

# INTERFACING OF MOLECULAR AND TERAHERTZ COMMUNICATIONS FOR INTERNET OF NANO THINGS (IONT) APPLICATIONS

BTP Code : B24LC01

Under Guidance of : Dr. Lokendra Chouhan

# AGENDA

- Problem Statement & Research Goal
- Nano Communication
- What's our Motivation to choose IONT
- Nanomachines & Nanonetwork
- Molecular Communication
- Terahertz Communication
- Reference

# PROBLEM STATEMENT & RESEARCH GOAL

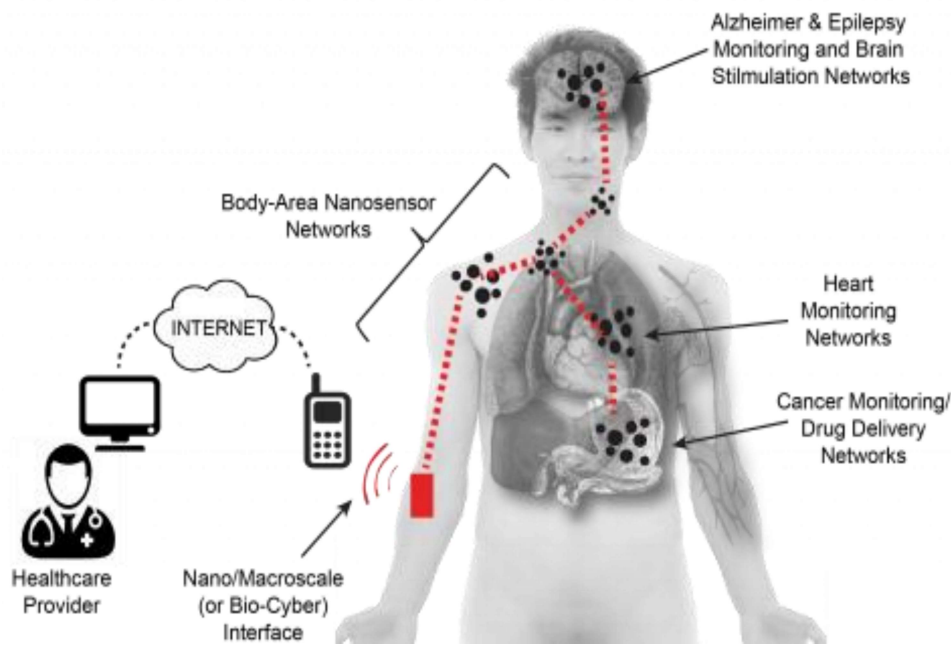


Fig 1: Internet of Bio-Nano Things [1]

## Objective

Investigating Molecular and Terahertz Communication Integration for IoNT

## Research Goals:

1. **Efficient Nanoscale Communication:** Explore Molecular and Terahertz integration for IoNT.
2. **Addressing IoNT Challenges:** Overcome power, bandwidth, and reliability constraints.
3. **Advancing IoNT Applications:** Enhance healthcare monitoring, environmental sensing, and industrial automation.

## WHAT IS NANO SCALE?

“THERE'S PLENTY OF ROOM AT THE BOTTOM -- RICHARD FEYNMAN”

