle + a_4|000\rangle + a_5|000\rangle + a_6|000\rangle + a_7|000\rangle$$

$$|001\rangle = |0\rangle \otimes |0\rangle \otimes |1\rangle$$

In vector form, using the computational basis

$$|\psi_3\rangle = a_0\begin{bmatrix}1\\0\\0\\0\\0\\0\\0\\0\end{bmatrix} + a_1\begin{bmatrix}0\\1\\0\\0\\0\\0\\0\\0\end{bmatrix} + a_2\begin{bmatrix}0\\0\\1\\0\\0\\0\\0\\0\end{bmatrix} + a_3\begin{bmatrix}0\\0\\0\\1\\0\\0\\0\\0\end{bmatrix} + a_4\begin{bmatrix}0\\0\\0\\0\\1\\0\\0\\0\end{bmatrix} + a_5\begin{bmatrix}0\\0\\0\\0\\0\\1\\0\\0\end{bmatrix} + a_6\begin{bmatrix}0\\0\\0\\0\\0\\0\\1\\0\end{bmatrix} + a_7\begin{bmatrix}0\\0\\0\\0\\0\\0\\0\\1\end{bmatrix}$$

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The Quantum Toolbox – Quantum Circuits

Elementary gates: single qubit quantum gates

$$\begin{bmatrix} a \\ b \end{bmatrix}$$

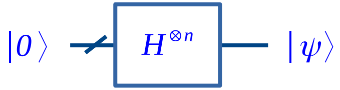
$$|\psi\rangle = X|\varphi\rangle = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}\begin{bmatrix} b \\ a \end{bmatrix} = b|0\rangle + a|1\rangle$$

$$Y = \begin{bmatrix} 0 & -j \\ j & 0 \end{bmatrix}$$

$$Z = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$$

$$H = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

Equal superposition by the application of Hadamard-gate



$$|\psi\rangle = H^{\otimes n}|0\rangle^{\otimes n} = \frac{1}{\sqrt{2^n}}\sum_{x=0}^{2^n-1}|x\rangle$$

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Quantum Algorithms – Classification and Examples

Quantum Fourier Transformation

Shor's algorithm for integer factorization – Bell Labs

Quantum phase estimation

Amplitude Amplification

Grover's search algorithm – Bell Labs

Quantum counting

Quantum Walks

Element distinctness problem

Quantum Algorithm Implementations for Beginners
Los Alamos National Laboratory, Los Alamos, New Mexico, USA
(IBM-Q)

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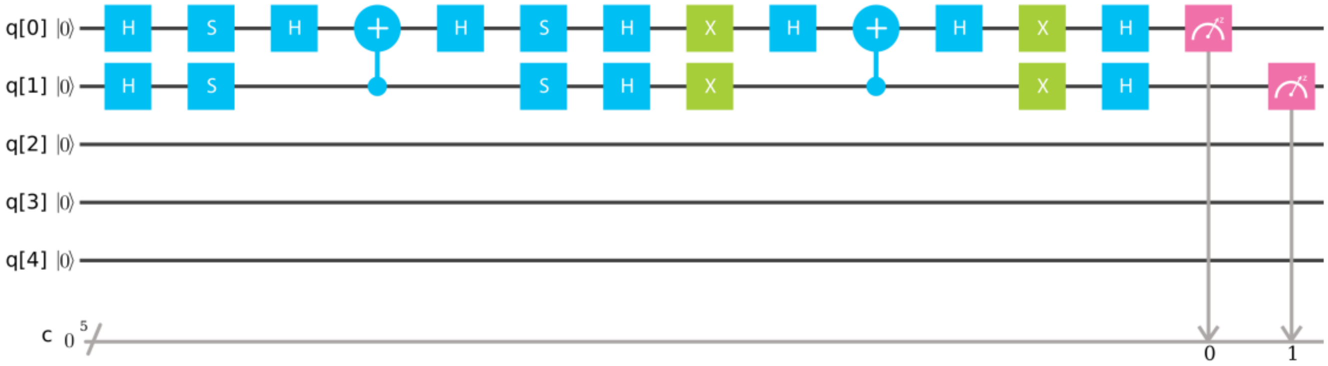
Quantum Algorithms – Grover Experiment on IBM-Q



https://quantumexperience.ng.bluemix.net/qx/editor?codeId=28945f9628c0369f63d78ff0fee8e047

