As per UGC guidelines an electronic bar code is provided to secure your paper

International Journal for Modern Trends in Science and Technology
Volume 12, Issue 05, pages 385-390
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol12issue05.html
DOI: https://doi.org/10.5281/zenodo.20560502

Integration of Artificial Intelligence with IoNT and Applications, Challenges

Kapil Sirohi[1] | Renu Janagal[2]

[1]*Department of electronics and Communication Engineering UIET, MD University, Rohtak, India-124001.*
[2]*Department of Electrical Engineering, UIET, MD University, Rohtak, India-124001.*

To Cite this Article
Kapil Sirohi & Renu Janagal (2026). Integration of Artificial Intelligence with IoNT and Applications, Challenges. International Journal for Modern Trends in Science and Technology, 12(05), 385-390. https://doi.org/10.5281/zenodo.20560502

Article Info
Received: 05 May 2026; Revised: 26 May 2026; Accepted: 29 May 2026.

KEYWORDS

Artificial intelligence; Internet of Nano-Things (IoNT); Nanotechnology; Internet of Things (IoT); Medical, military, agriculture, and environment.

ABSTRACT

Several developments are being undertaken by society to advance artificial intelligence, nanotechnology and apply it in medicine, defense, agriculture, telecommunications, and computing. A lot of funding is being made available to non-profits and corporations to help develop this technology. As part of the Internet of Things (IoT), the goal is to get sensors to connect to each other and interact intelligently with each other. However, replacing sensors with nano-sensors has provided a completely new aspect to IoT, which is called Internet of Nanothings (IoNT). In the near future, IoNT may become a powerful tool with the integration of artificial intelligence. The technology has a variety of applications and promising prospects. We will study and analyze the opportunities and challenges of IoNT in the various applications that are related to the various domains in this paper. Since AIoNT is considered the next generation of IoNT, we will focus on it in this paper.

1. Introduction

Most Today, researchers have shown immense interest in dealing with the field of IoT and exploring its applications. The Internet is a communication system that is used to connect individuals to information, while the Internet of Things (IoT) is a system of interconnected physical objects that are addressable and have a range of processing, sensing, and actuation capabilities [1-2]. Therefore, the Internet of Things' main goal is to enable objects to communicate with other objects, or individuals, over any network, path, or service at any time or place. Basically, the Internet of Things consists of a large number of things or devices like sensors, actuators, transducers, computing units, RFID (radio frequency interface devices), and other technologies, which can facilitate the collection or exchange of data through the Internet [3-4]. Further, IoT with nanotechnology has enabled advanced sensors to expand into smart communication networks that facilitate data collection at poorly accessible locations [5-6]. With the use of nanotechnology, devices are being developed at the nanoscale that can interact at the molecular level through atom-by-atom engineering [6-7]. Due to their nanosizes, they can penetrate into cells and can develop more complex applications like health monitoring with nanosensor networks or body sensor networks [8]. So, the Internet of Nano Things is the network of nanomachines or devices such as nano-biosensors integrated in the network infrastructures, which has seen keen interest of research, especially in the field of medical diagnostics [9]. IoNT can transform the way of communications and realize the world at the "bottom" level by improving communication efficacy at the molecular scale [9,6]. Based on IoT, many technologies have been developed, like the Internet of Nano Things, Internet of Things in healthcare (including remote monitoring systems), and the Internet of Medical Things, which blends medical devices with internet connectivity[10-11]. The Internet of Nano Things represents an advanced evolutionary stage of the Internet of Things, characterized by the integration of nanoscale sensors and devices into existing communication networks [12]. By leveraging the unique properties of nanoscale materials, this paradigm enables the monitoring of biochemical signals in complex in vivo environments or at remote locations that are otherwise unreachable by conventional sensing technology [13]. This architectural transition involves the use of nanorouters that act as bridges between these miniature components and macro-scale network infrastructure [14-15]. These hybrid nano-micro interface devices aggregate data from nanorouters and translate information across scales, utilizing the terahertz band for high-frequency communication [16]. The exploration of the Internet of Things (IoT) has been showing breakthroughs in the various fields of applications like communication networks, healthcare systems, traffic monitoring, agriculture, smart cities, industries, etc [17]. Majorly, these technologies are being used for monitoring and management of patients in real time. Furthermore, IoNT is also used in other applications like agriculture, industrial areas, environments, etc. From the last few years, IoT has become a significant part of life as the population increases day by day, especially in the field of healthcare and medical systems. This technology is used to monitor the various kinds of chronic diseases at home. IoT technology can transform the healthcare system with the innovation of new medical devices like wearable technologies that make it easy to monitor the various chronic diseases.