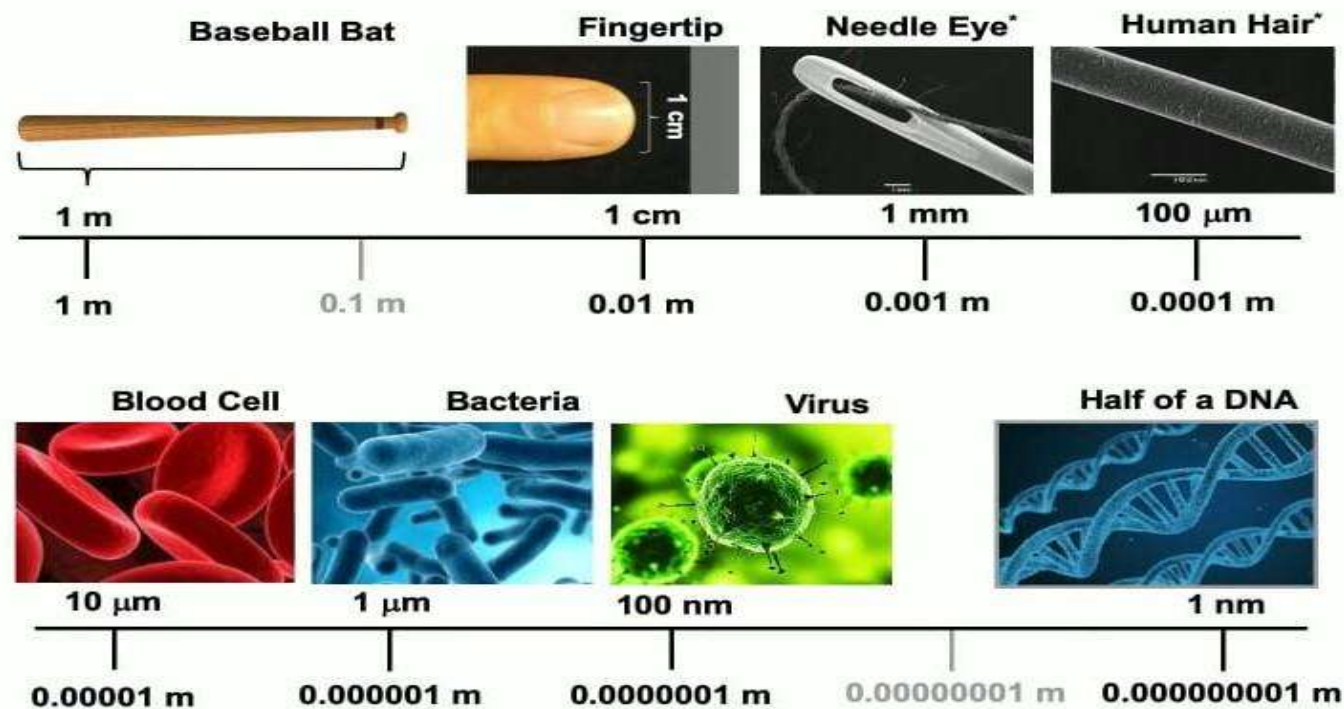


Fig 2: Nano scale spectrum [2]

# NANO-COMMUNICATION

Nano-communication is the lifeblood of nano-networks, enabling seamless interactions between nano-devices and the broader micro or macro-systems they interface with.

## Types of Nano-Communication

1. **Molecular Communication** : Utilizes chemical messengers for data exchange.
2. **Electromagnetic Communication**: Relies on electromagnetic waves for swift transmission.
3. **Acoustic Communication**: Harnesses sound waves for efficient data transfer.
4. **Nano-Mechanical Communication**: Utilizes mechanical means for precise information exchange.

These distinct modes of nano-communication, meticulously explored in prior research endeavors, lay the groundwork for fostering resilient and dynamic nano-networks.



## WHAT'S OUR MOTIVATION TO CHOOSE IONT:

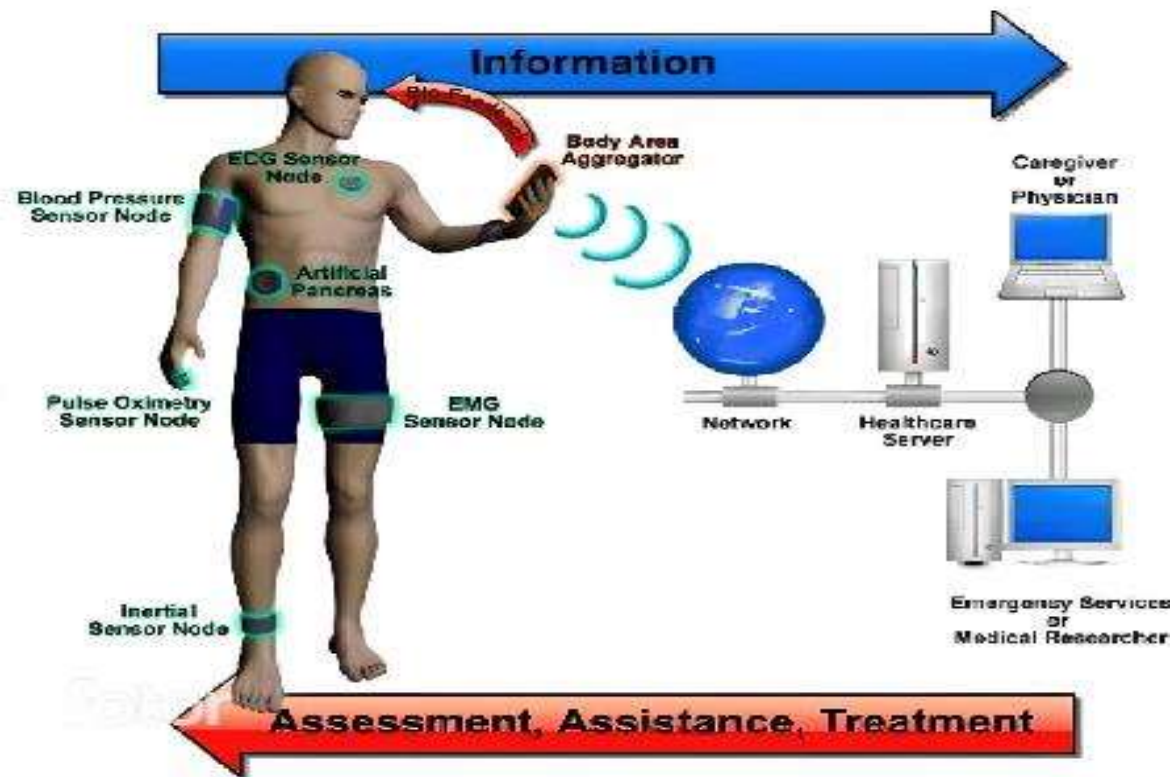


Fig 3: Health Monitoring via Nano Sensors comprising Real Time Health Monitoring Internet of Nano Things (IoNT) [3]

## APPLICATION OF NANOTECHNOLOGY:

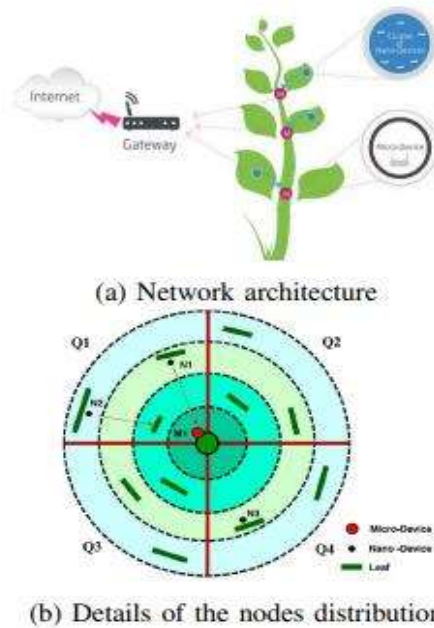


Fig 4: Network architecture of the Plant [4]

