Quantum Technology for Securing Maritime Communications

For Prelims: Indian Navy, Quantum mechanics, Semiconductor, **Internet-of-Things**, machine learning, **Robotics, Artificial intelligence.**

For Mains: **Quantum Technology**, Significance and Challenges.

Why in News?

RRI (Raman Research Institute) has inked a **Memorandum of Understanding (MoU)** with the **Indian Navy** on **Quantum Technologies** to develop secure maritime communications.

- RRI is an autonomous institute of the Department of Science and Technology (DST).
- Under this agreement, RRI's Quantum Information and Computing (QuIC) lab will lead the research efforts towards **developing** Quantum Key Distribution (QKD) **techniques** that the Indian Navy could leverage in the nation's efforts towards securing free space communications.

Note

- **Quantum Technology** is a field of science and engineering that deals with the study and **application of quantum mechanics principles.**
  - Quantum mechanics is the branch of physics that describes the behavior of matter and energy at the atomic and subatomic level.
- There are **Four domains of Quantum Technology:**
  - **Quantum communication**
  - Quantum simulation
  - **Quantum computation**
  - Quantum sensing and metrology

What is Quantum Communication?

- **Quantum Communication:**
  - Quantum communication is **a subfield of quantum technology** that focuses on the development of secure communication systems that use the principles of quantum mechanics.
  - Quantum communication uses a **fundamentally different approach to encryption.**
    - The most common example of quantum communication is **QKD**, which allows two parties to generate an **encryption key that is virtually uncrackable.**
- **Mechanism of Quantum Communication:**
  - **Encoding Information:** Information is encoded onto quantum bits (qubits), which can exist in **multiple states simultaneously.**

        - This property is known as **superposition.**
    - **Transmitting Information:** The encoded **qubits are transmitted over a quantum communication channel,** such as a fiber optic cable **or a free-space link.**
        - The qubits are **typically transmitted one at a time.**
    - **Receiving Information:** The receiving party measures the qubits using a quantum measurement device.
        - The measurement **process collapses the superposition state of the qubit to a single state**, revealing the encoded information.
    - **Detecting Eavesdropping:** One of the key features of quantum communication is that any **attempt to eavesdrop on the communication will disturb the quantum state of the qubit,** making it immediately detectable.
        - This is known as the **"no-cloning theorem" and is a fundamental principle** of quantum mechanics.
    - **Establishing a Secret Key:** By exchanging a sequence of qubits, the transmitting **and receiving parties can establish a secret key that can be used for secure communication.**
        - This key can be used with conventional encryption algorithms to **ensure the confidentiality and integrity** of transmitted information.

How Can Quantum Technology be useful In Maritime Communication?

- **Secure Communication:**
    - Quantum **encryption can be used to ensure secure communication between ships** and shore stations, making it difficult for hackers to intercept or eavesdrop on the communication.
- **High-speed Communication:**
    - Quantum technology can enable **faster communication between ships and shore stations** by using quantum entanglement to transmit information instantaneously over long distances.
        - This could be **particularly useful for communication in remote areas** where traditional communication methods are limited.
- **Precision Navigation:**
    - Quantum sensors can be used to improve navigation accuracy by measuring the **Earth's magnetic field with high precision.**
    - This could help ships **navigate through narrow channels,** avoid obstacles, and improve overall safety.
- **Improved Weather Forecasting:**
    - Quantum computers can be used to **run complex simulations of weather patterns,** which can provide accurate and timely information to mariners about impending storms or other dangerous weather conditions.

Way Forward

- **Implementing quantum communication technologies,** such as QKD at scale is a **major challenge** as they are still in the early stages of development and implementation.
    - **Pilot projects can be established** to test the technology in real-world settings and refine the implementation process.
- Quantum communication technologies are **expensive to develop and deploy. Adequate funding for R&D** could lead to more cost-effective solutions.
- **Quantum communication technologies are not yet standardized**, making it difficult for different systems to communicate with each other.
    - **Standards and protocols can be developed** to enable different quantum communication systems to communicate with each other

Source: PIB