Indore Institute of Science & Technology

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तकनीकी BUZZ

Department of Computer Science & Engineering

Technical Contributor : Mr. Puneet Duggal
Takniki Buzz-Editor : Ms. Poorva Shukla

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Vision of the Institute

To be a nationally recognized institution of excellence in technical education and produce competent professionals capable of making a valuable contribution to society.

Mission of the Institute

- To promote academic growth by offering state-of-the-art undergraduate and postgraduate programs.
- To undertake collaborative projects which offer opportunities for interaction with academia and industry.
- To develop intellectually capable human potential who are creative, ethical and gifted leaders

Vision of the Department

To be a center of academic excellence in the field of computer science and engineering education.

Mission of the Department

- Strive for academic excellence in computer science and engineering through well designed course curriculum, effective classroom pedagogy and in-depth knowledge of Laboratory work
- Transform under graduate engineering students into technically competent, socially responsible and ethical computer science and engineering professionals.
- Create computing centres of excellence in leading areas of computer science and engineering to provide exposure to the students on latest software tools and computing technologies.
- Incubate, apply and spread innovative ideas by collaborating with relevant industries and R&D labs through focused research group.
- Attain these through continuous team work by group of committed faculty, transforming the computer science and engineering department as a leader in imparting computer science and engineering education and research .

(Rise of Quantum Computing)

Quantum computing represents one of the most revolutionary advancements in the history of computational science. Unlike classical computers, which process data using binary bits (0s and 1s), quantum computers operate using **quantum bits or qubits**, which can exist in a state of 0, 1, or both simultaneously, thanks to a quantum property known as **superposition**. This unique capability allows quantum computers to process and analyze complex datasets and problems at exponentially faster rates than traditional systems.

Another fundamental property—**entanglement**—enables qubits to be interconnected in such a way that the state of one instantly influences the state of another, no matter the distance between them. Together, these principles open the door to solving problems previously deemed computationally impossible, or that would take classical computers centuries to resolve.

The rise of quantum computing is being propelled by both academic research and private-sector investment from tech giants like IBM, Google, Intel, Microsoft, and emerging startups such as Rigetti, IonQ, and D-Wave. In 2019, Google claimed to achieve **quantum supremacy**—the milestone where a quantum processor solved a specific problem faster than the world's most powerful classical supercomputer. Though the practical implications of this specific problem were limited, it marked a turning point in public and scientific interest.

2. How It Works – Core Principles

- **Superposition**: Qubits explore multiple solutions at once.
- **Entanglement**: Linked qubits share information instantly, enhancing computational efficiency.
- **Quantum Interference**: Used to amplify correct answers and cancel wrong ones in algorithms.

3. Key Milestone: Quantum Supremacy

- In 2019, Google announced achieving quantum supremacy: solving a problem in 200 seconds that would take a classical supercomputer 10,000 years.
- Though symbolic, it demonstrated real-world potential and sparked intense global interest.