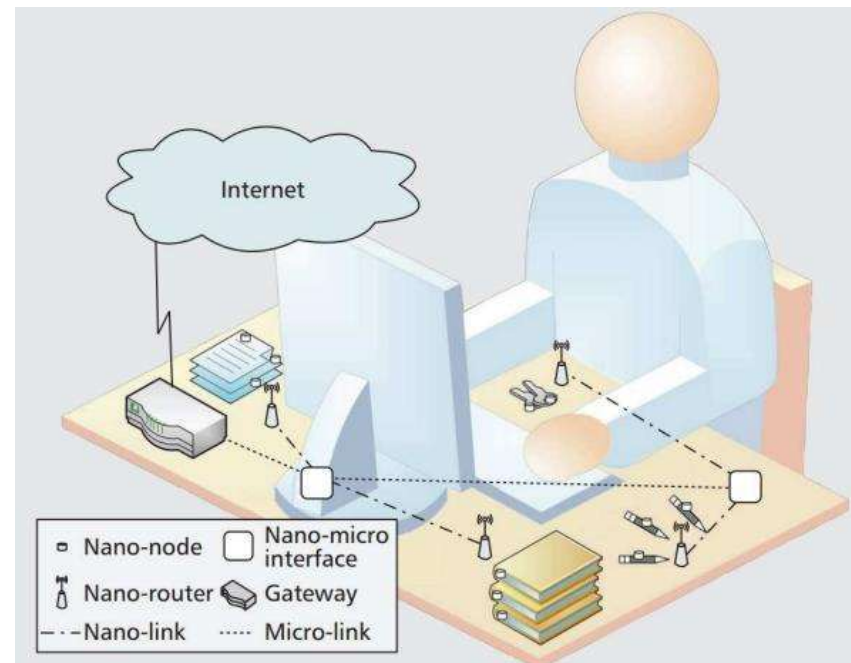


Fig 5: Network architecture of the e-office [4]

# NANOMACHINES & NANONETWORK

Miniature devices engineered with sizes typically ranging from 1 to 100 nanometers.

## ❖ **Key Components:**

Nano sensors, Nanoactuators, Nano Memory, Nano Antennas, Nano Processors, Nano EM Transceivers, Nano Power Units.

## ❖ **Precision and Functionality:**

The design and integration of these components enable nanomachines to perform specific functions with extraordinary precision and functionality.

## ❖ **Challenges and Future:**

Fabrication, control, environmental interactions.

Continued R&D crucial for realizing potential and addressing challenges.



