Review Article

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A Comprehensive Survey on Nano-sensor Devices and Architectures for the Internet of Nano-Things (IoNT)

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ABSTRACT

In a rapidly changing world, technological breakthroughs in the Internet and information and communication technologies (ICT) have led to innovative solutions that significantly improve people's quality of life. IoT technology connects digital objects to the Internet, making it applicable in several industries. Internet of Nano-Things (IoNT) is the most recent evolution of IoT and has gained interest from researchers and scientists. It combines nanotechnology and IoT, provides a more advanced approach and has the potential to transform the present IoT technology. Although the benefits of IoT are boundless, there are ongoing problems in the expanding IoNT ecosystem to be addressed. This research focuses on the security and privacy problems related to IoNT and nano communication. It also explores key IoNT architectures, nanoscale communication, real-world applications, and relevant simulators and testbeds. This review addresses issues in incorporating new technologies, particularly Artificial Intelligence (AI), into IoNT.

Keywords: Biomedicine; Nanosensor; Nanochip; Internet of nanothings.

1. INTRODUCTION

Internet of Nano-Things (IoNT) operates at the nanoscale level, utilizing microscopic devices to capture sensitive data from inaccessible locations like the human body. This enables significant breakthroughs in biomedicine, environmental monitoring, and material research, where standard IoT devices fall short. Although nano devices have advantages such as small size and flexibility, integrating them with the Internet poses significant obstacles. Securing sensitive data on these nano devices requires creative storage methods. Connecting IoNT devices to the Internet exposes them to risks, requiring strong security measures to prevent privacy and data breaches with serious repercussions. The lack of established protocols and security procedures in nanoscale communication limits its potential. Several studies have been conducted on the Internet of Things from various perspectives (Dell'Olio, 2025) to provide a brief overview of IoNT architecture, applications, medical uses and problems. It also covers network models, architectural needs, implementation issues, networking aspects, and layer-based *vs*. non-layer-based model comparisons.

2. IoNT ARCHITECTURES

This study presents three distinct IoNT topologies, providing readers with a comprehensive understanding of the technology's seamless connectivity and interaction among devices. It compares existing nanocommunication approaches across several dimensions (Huang *et al*. 2025) and offers insights into recent nanonetwork breakthroughs while highlighting standardization efforts by relevant organizations.

2.1 Contribution

The IoNT technology, which involves connecting nanodevices to the Internet has a transformative impact on healthcare. The use of IoNT concepts has led to the development of more customized, convenient, and time-sensitive health monitoring and treatment solutions.

2.2 Scope

Although there are many exciting medical uses for nanotechnology and IoNT in fields like regenerative medicine, nanodentistry, nanomedicine, nanosurgery, and nanodiagnostics, there are some valid concerns as well.

2.3 Methodology of the Survey

The development of nanotechnology will lead to new lines of inquiry that will facilitate the use of nanotechnology in everyday life (Fig. 1). Nanotechnology is one of the most crucial technologies for creating nanoscale devices for a variety of industries, including healthcare and medicine. Nanorobotics can be created by combining nanodevices, which develops and builds robots with nanoscale dimensions.

The 2021 AI/ML (Artificial Intelligence and Machine Learning). A thorough examination of AI/ML techniques, algorithms, and their applications in a variety of fields (including COVID-19 diagnostics and recommendation systems). The 2022 Wearable Sensors Analysis of sensor modalities (inertial, electrophysiological) for health monitoring, activity detection, and sleep quality assessment. Developed a taxonomy for wearable devices based on their application areas (sports, health, and safety) and technical characteristics. In 2023, edge computing is moving from cloud to edge/fog computing to support real-time, low-latency, and data-intensive IoT applications. The edge architectures (cloudlets, fog computing). The 2024 IoT healthcare integrates AIoT (AI + IoT) for remote patient monitoring, smart diagnostics, and wearable health surveillance. Conducting an architecture review involves analyzing the entire framework from data collection (sensors) to communication (edge/cloud), analysis, and decision support. The 2025 Internet of Nano-Things (IoNT) / Next-Gen AIoT. Advanced, intelligent, and possibly in-body/micro-scale sensing combined with AIoT for advanced healthcare diagnostics. The emerging research on nano-biosensors and in-body network