2. IoNT Architecture

Figure 1 illustrates a hierarchical Nano-network architecture, which is a fundamental framework for the Internet of Nano-Things (IoNT). This architecture enables communication between nanomachines-devices integrated at the nanoscale-and the macro-scale world.

1) Nano-sensors (NS): They are nano-machines that accomplish various tasks, such as computation and transmission of data. It can be used where transmission is required for smaller distances and utilizes small memory for the storage of data. Such as a biosensor network, a physical nanosensor, and a chemical nanosensor, which are being fixed inside the human body through nanodes. Normally, these nanosensors are being used in the healthcare systems to perform various tasks such as detection, monitoring, and treatments. They can sense the chemical compound in parts per billion or can detect the various infection agents, i.e., viruses, injurious bacteria, etc. The sizes of the nanosensors are comparable with the dimensions of bio-cells (1-100 nm), for example, bio-transferrable graphene wireless nanosensors. Further, collective data via nano-sensors are being processed and are communal with the other nano-devices. Accordingly, the nanodevices with their miniaturized computational part are being encapsulated in the small tiny box, i.e., nanomachines. Further, numerous nanomachines can be connected via nanorouters to route the measured data to other external or internal devices such as mobile phones. An interconnected cluster of these nanodevices is called a "nanonetwork."

2) Nano routers (NR): The aggregation of all the information collected from nano-machines can be controlled through nano-routers. They acquire large computational power in contrast to nanodes.

3) Nano-Micro interface gadgets: These devices further aggregate the data from all nano-routers and have the responsibility of data accumulation, initiating from nano-switches, and sending it to the microscale machines. These devices function as hybrid gadgets that operate at the nanoscale using nano communication systems, as well as traditional communication systems with established network protocols.

4) Cognitive Nano-Router (CNR): The Cognitive Nano-Router is a more sophisticated component that introduces intelligence into the network. Unlike a standard NR, a CNR can: (i) Spectrum Management: Dynamically adapt its communication parameters (often in the Terahertz (THz) band) to avoid interference and optimize throughput. (ii) Decision Making: Process data from multiple NRs to make high-level routing decisions. (iii) Coordination: Manage the overall traffic flow within a specific nano-network domain before passing it to the gateway.

5) Gateway: It enables the remote control of the entire nano-things network over the Internet. Example: Considering Body Sensor Networks-with the use of a gateway, all the sensor data from the human body can be accessed anywhere and everywhere by doctors over the Internet. The Gateway serves as the bridge between the nanoscale domain and the macroscale world (e.g., the Internet or a local server). It performs protocol translation, converting the specialized communication protocols used by nanomachines into standard protocols like TCP/IP. This allows remote users to monitor and control the nano-network from a macro-scale device, such as a smartphone or a computer.

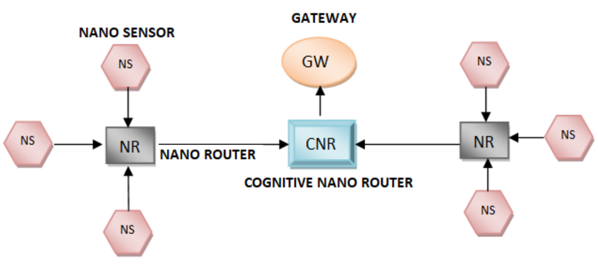

Figure 1: Hierarchical nano-network architecture

3. Evaluation of IoNT to AIoNT

Artificial Intelligence enabled Internet of Nano Things (AIoNT) is an emerging interdisciplinary field that combines nanotechnology, communication networks, and artificial intelligence to develop intelligent nano-scale devices capable of sensing, processing, and exchanging information. In AIoNT, nanosensors and nanodevices operate in coordinated nano-networks to collect highly accurate data from various environments such as healthcare systems, industrial processes, and environmental monitoring. The integration of AI techniques, including machine learning and deep learning, enables these nano-devices to make local decisions, reduce communication overhead, and enhance overall system efficiency. AIoNT extends the capabilities of the traditional Internet of Things (IoT) by embedding intelligence at the nano-scale, supporting advanced applications such as targeted drug delivery, early disease detection, smart materials, and real-time pollution monitoring. However, this technology still faces several challenges, including severe energy limitations, security concerns at the nano-scale, and the need for reliable communication protocols. Despite these challenges, AIoNT holds strong potential for next-generation intelligent systems with high precision, autonomy, and scalability [36-37].