# NANOMACHINE ARCHITECTURE

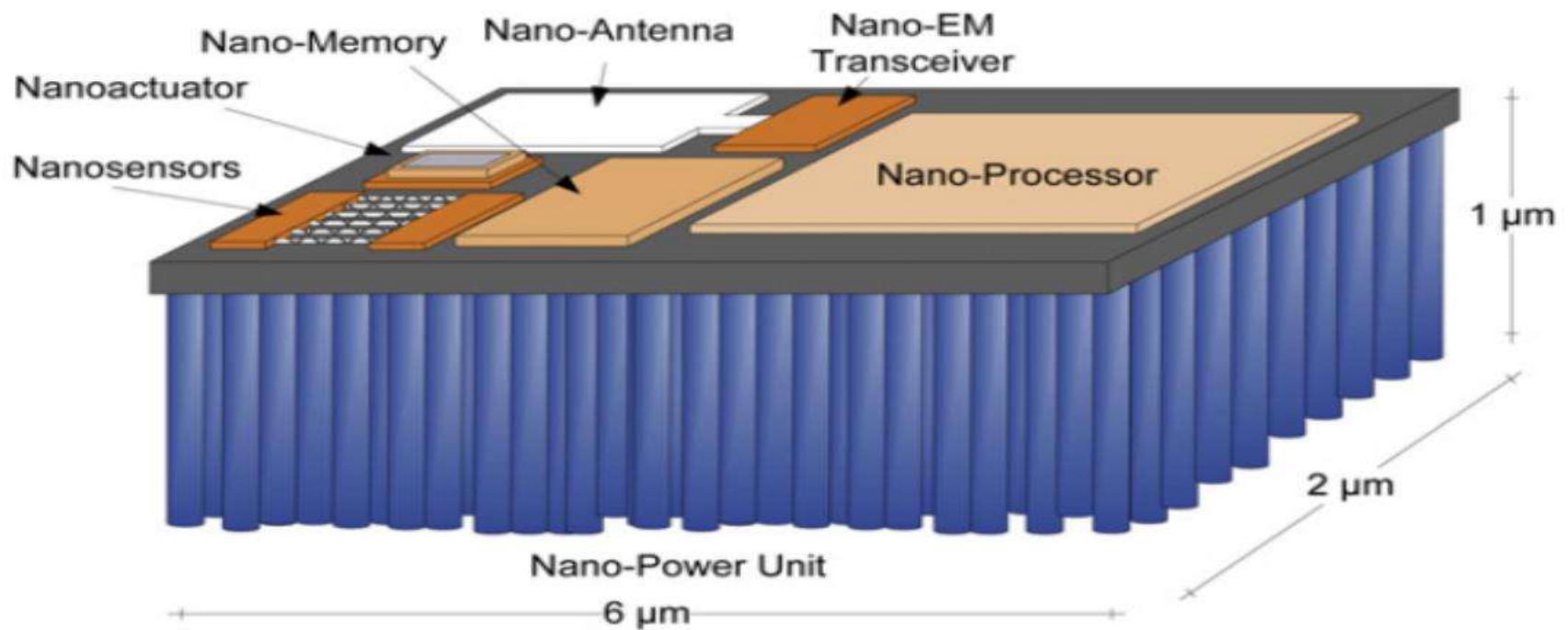
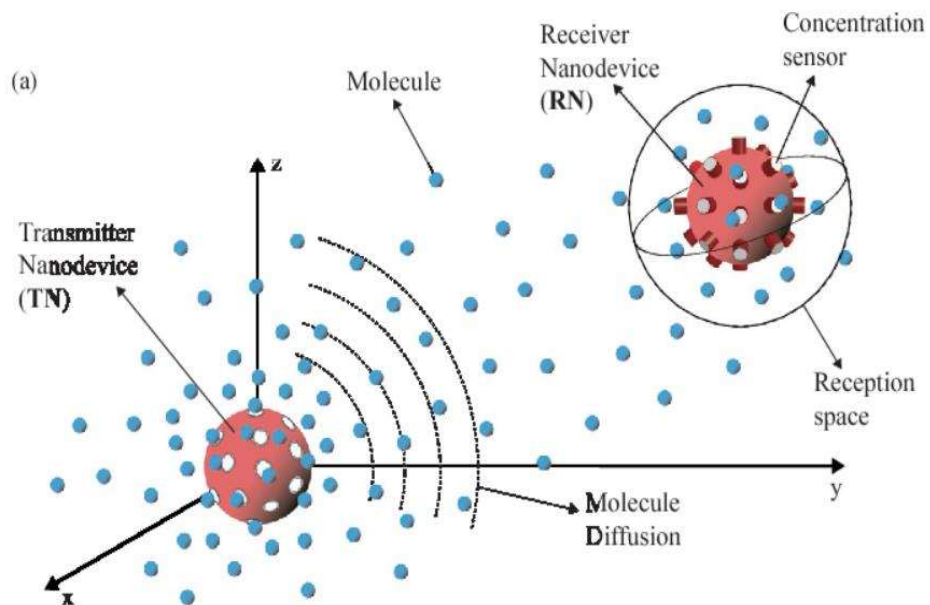


Fig 6 :An integrated nano sensor device.[5]

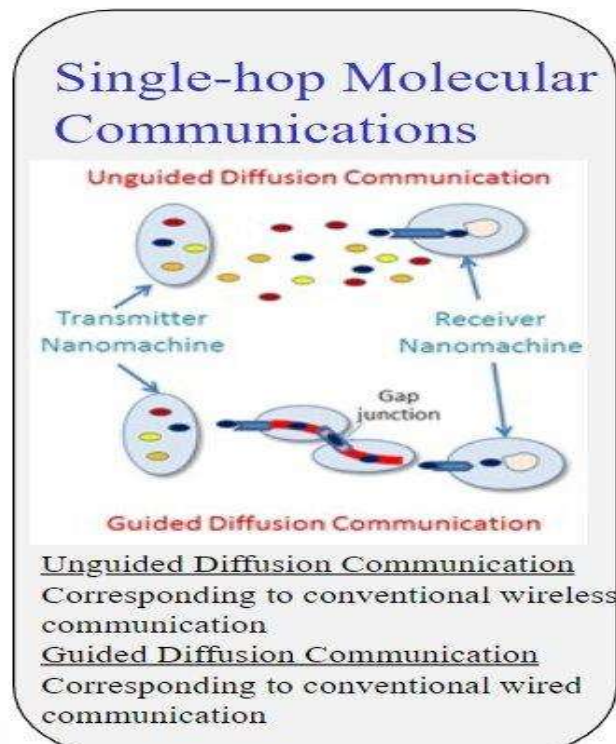
# MOLECULAR COMMUNICATION



- ❖ Molecular Communication is a method based on diffusion, inspired by biological systems, and useful over transmission distances in the nanometre to micrometre range.
- ❖ Molecular Communication systems use the presence or absence of a selected type of Molecule to digitally encode messages. The molecules are delivered into communication media such as air and water for transmission.