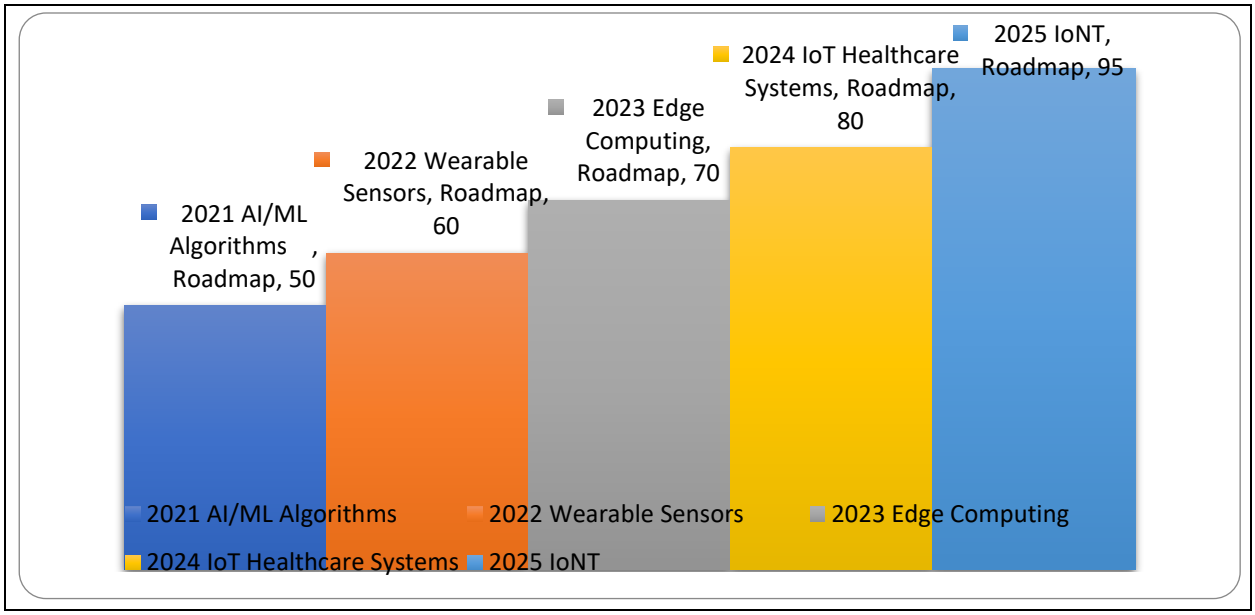


Fig.1: Roadmap on IoNT

3. NETWORK ARCHITECTURE

The essential components of the fundamental basis for the nano-network architecture are discussed below.

3.1 Nanonodes

Nanonodes, the smallest and simplest nanomachines, are the core components of nano networks. Nanoscale nodes have limited computing power and memory capacity. They generally execute fundamental activities like sensing, actuation, and reacting to commands from micro routers. Nanonodes have limited energy and communication capacity, restricting their ability to communicate beyond short range. Some examples are nanosensor nodes in the human body and nanomachines integrated into smart home appliances.

3.2 Nanorouters

Nanorouters are innovative devices that connect nanodevices and nanonetworks to the outside world and are necessary due to their unique characteristics. When two nanodevices communicate molecularly, they can exchange electromagnetic radio waves in the terahertz (THz) range. Nanoscale surgery, intelligent drug delivery, and the identification and management of infectious disease outbreaks are a few of the medical and healthcare uses of nanonetworks. Using nanosensors or nanorobots that are implanted in the patient's body, medical professionals can remotely monitor and control any unanticipated changes in the body as well as gain

insights into the patient's current health state, thus enabling them to engage in IoNT.