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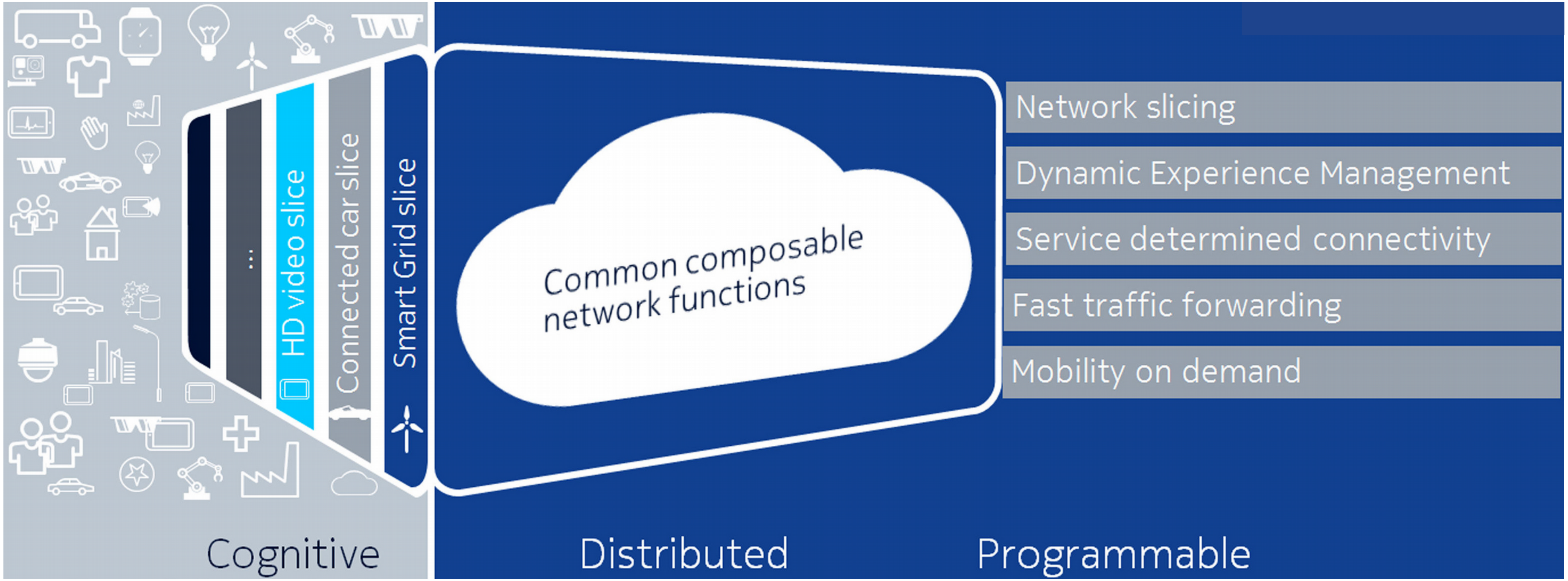
Telecommunication Environment – Evolution Towards 5G



Centralized to Distributed

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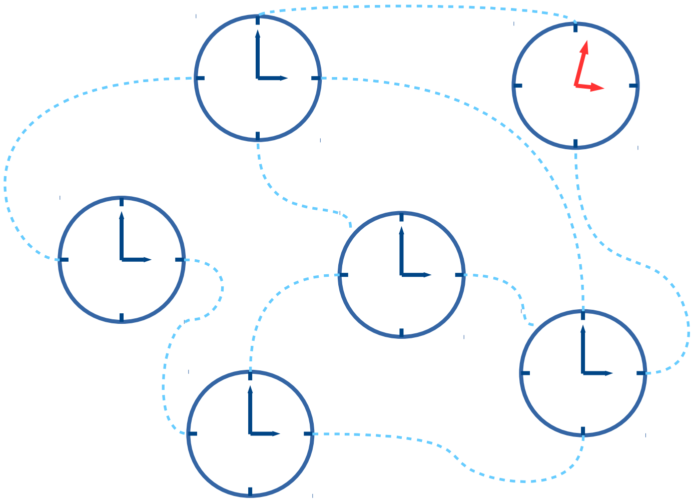
Distributed Algorithms – Problem Identification

Consensus or Distributed Agreement on

Leader election

Synchronization



Load balancing need

(Blockchain – distributed ledger)

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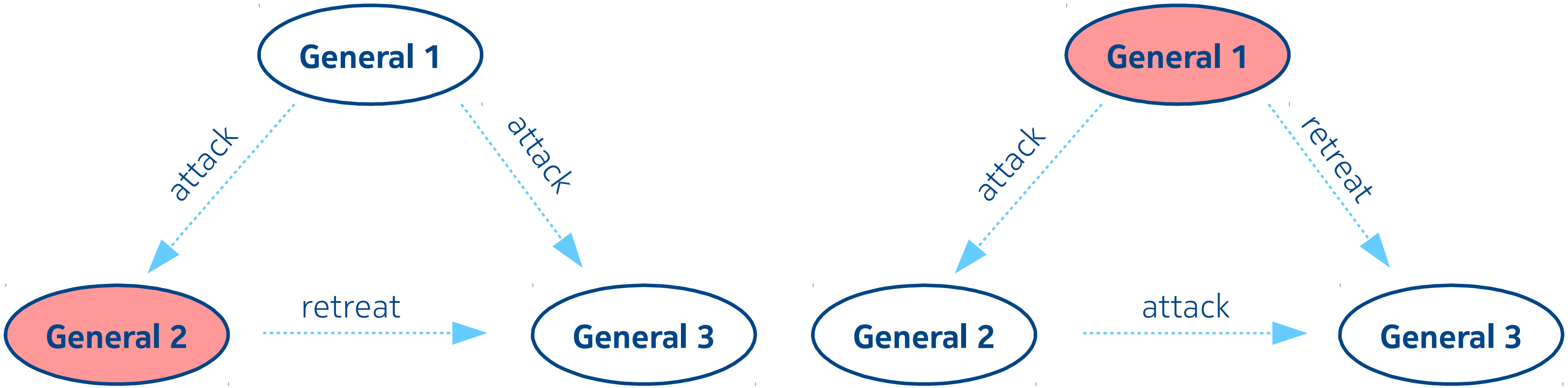
Byzantine Agreement or Byzantine Generals Problem

Original description



n = 3f + 1 → possible 2 handle

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Quantum Byzantine Agreement

Original protocol

Pease-Shostak-Lamport

Synchronous

Authentication: Oral

Threshold: n > 3f

Comm rounds: **f + 1**

Total comm: **O (n^f)**

Quantum Byzantine Promises

Asynchronous

Comm. round: **O(1)**

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Thank You!