Fig 7: The diffusion-based MC model between TN and RN.[6]

# MOLECULAR COMMUNICATION



## Cooperative Communication System Model

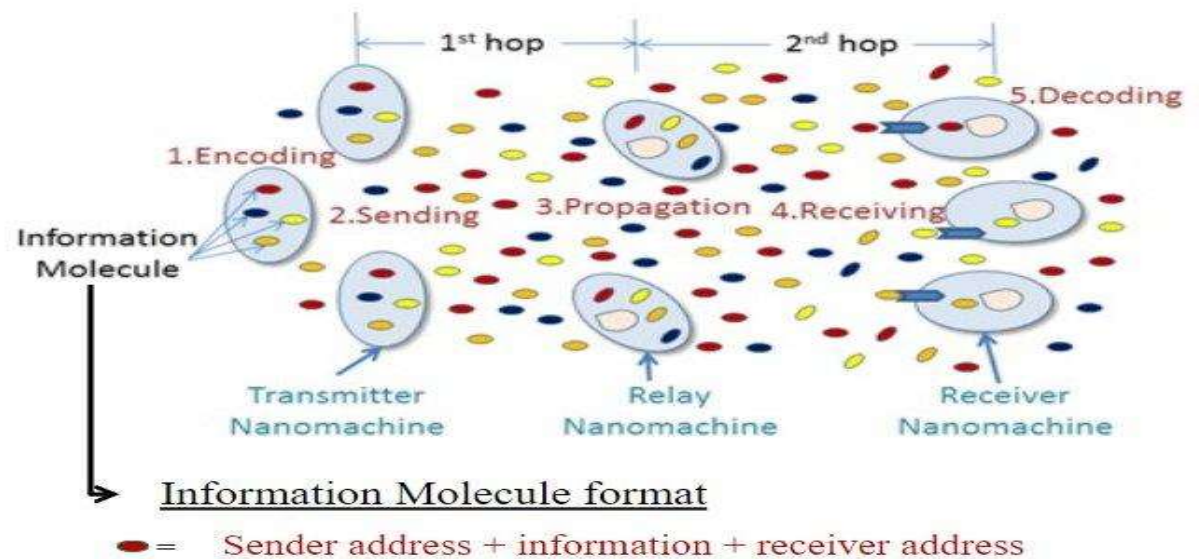


Fig 8: cooperative communication system model for molecular communications

## MOLECULAR COMMUNICATION ADVANTAGES :

- ❖ Molecular communication offers several advantages for nanoscale communication, including:
  - **Biocompatibility:** Utilizes naturally occurring molecules, making it suitable for communication within biological systems.
  - **Low energy consumption:** Molecular communication requires minimal energy compared to traditional electromagnetic methods, making it suitable for energy-constrained environments.
  - **Robustness:** Molecular signals can penetrate obstacles and operate in complex environments with minimal interference.

# TERAHERTZ COMMUNICATION

## ❖ **Characteristics:**

- Utilizes terahertz (THz) waves for wireless data transmission.
- Frequency range: **0.1 to 10 terahertz**, between microwave and infrared radiation.