3.3 Nano-Micro Interface Device (NMID)

Nano-Micro Interface Devices are vital in nano networks as they act as mediators between nano routers and microscale devices. Additionally, they can receive data from microscale devices and send it to nano routers. The NMIDs are hybrid devices that combine nanoscale communication techniques with traditional communication paradigms. This two-way communication enables seamless integration between nano and traditional networks. These devices allow for information interchange between nanonetworks and larger communication systems.

3.4 Gateway

The gateway device allows remote control of the IoNT system over the Internet. It connects the IoNT system to the Internet, allowing users to obtain aggregated data from any location with an Internet connection. Smart gadgets, like smart phones and smart watches, can act as gateways to manage the IoNT system (Huang *et al*. 2025). The remote control feature enables seamless connection and information exchange between the IoNT system and external entities, including healthcare providers. In an intrabody network, a sophisticated mobile device can receive information from a gateway device on the wrist and send it to a healthcare provider over the Internet.

3.5 Table 1. IoNT and IoT

S. No.	IoNT	IoT
1	The IoNT system is made up of the deployment of internetworked nanodevices.	Nanotechnology and the Internet of Things have many positive applications in healthcare.
2	The IoNT has developed as a result of nanotechnology. IoNT applications will grow as a result of information exchange and coordination between nanodevices and internet devices.	Better disease detection and diagnosis, quicker, more precise, and sophisticated disease treatment, better patient health status monitoring,
3	Numerous facets of our everyday lives and society will greatly benefit from the development and widespread application of nanotechnology-based technologies	The disease prevention will be the cornerstones of the future healthcare system
4	IoNT principles have enabled new, more personalized, quicker, and more convenient methods of health monitoring and treatment.	The IoT conventional sensors, actuators, software, cloud platforms.
5	This interconnected structure has huge potential to enhance patient satisfaction and remove obstacles in the provision of healthcare.	The gateways and nanomicro interface devices use standard protocols for communication (Wi-Fi, Bluetooth, cellular, RFID)

4. NANODEVICE ARCHITECTURE

The operation and functionality of individual nanodevices in IoNT (Rajkumar *et al*. 2025) is dependent upon the fundamental components and design ideas that enable nanodevices to interact with their surroundings and integrate into the IoNT network.

Nanodevice is the core component of the IoNT infrastructure, which can be applied to a variety of sectors, including multimedia and biology. They are used to create extremely quick communication mechanisms.

4.1 Power Unit

Power unit provides energy to nanodevices by harvesting light and heat from external sources. This component is crucial for nanodevice construction as it powers all internal components. The device stores energy for future use, providing a consistent power supply for several operations and activities.

4.2 Control Unit

The control unit supervises and manages all components in the nanodevice. It executes commands, collects environmental data, and manages tasks. The storage unit can be integrated with the control unit to enhance the nanodevice's functionality and autonomy. This unit stores and retrieves device-specific data. The communication unit develops channels and procedures for sending and receiving data at the nanoscale. It utilizes nano transceivers, specialized components capable of sending and receiving data at the molecular level. Nano transceivers serve as interfaces for the communication unit, enabling data interchange with the environment. The IoNT system primarily consists of nanosensors and actuators. Nanosensors provide valuable environmental data by sensing and measuring many features. They can sense temperature, chemical composition, humidity, and pressure. Actuators allow nanodevices to perform specific actions based on incoming information. In response to external cues, they might trigger bodily changes or motions. Nanosensors and actuators include nanorobots, sensors with specialized detecting capabilities, and nanocatalysts for faster chemical reactions. These components improve the nanodevice's functionality and responsiveness within the IoNT system.