Table: 1 Comparison between IoT, IoNT and AIoNT

Feature	IoT (Internet of Things)	IoNT (Internet of Nano Things)	AIoNT (Artificial Intelligence of Nano Things)
Basic Concept	Network of physical devices connected to internet	Network of nano-scale devices communicating with each other	IoNT integrated with Artificial Intelligence
Device Size	Large to small devices (sensors, appliances, machines)	Nano-scale devices (1-100 nm)	Nano devices + intelligent AI systems
Communication Range	Short to global (via internet)	Extremely short (nano communication, molecular level)	Nano + intelligent long-range decision systems
Technology Used	Sensors, Wi-Fi, cloud computing	Nanotechnology, molecular communication	AI, Machine Learning, Deep Learning + IoNT
Data Processing	Cloud / Edge computing	Very limited processing at nano level	AI-based real-time intelligent processing
Autonomy	Semi-automated	Highly constrained, mostly controlled	Fully autonomous intelligent systems
Energy Requirement	Moderate to high	Extremely low (nano-energy harvesting)	Optimized using AI for efficiency
Applications	Smart home, smart city, healthcare, industry 4.0	Medical nano-robots, environmental monitoring,	Smart healthcare diagnosis, intelligent

		targeted drug delivery	nano-sensors, defense systems
Complexity	Medium	Very high (scientific + nano engineering)	Extremely high (nano + AI integration)
Decision Making	Rule-based / cloud-based	Very limited	Intelligent decision-making using AI

4. Applications of AIoNT

IoNT has great potential in the various fields of applications especially in medical and healthcare system.

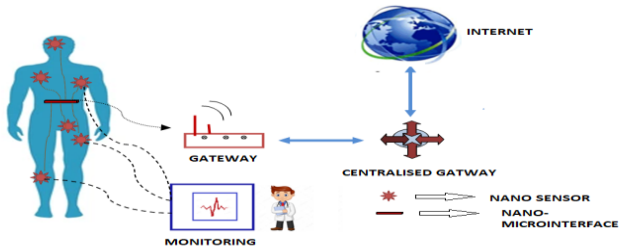

Figure 2: Health monitoring system via IoNT

1) Healthcare: The Internet of Bio-NanoThings represents a paradigm shift in medical applications, where biocompatible nanodevices are integrated into communication networks for novel monitoring and intervention capabilities [18]. This integration allows real-time data acquisition from inside the human body, which facilitates remote diagnostics, targeted drug delivery, and continuous monitoring of health parameters by healthcare providers [19-20]. The capability of this is mainly derived from the application of nanosensors in the human body that continuously monitor important biological information and communicate it to external systems [21]. These nano-networks facilitate precise therapeutic actions within the body, such as localized drug delivery, regenerative tissue engineering, and advanced nanoscale or intracellular surgery [22,16]. Furthermore, the integration of these molecular and nanomachines within a heterogeneous bio-nano-thing paradigm, as part of the comprehensive IoBNT architecture, allows for sophisticated external, distributed, or programmed control of therapeutic and diagnostic interventions, achieving high spatiotemporal resolution [23]. This framework extends beyond the capabilities of individual devices by creating bio-nanonetworks that facilitate data sharing, fusion, and coordinated information processing in biological environments through molecular communication [25-26].

2) **Environmental monitoring**: Through the deployment of nanosensors in various public locations, IoNT facilitates precise and real-time environmental monitoring by detecting chemical compounds released by plants and overall pollution levels [13]. This advanced monitoring extends to tracking car traffic more efficiently and to observing climate change and temperatures with extreme accuracy [28]. Furthermore, nanosensors can detect pathogens and allergens indoors and outdoors, enabling real-time monitoring of air pollutants in concentrated areas and triggering remediation efforts [21]. Beyond atmospheric analysis, IoNT applications also encompass optimizing agricultural practices by monitoring crop conditions and aiding pest management [30]. The IoNT also provides a robust framework for detecting greenhouse gases via over-the-air spectroscopy, thereby contributing to climate change mitigation strategies [31].

3) Agriculture: The integration of the Internet of Nanothings facilitates unprecedented precision in resource management by utilizing nanoscale sensors and actuators to optimize the application of water, fertilizers, and pesticides. Systems enable real-time monitoring of soil nutrient levels and crop health, ensuring that inputs are applied only when and where required to maintain sustainability and cost-effectiveness [29-30]. Beyond resource optimization, these networks also employ smart delivery systems that enable site-specific release of agrochemicals, significantly reducing environmental runoff and the risk of eutrophication [27]. Furthermore, the integration of the Internet of Bio-NanoThings enables the deployment of biosensors and actuators directly within or in close proximity to plant structures to monitor internal chemical signaling and metabolic processes [32]. These advancements extend to livestock management as well, where nanoscale sensors track hormone levels to optimize fertility and health outcomes [16]. Additionally, implementing such networks enables real-time detection of greenhouse gases to mitigate climate-related impacts and enhances continuous monitoring of agricultural yields for quality.