## ❖ **High Bandwidth**

**Advantage:** Enables gigabit-per-second data rates.

**Significance:** Essential for handling large data volumes in modern communication systems.

## ❖ **Short Wavelength**

**Advantage:** Facilitates miniaturization of components.

**Significance:** Enables development of compact communication devices and nanoscale communication.

## ❖ **Non-Ionizing Radiation**

**Advantage:** Safe for biological tissues.

**Significance:** Opens possibilities for medical applications without harmful effects on living organisms.



## HOW TERAHERTZ COMMUNICATION HELPS TO COMMUNICATE NANO DEVICE ?

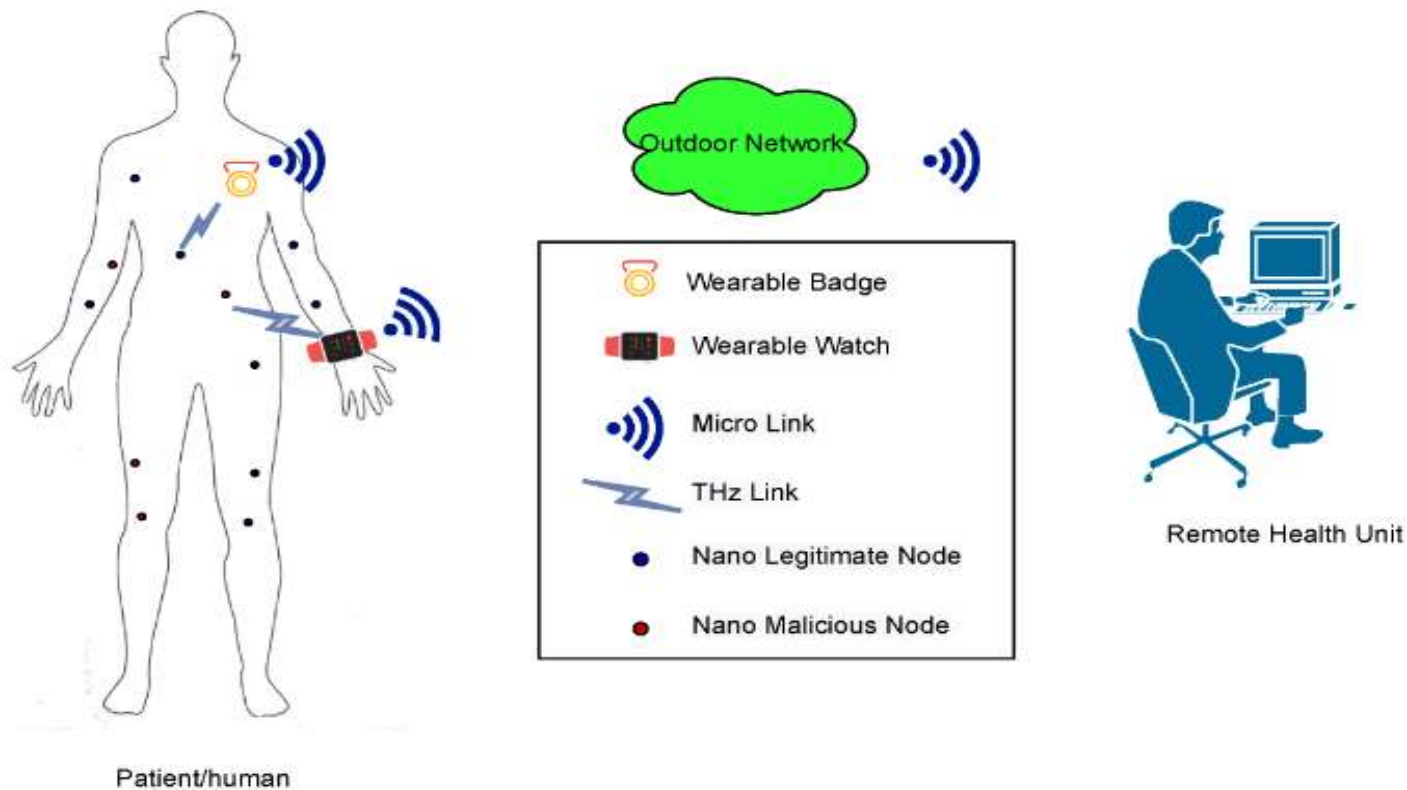


Fig 9: An envisioned future body-centric nanoscale healthcare system with possible malicious nodes.[7]

## TERAHERTZ COMMUNICATION APPLICATIONS

- ❖ Terahertz communication has diverse applications across various fields, including:
  - **Wireless communication:** Terahertz waves can be used for high-speed wireless data transmission in environments where traditional radio frequency communication is limited.
  - **Imaging and sensing:** Terahertz imaging enables non-destructive inspection of materials, medical imaging, and security screening.
  - **Medical diagnostics:** Terahertz waves penetrate biological tissues with minimal absorption, enabling non-invasive imaging and sensing for medical diagnosis and monitoring.

## THE SKETCH OF THE PROPOSED NANO COMMUNICATION NETWORK:

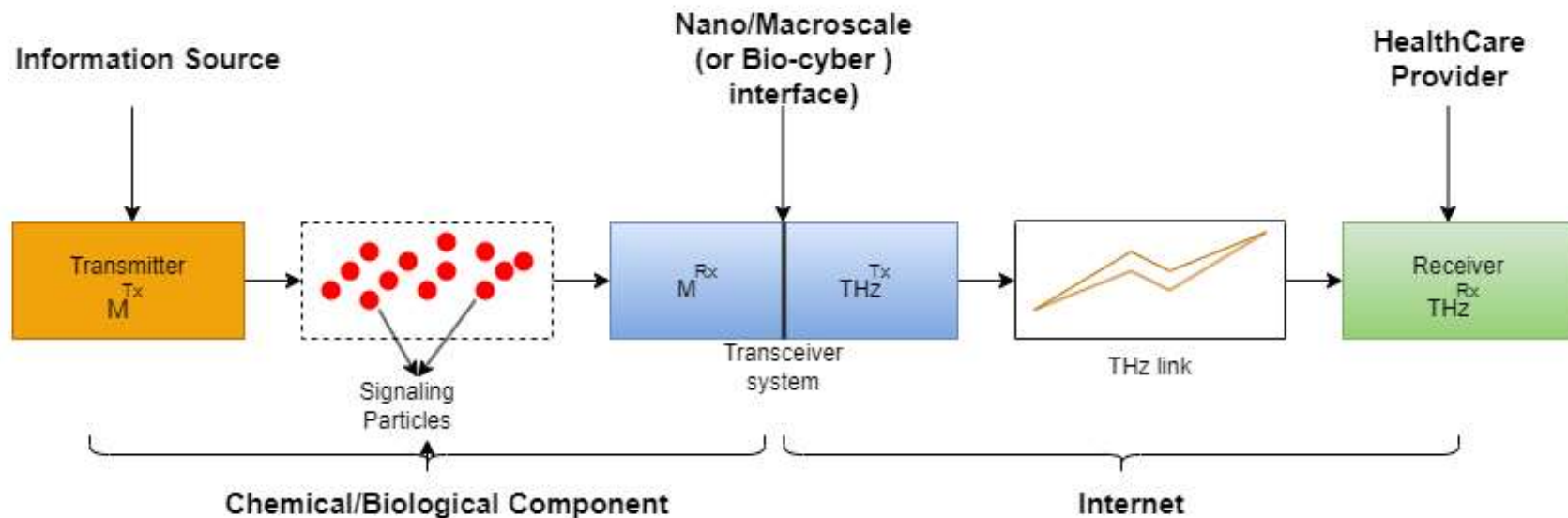


Fig 10: The sketch of the proposed nano communication network.[8]