4.3 Storage and Data Processing

The IoNT system creates vast volumes of data, necessitating specialized technologies for storage and processing. The IoNT manages and processes enormous amounts of data through storage and processing components within the nanodevice framework. The IoNT system requires these aspects to effectively manage and extract insights from the data it generates. Nanoscale memory systems, including nanocapacitor-based

memory, are employed to achieve this. Nanoscale computers are also used for data processing processes.

These computing devices may use cutting-edge technologies such as quantum or molecular computing. Quantum computing uses quantum physics to do complex computations, whereas molecular computing processes data at the molecule level.

4.4 Reproduction Unit

The reproduction unit assembles and fabricates all nanomachine components (Bhuiyan *et al*. 2025). It assembles the components to create the nanodevice. The reproduction unit offers the necessary instructions for completing this task. The nanomachine replicates itself utilizing external resources and instructions stored in the reproduction unit. This ensures the IoNT system's scalability and availability of nanodevices.

5. NANODEVICES

Smart cities use seamless connectivity between appliances and sensors to optimize administration. Citizens own advanced sensors, actuators, and digital devices to collect data on many urban features. Although IoT has been extensively studied, advances in nanotechnology and IoNT provide considerable benefits.

5.1 Nanosensors

Exceptional efficiency of nanosensors allows for comprehensive and detailed data collection across a wide variety of parameters (Singh *et al*. 2025). Applications of nanosensor are found in self-sensing structures, environmental monitoring, traffic control, and urban services. New studies may examine the potential applications of nanogenerators in water and wind energy, as well as intelligent mobility.

5.2 Nanogenerators

Nanogenerators have potential applications in smart healthcare and human-machine interfaces, including water-driven tunnels and raindrop energy collection. They can also be integrated into fabrics, wearables, and healthcare devices. Their ability to capture energy from water and wind waves has the potential to address worldwide energy concerns. Although IoNT in smart cities is still in its early phases, further study will enhance and strengthen this emerging discipline.

Recent works in nanotechnology study the application of previously underutilized nanosensors, nanofluids, nanocatalysts, nanoemulsions, and nanomembranes in the oil and gas industry. Nanotechnology can improve economic, efficient, and sustainable methods in exploration, drilling, production, refining, and enhanced oil recovery. In this regard, carbon nanotubes are also used as sensitive nanosensors for oil gases, addressing environmental and industrial safety problems through DFT calculations.

In addition, wireless nanodevices have been introduced for oil well monitoring, providing a cost-effective alternative to maximize output and reduce operational hazards in offshore installations (Cao *et al*. 2025). Although IoNT in the oil and gas industry is still under development, studies show tremendous progress and potential in this attractive field.

5.3 Agriculture

IoNT in agriculture has various uses, with a focus on precision agriculture. Nanotechnology tackles issues in traditional agriculture, focusing on pesticides and chemical fertilizers. Nanomaterials, nanochips, and nanoencapsulated agrochemicals can improve yield while limiting environmental effect. Advanced nano-engineering can address the worldwide agricultural challenge of climate change by improving crop yield, sustainability, and input efficiency to fulfill growing food demands

Nanotechnology has the ability to improve monitoring, food quality, and reduce chemical usagec (Mathivanan and Michael, 2025). Applications include precision farming, antimicrobial materials, nano-pesticides, smart gene delivery, and disease detection. Nano-fertilizers enhance nutrient absorption, disease detection, and productivity while preserving soil and water quality. Wireless Nanosensor Networks can be used for nano-scale monitoring in dairy production, including grass monitoring and animal health management.

Smart farming focuses on employing IoNT to improve soil, conserve water, manage pests, and promote plant development. These contributions considerably expand our understanding of IoNT and nanotechnology, highlighting their revolutionary impact in agriculture.

5.4 Defence

Continuous improvement is crucial for maintaining defence effectiveness and readiness. It seeks to maximize impact with limited resources (Krobot, 2025). This sector now includes nanotechnology, nanodevices, and Internet of Things. Nanosensors and nanoactuators are used in NBC defenses to detect threats and coordinate defensive reactions.