4. Real-World Applications

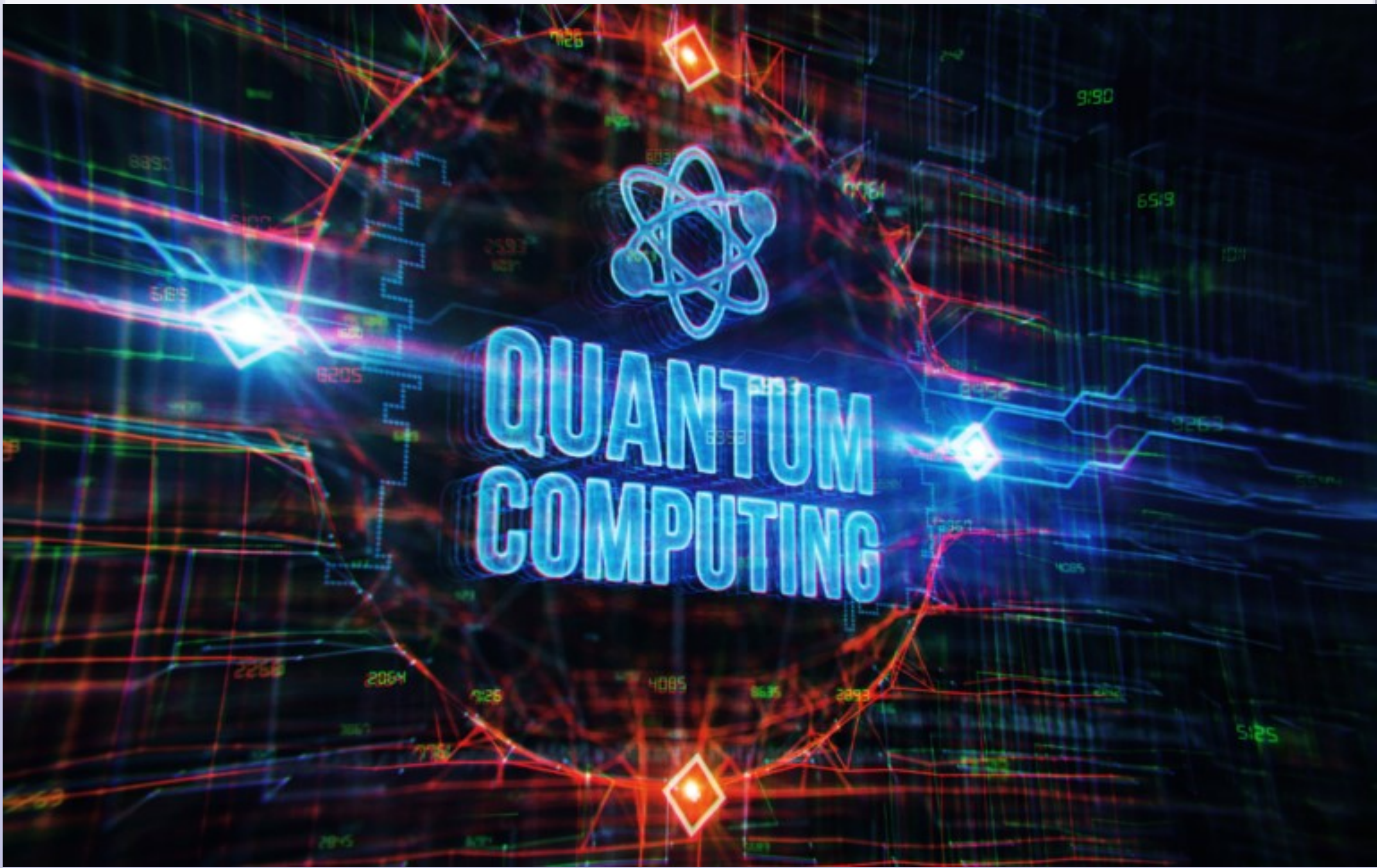
- **Cryptography**: Quantum computers could break traditional encryption using **Shor's algorithm**, threatening RSA and similar systems.
- **Drug Discovery**: Simulating molecules and reactions to create new medicines faster and more precisely.
- **Materials Science**: Discovering superconductors, better batteries, or lightweight alloys using quantum simulations.
- **Optimization Problems**: Solving complex logistics, traffic routing, or financial modeling much faster than classical systems.
- **Machine Learning**: Enhancing training models and data analysis using quantum-enhanced algorithms.

5. Impact on Cybersecurity

- Existing encryption systems (RSA, ECC) may become obsolete.
- Urgent need to develop **post-quantum cryptography** that can resist quantum attacks.

6. Role in Artificial Intelligence

- Quantum AI could solve problems in seconds that take traditional AI days.
- Possible applications: faster neural networks, improved pattern recognition, better optimization models.



7. Industrial and Government Involvement

- Major tech companies (IBM, Google, Microsoft, Intel, Amazon) are investing heavily.
- Governments (USA, China, EU, India) have national quantum initiatives and billions in funding.
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8. Current Stage: NISQ Era

- We are in the **Noisy Intermediate-Scale Quantum** (NISQ) phase.
- Current systems are limited by **errors**, **low qubit counts**, and **decoherence**.
- Efforts are ongoing to build more **stable**, **scalable**, and **error-tolerant** quantum machines.