## LITERATURE REVIEW

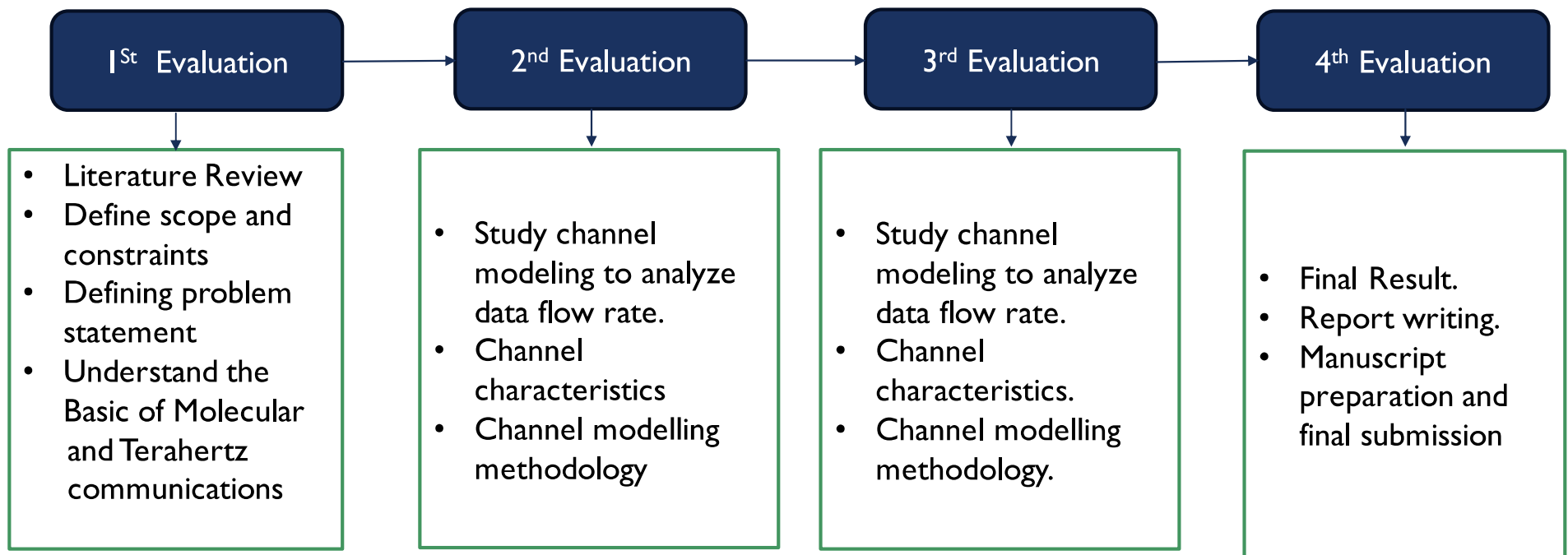
| S No. | Research Paper   | Summary   |
|-------|--|---|
| 1.    | A Comprehensive Survey on Hybrid Communication in Context of Molecular Communication and Terahertz Communication for Body-Centric Nanonetworks | <ul style="list-style-type: none"><li>• The research paper explores the advancements in nanotechnology that have paved the way for the development of nanonetworks.</li><li>• It highlights the production of novel nano-materials and nano-particles with unique properties at the nanoscale.</li><li>• The collaborative effort in linking nano-devices has led to the vision of nanonetworks, expanding the capabilities of nano-machines.</li><li>• This shift towards nanonetworks from traditional IoT is driven by the potential of nano-communication paradigms like molecular and terahertz communication.</li></ul> |
| 2.    | Model-based: End-to-End Molecular Communication System through Deep Reinforcement Learning Auto Encoder  | <ul style="list-style-type: none"><li>• The research paper focuses on integrating Deep Reinforcement Learning (DRL) with Molecular Communication (MC) systems.</li><li>• A DRL autoencoder is utilized to optimize transceiver techniques for MC systems.</li><li>• The study demonstrates improved performance in terms of Bit-Error Rate (BER) optimization.</li><li>• The research paves the way for intelligent and efficient communication systems in nanoscale networks.</li></ul>  |

## LITERATURE REVIEW

| S No. | Research Paper  | Summary  |
|-------|---|--|
| 1.    | Modelling of the Terahertz Comm. Channel for In-vivo Nano-networks in the Presence of Noise | <ul style="list-style-type: none"><li>• The research paper introduces a novel model for modelling communication channel noise in human tissues at the THz band.</li><li>• Results indicate that channel noise power spectral density decreases with distance and frequency, with higher noise levels in tissues with greater water concentration.</li></ul>  |
| 2.    | Realizing Molecular Machine Learning Through Communications for Biological AI               | <ul style="list-style-type: none"><li>• The research paper explores the integration of Artificial Neural Networks (ANN) with gene regulatory networks (GRN) in biological systems for Molecular Machine Learning (MML).</li><li>• It discusses the use of intracellular molecular communication and engineered genetic circuits to enhance the efficiency and structure of ANN models in biological AI.</li></ul>      |
| 3.    | Applications of molecular communications to medicine: a survey                              | <ul style="list-style-type: none"><li>• The research paper explores the applications of molecular communications in medicine, highlighting the potential for personalized disease predictions and treatments.</li><li>• It emphasizes the use of nanotechnology to emulate biological processes, develop nano-sensors for disease detection, and optimize communication strategies for medical advancements.</li></ul> |