Nanocellulose, a nanomaterial, is used in military gear for its lightweight design, better protection, stealth characteristics, and environmental acceptability, meeting many needs. Nanomaterials, including aramid nanofiber and MXene/silver nanowire composites, are

being investigated for electromagnetic interference shielding and heat management applications (Pillai *et al.* 2025). Real-life applications for military gear include protective garments, construction, automotive, aerospace, eco-textiles, and e-textiles.

5.5 Medical Industry

IoNT has transformed healthcare industry by enabling individualized treatment plans, remote patient monitoring, improved diagnostics, and novel research. Nanosensors in healthcare monitor factors such as blood pressure, salt, and glucose, allowing for early identification of hazardous compounds and malignancies, leading to quick therapeutic reactions. Combining nanosensors with myelin sheaths can help restore demyelinated neurons (Peng *et al*. 2025). Additionally, they have the potential to improve communication, nerve impulse transmission, and therapy effects. Body sensor networks use nanosensors to track biological data, allowing for real-time health monitoring *via* wearables or external devices.

This enables continuous vital sign monitoring, early disease detection, and personalised healthcare treatments. Adoption of IoNT offers expanded benefits and possibilities for future applications in healthcare monitoring, diagnosis, and treatment.

5.6 Biomedical Applications

Nanoparticles interact with living cells, enabling breakthroughs in immune system support, nanomedicine, and drug delivery. IoNT-based drug delivery systems use nanodevices to precisely control and treat metabolic disorders such as diabetes using smart glucose reservoirs and nanosensors and nanomedicine.

5.7 Nanomaterial-based Biological Sensors

Nanomaterial-based biological sensors can detect diseases like cancer and infections in the human body. IoNT supports the immune system by using nanodevices at various scales to identify and eliminate harmful compounds and cancer cells. These applications have the potential to improve healthcare by allowing for accurate drug administration, early illness identification, and immune system improvement, leading to better patient outcomes.

5.8 Food Packaging

IoNT-based food packaging has shown considerable market benefits. The use of nanomaterials in food packaging, such as polymer nanotechnology, has improved quality monitoring, controlled preservative release, and shelf life. Nanosensors and nanodevices improve food quality and safety during storage and transportation. These electro-optical systems can provide magnified signals to detect tiny quantities of analytes or pathogens.

5.9 Polymer Nanotechnology

Polymer nanotechnology creates new polymers with improved mechanical, and antibacterial properties, leading to better food quality, safety, and shelf life. RFID sensors are increasingly popular in food packaging. Nanomaterials like graphene and carbon nanotubes are used to detect harmful gasses and chemicals. They may be printed on many surfaces, making them suitable for wearable and flexible electronics. RFID-based tags and inkjet-printed flexible electronic devices are commonly used in food packaging, providing smart skin functionality to monitor and improve food quality and safety.

5.10 Technologically Enhanced Textiles and Smart Fabrics

Nanodevices and nanosensors can revolutionize clothes. In healthcare, nanotechnology integration includes antibacterial fabrics with silver nanoparticles, increased filtration using nylon nanofibers, and thermoregulation with phase-change materials (Filippou *et al*. 2025). Applications include medicinal dressings, protective equipment, and creative alternatives to standard incubators. E-bra technology with nanosensors used for cardiovascular monitoring overcomes the constraints of noninvasive techniques.

Nanosensors made of nanoparticles or textiles use dry electrodes to capture electrocardiogram signals. Data is wirelessly transmitted to a textile-mounted module and processed by a smartphone or Bluetooth-enabled PC. This allows for continuous monitoring for early identification and preventive interventions. Nanodevices improve military and sports performance by monitoring soldiers' health and creating lightweight, bullet-proof jumpsuits. They also provide moisture management and physiological monitoring in sports fabrics.