9. Key Technologies and Models

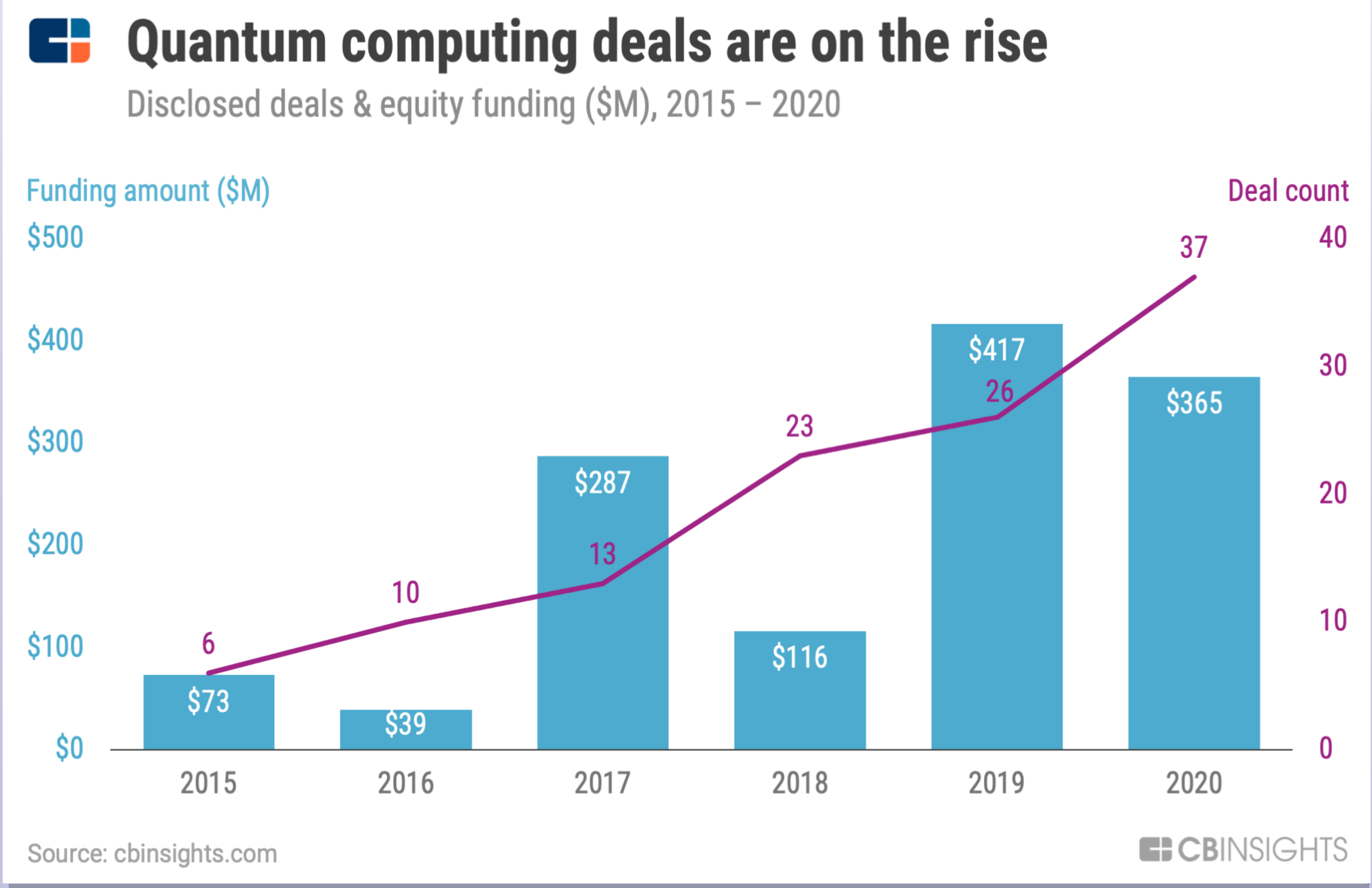
- **Quantum Gates and Circuits**: The basic building blocks of quantum algorithms.
- **Quantum Annealing**: Used by D-Wave for optimization problems.
- **Topological Qubits**: A promising method to reduce quantum error rates.

Quantum Annealing

- **What it is:** A quantum computing model used for **optimization problems**.
- **How it works:** Uses quantum tunneling and energy minimization to find the lowest-energy (best) solution in a large solution space.
- **Key Use:** Especially effective for solving combinatorial optimization problems where classical solutions struggle.
- **Example:** D-Wave Systems builds quantum annealers optimized for routing, logistics, and scheduling problems.
- **Difference from Gate-based:** Unlike circuit-based quantum computing, annealing does not rely on qubit-by-qubit logic gates.

Topological Qubits

- **What they are:** A proposed type of qubit that stores information in the **global topology** of quantum particles rather than their local state.



•**How it works:** Uses **anyons** (quasiparticles that exist in 2D systems) and their braiding paths, which are immune to small disturbances.
•**Why it's important:** Topological qubits are theorized to be **naturally error-resistant**, reducing the need for heavy error correction.
•**Major Contributor:** Microsoft is researching topological qubits under its StationQ project.
•**Current Status:** Still largely experimental, but promising for building scalable, stable quantum systems.

10. Challenges Ahead

•**Decoherence**: Qubits lose their state easily due to noise.
•**Error Correction**: Large qubit overhead is required to correct quantum errors.
•**Scalability**: Difficult to build large, stable quantum systems.
•**Cost and Complexity**: Requires ultra-low temperatures, specialized hardware, and quantum programming skills.

11. Quantum Software Development

•New programming languages (e.g., Q#, Qiskit, Cirq) are emerging.
Quantum simulators help developers write and test quantum algorithms before running on actual hardware.

12. Future Outlook

•Quantum computing is not a replacement for classical computers but a **complement** for solving specific high-complexity problems.
•As hardware and software mature, it may revolutionize industries like:
•Healthcare,
•Energy,
•Climate modeling,
•Financial services,
•National security.

Conclusion

Quantum computing represents a **paradigm shift** in computing. Although still in its early stages, the progress is accelerating. Its ability to process vast and complex problems far beyond classical limits positions it as a **critical technology of the future**. Continued investment, global collaboration, and scientific breakthroughs will determine how fast quantum computing moves from research labs to real-world use.

Although **quantum computing is still in its early stages of development**, rapid advancements are being made in both hardware and algorithms. Tech giants, startups, and research institutions worldwide are investing heavily in developing **stable qubits**, **quantum error correction**, and **scalable architectures**—the key challenges currently limiting practical implementation.