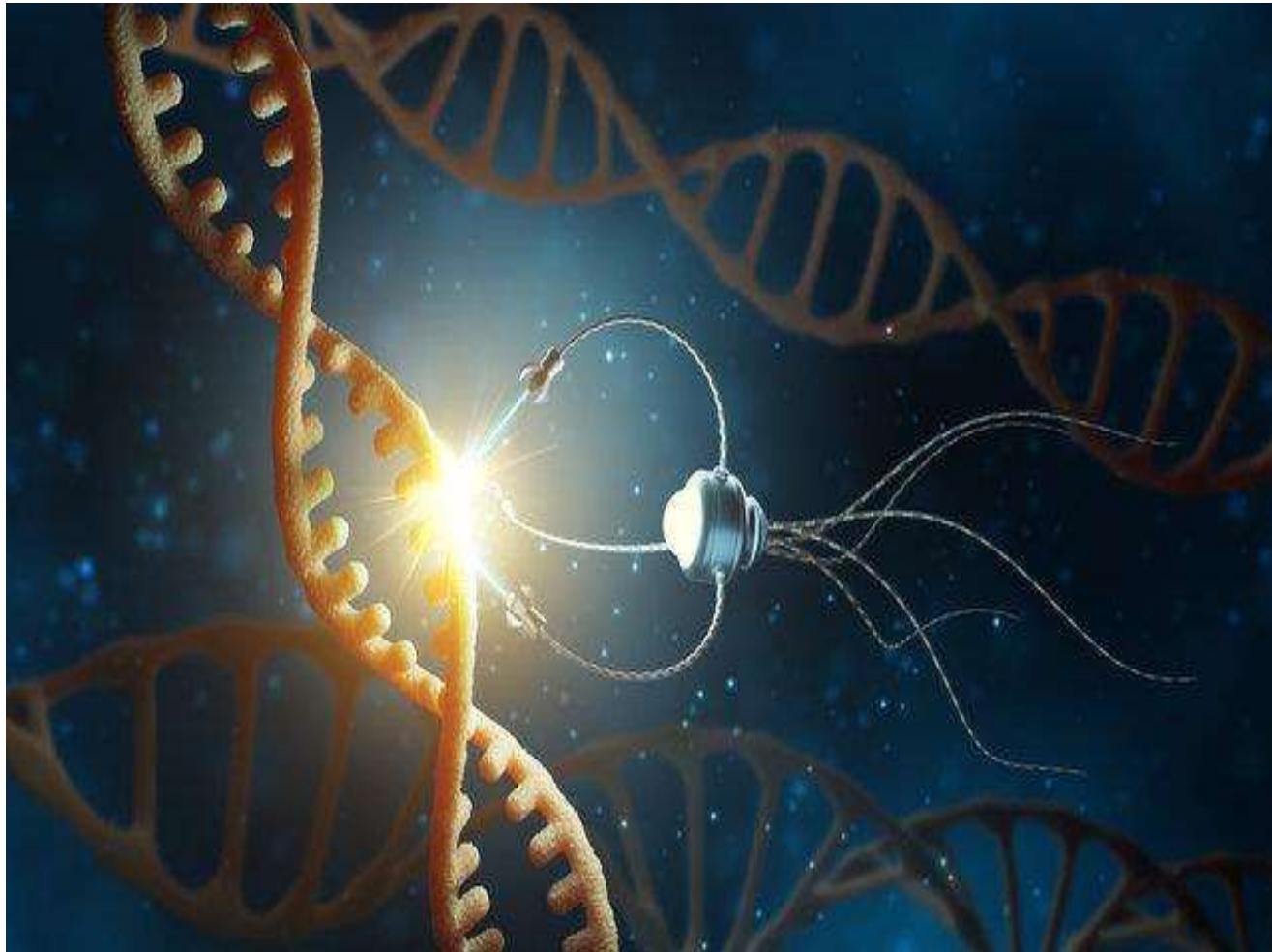


# PROPOSED TIMELINE



## REFERENCES

- [1] <https://ioe.eng.cam.ac.uk/Research/Research-Areas>
- [2] <https://youtu.be/M8d3pxVb4c4?si=UFMwSgfi4HDtVMqX>
- [3] [https://www.researchgate.net/publication/313523261\\_Internet\\_of\\_Nano\\_Things\\_IoNT\\_Next\\_Evolutionary\\_Step\\_in\\_Nanotechnology](https://www.researchgate.net/publication/313523261_Internet_of_Nano_Things_IoNT_Next_Evolutionary_Step_in_Nanotechnology)
- [4] K. Yang et al., "A Comprehensive Survey on Hybrid Communication in Context of Molecular Communication and Terahertz Communication for Body-Centric Nanonetworks," in IEEE Transactions on Molecular, Biological and Multi-Scale Communications, vol. 6, no. 2, pp. 107-133, Nov. 2020, doi: 10.1109/TMBMC.2020.3017146.  
keywords: {Nanobioscience; Monitoring; Biomedical monitoring; Nanoscale devices; Biomedical imaging; Molecular communication (telecommunication); Nano-communication; nano-technology; terahertz; molecular communication; hybrid networks},
- [5] <https://www.sciencedirect.com/science/article/abs/pii/S1878778910000050?via%3Dihub>
- [6] D. Kilinc and O. B. Akan, "Receiver Design for Molecular Communication," in IEEE Journal on Selected Areas in Communications, vol. 31, no. 12, pp. 705-714, December 2013, doi: 10.1109/JSAC.2013.SUP2.1213003.  
keywords: {Noise; Equalizers; Receivers; Nanoscale devices; Measurement; Detectors; Joints; Molecular communication; sequence detection; channel equalization; signal-dependent noise; intersymbol interference},
- [7] <https://www.mdpi.com/1424-8220/21/10/3534>
- [8] <https://www.semanticscholar.org/paper/A-Comprehensive-Survey-on-Hybrid-Communication-in-Yang-Bi/ea5d2f054c97ad34504167ac7e866e332b6c8423>



# THANK YOU

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