5.11 Ground Water Remediation

Environmental contamination has a significant impact on human health, soil, air, water, and ecosystems. Waterborne infections are a major problem, particularly given the reliance on groundwater as a clean water source (Hussain *et al*. 2025). Nanoremediation, which uses reactive nanoparticles for *in situ* modification and detoxification, is a novel technique to groundwater cleanup. Nanomaterials such as nZVI, titanium dioxide,

carbon nanotubes, and bimetallic nanoparticles provide advantages over typical pump-and-treat methods. Advantages of this approach include cost savings, shorter cleanup times, and no need for soil transportation or disposal.

5.12 Brain Computer Interfaces

IoNT can be combined with brain-computer interfaces (BCI) to advance research and applications in neuroscience. This integration has potential for applications including neuroprosthetics, brain-controlled gadgets, and cognitive enhancement. Nanosensors implanted on the brain's surface can wirelessly transmit neural signals such as EEG and ECG. IoNT technology could provide biocompatible, less invasive implants for real-time data transfer and brain tissue interfacing. Combining IoNT with BCIs can increase cognitive abilities by activating specific brain regions for better memory, attention, and sensory perception.

Advanced brain-machine interfaces provide direct communication and control between the brain and external devices, improving prosthetics, virtual reality, and teleoperation. proposed BCI chip with IoNT sensors. The diagram shows how nanosensors are integrated into the electrodes of an invasive BCI chip to detect and transmit important information. This novel technique enables smooth connection between the brain and external equipment. Technical and ethical difficulties must be solved to assure the safety, dependability, and long-term compatibility of nanoscale devices with neural tissues.

5.13 Smart Dust

Smart dust uses microelectromechanical systems such sensors, robots, and other devices to monitor and send environmental data. IoNT and smart dust are nanotechnology-based, but differ in size, power, and functionality. IoNT devices range in size from 0.1 to 100 nanometers, whereas smart dust devices are often sub-millimeter-scale, up to a few cubic millimeters. IoNT devices have greater autonomy and intelligence than smart dust devices, as they can do calculation, storage, and actuation, whereas smart dust devices are primarily passive sensors or transmitters. IoNT devices use less power than smart dust devices since they can gather energy from their environment like light, heat, or vibrations. Smart dust devices require batteries or wireless charging. Hybrid systems can be created by integrating IoNT with smart dust, leveraging their respective benefits. Smart dust can function as a gateway or interface between devices.

The Internet connects IoNT devices to larger computer systems, allowing for data relay. Smart dust can enhance the sensing capabilities of IoNT devices by providing additional or redundant information about the surroundings.

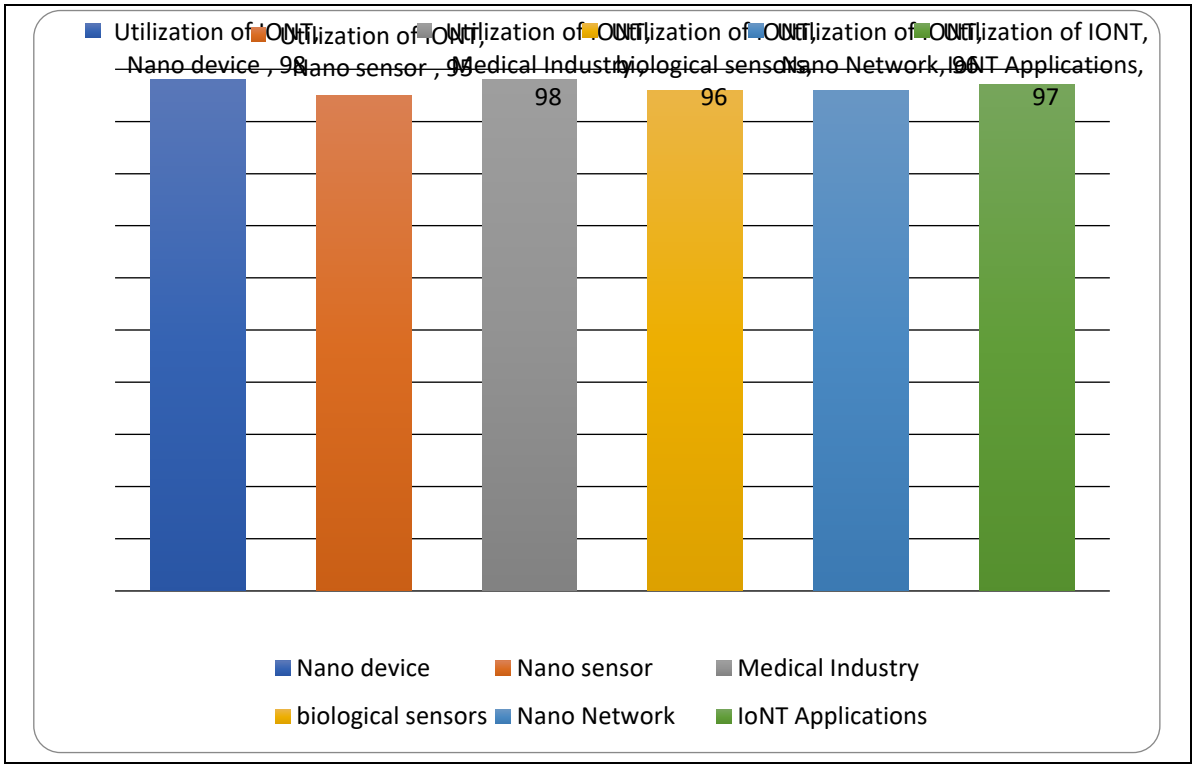


Fig. 2: Utilization of IoNT

6. NANOSCALE COMMUNICATION

Collaboration can improve adaptability, dependability, and security by fostering cooperation and self-organization, resulting in resilient system performance. Miniaturized phones will significantly advance IoNT in the future years. Miniaturized phones, similar to nanodevices, could be a promising future use of IoNT. Miniaturized phones designed just for calling would offer convenience and simplicity. In this scenario, a nanodevice might be put in the user's wrist and another in their ear.

To make a call, the user activates the wrist sensor, and the nano phone connects the call to their ear device. This streamlined communication procedure would eliminate the need for traditional smartphones with multifunctional functions. Additionally, using nanoscale communication devices could assist the environment. Nano phones produce less pollution than traditional cell phones, leading to a cleaner and healthier environment. However, the creation of tiny phones is largely hypothetical and technical obstacles remain. Miniaturization, power management, and smooth connection are key factors in achieving this futuristic application. Miniaturized phones, a future application of IoNT, can simplify communication and alleviate environmental problems. Advancing IoNT could lead to new solutions that improve human experiences while minimizing environmental impact.

7. BENEFITS OF IoNT

The IoNT has various advantages over other technologies.

- **Nanoscopic Scaling:** Nanotechnology offers many advantages, including the potential to manufacture extremely small electronics. This advantage allows for wearable or implantable devices that are more comfortable and less obtrusive. The seamless integration of these technologies into our daily lives improves their usability and accessibility. Nanotechnology can enable smaller, less obtrusive IoNT solutions, increasing user experience and expanding the technology's possible applications.

- **Improved Precision and Accuracy:** Nanoscale IoT devices outperform larger devices in terms of accuracy and precision. Nanosensors and nanodevices' small size allows for precise monitoring and measurement, leading to more reliable data acquisition. This level of precision is extremely useful for medical diagnosis and treatment. Nanotechnology-based medical devices provide precise and detailed data on the human body, aiding in early diagnosis and personalized treatments IoNT uses nanotechnology to improve data reliability and precision, leading to advancements in industries requiring precise measurements.

- **Enhanced Energy Efficiency:** Nanoscale devices in IoNT offer exceptional energy efficiency, making them a key benefit. These gadgets are designed for maximum efficiency and low energy consumption. These properties make them excellent for energy-efficient applications like wearable technology and portable devices. Nanoscale devices can improve battery life and reduce energy consumption in IoT systems by operating at low power levels. Saving energy resources enhances the utility and convenience of wearable technology and contributes to environmental initiatives. IoNT nanoscale devices offer energy efficiency, allowing for long-lasting solutions that do not require frequent recharging or power source replacement. Improved energy efficiency opens up new prospects for IoNT utilization in several areas, leading to sustainable technological achievements.

- **Enhanced Durability:** Nanoscale components in IoNT offer increased endurance, which is a significant advantage. Compared to bigger IoT devices, they are more resistant to wear and breakage. Increased longevity leads to decreased maintenance and total expenditures. Nanoscale components are strong enough for continuous operation and durability in applications like environmental monitoring and remote infrastructure management. Improved durability reduces the need for frequent repairs and replacements, promoting system stability and cost effectiveness.

8. IoNT AND NANOTECHNOLOGY

Fig. 2 shows the importance of nanotechnology and IoNT in advancing healthcare toward a more sustainable and precise future. It also illustrates the benefits of nanomedicine, the application of IoT concepts

on the nanoscale, and associated concerns about nanotoxicity, privacy, and security.

9. SALIENT FEATURES

The salient features of IoNT include advanced nanomaterial engineering for high density memory with reduced storage area, dynamic data collection supported by intelligent algorithms for efficient processing, and the development of terahertz channel models along with specialized communication protocols and alternative communication mechanisms for improved reach and efficiency. Strong security frameworks are emphasized through encryption, authentication, secure hardware, regular software updates, lightweight cryptography, physical layer authentication, and dedicated security protocols for electromagnetic and molecular nanonetworks. IoNT also integrates adaptive machine learning algorithms with online learning for real time data adjustments, noise reduction and filtering for nanoscale communication reliability, and preprocessing techniques to manage data heterogeneity. Additional features include effective data labeling under device constraints, edge computing to minimize latency and data transfer, model compression for resource efficiency, privacy preserving machine learning, automated feature engineering, and dimensionality reduction to handle high dimensional data while improving interpretability and lowering computational costs.

10. DISCUSSION

Internet of Nano-Things monitor ecosystems and acquire real-time health data using environmental, biological, and climatic sensors. They gather information on temperature, humidity, species behavior, air pollution, water quality, and soil moisture. In agriculture, crop growth and soil health are continuously monitored, along with biodiversity, wildlife health, and migration patterns. However, environmental sensors are expensive, need regular maintenance, and must be weatherproof. In precision agriculture, IoNT technologies are used to evaluate and optimize crop health, soil conditions, and weather patterns. These technologies improve farming efficiency, reduce input costs, and minimize environmental impact through targeted interventions. Key applications include monitoring soil moisture, measuring pH and temperature, tracking nutrients, and using AI for data-driven decision making.

In the biomedical field, structures are developed using metallic, polymeric, or ceramic materials. These materials are classified by function as biodegradable, biotolerant, bioinert, or bioactive. Regulatory organizations oversee environmental management and waste disposal practices related to these materials.

In industrial manufacturing, sustainability is promoted through the sharing of materials, energy, water, and by-products across different businesses, supporting more efficient and circular production systems.

11. CONCLUSION

Rapidly evolving IoNT technology combines nanotechnology and IoT to create interconnected nanoscale objects and systems. It is a new paradigm for communication and interaction with the physical environment. This review focuses on the security and privacy problems associated with IoNT and nano communication. Addressing these challenges is crucial to ensure the safety and trustworthiness of IoNT ecosystems. The integration of AI into IoNT is emphasized, recognizing its potential to accelerate the development and effectiveness of IoNT applications. Further research is needed to establish strong security and privacy frameworks. Unlocking the actual capabilities of IoNT may pave the road for a future where nanoscale technology and connectivity converge create a smarter and more linked world. As IoNT is still in its early phases, this review paper is a crucial step toward understanding its complexities.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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