5. Limitation and challenges

IoNT is regarded as the most miniaturized nanosensor network, with significant potential for adoption in real-time applications across diverse fields. Despite numerous advantages, IoNT also faces challenges, including communication routing efficiency, limited processing capacity at the nanoscale, and the imperative to develop robust security frameworks to mitigate data theft and unauthorized system disruption [33]. Furthermore, the vulnerability of these devices to physical tampering remains a primary concern due to their minute dimensions, which complicates the implementation of traditional hardware-level defensive measures [34]. Furthermore, the deployment of large-scale nanonetworks introduces acute scalability challenges, as the cumulative traffic overhead from high node density frequently overwhelms the limited bandwidth capacity of current gateways [13]. Moreover, the lack of standardized communication protocols across heterogeneous nanomaterial architectures complicates seamless interoperability between disparate sensing platforms [35]. Beyond these interoperability issues, the reliance on chemical-based molecular communication requires deeper investigation into signal-propagation stability to ensure reliable data transmission in complex biological or environmental media.

6. Conclusion

The advancement of AI, nanotechnologies and nanomachines, the Internet of Things (IoT), and the Internet of Nano Things (IoNT) will have a significant influence on nearly everything. Every field in the near future. In the near future, researchers are developing AIoNT-based nanomachines for live deployment in a variety of locations. In addition to nanomachines, applications, and research fields, this study presents a thorough analysis of the Internet of Nano Things (IoNT), which is thought to be the next evolutionary step in the field of AI and nanotechnology.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

References

[1] A.P.H.A. (1985). Standard methods for the examination of water and Waste Water (16th ed.). American Public Health Association., Washington DC.

[2] Abdul-Qawy, Antar Shaddad, P. J. Pramod, E. Magesh, and T. Srinivasulu. "The internet of things (iot): An overview." International Journal of Engineering Research and Applications 5, no. 12 (2015): 71-82.

[3] Gubbi, Jayavardhana, Rajkumar Buyya, Slaven Marusic, and Marimuthu Palaniswami. "Internet of Things (IoT): A vision, architectural elements, and future directions." Future generation computer systems 29, no. 7 (2013): 1645-1660.

[4] Dudhe, P. V., N. V. Kadam, R. M. Hushangabade, and M. S. Deshmukh. "Internet of Things (IOT): An overview and its applications." In 2017 International conference on energy, communication, data analytics and soft computing (ICECDS), pp. 2650-2653. IEEE, 2017.

[5] Shah, Sajjad Hussain, and Ilyas Yaqoob. "A survey: Internet of Things (IOT) technologies, applications and challenges." 2016 IEEE Smart Energy Grid Engineering (SEGE) (2016): 381-385.

[6] Popović, Dejana N. Jovanović. "Nanotechnology and the internet of nanothings benefits and risks." Социолошки преглед 57, no. 1 (2023): 124-146.

[7] Naser, Hayder A., Alaa Thaer Lateef, Falah A. Bida, and Mohammed Zorah. "Systematic review of internet of nano things (IoNT) technology: taxonomy, architecture, open challenges, motivation and recommendations." Iraqi Journal of Natural Sciences and Nanotechnology 2 (2021): 7-19.

[8] Anwar, Raja Waseem, Anazida Zainal, Tariq Abdullah, and Saleem Iqbal. "Security threats and challenges to IoT and its applications: a review." In 2020 Fifth international conference on fog and mobile edge computing (FMEC), pp. 301-305. IEEE, 2020.

[9] Ghorbian, Mohsen, Mostafa Ghobaei-Arani, Mohamad Reza Babaei, and Saeid Ghorbian. "Nanotechnology and nanosensors in personalized healthcare: A comprehensive review." Sensing and Bio-Sensing Research 47 (2025): 100740.

[10] Akhtar, Nikhat, and Yusuf Perwej. "The internet of nano things (IoNT) existing state and future Prospects." GSC Advanced Research and Reviews 5, no. 2 (2020): 131-150.

[11] Khaled, Ahmed E., Mohammed Ashfaq, and Sebin Puthenthara Suresh. "E-iot: Emulator to develop and test iot application." In 2022 IEEE 8th World Forum on Internet of Things (WF-IoT), pp. 1-6. IEEE, 2022.

[12] Razdan, Sahshanu, and Sachin Sharma. "Internet of medical things (IoMT): Overview, emerging technologies, and case studies." IETE technical review 39, no. 4 (2022): 775-788.

[13] Cruz Alvarado, Mainor Alberto, and Patricia Bazán. "Understanding the Internet of Nano Things: overview, trends, and challenges." E-Ciencias de la Información 9, no. 1 (2019): 152-182.

[14] Akhtar, Nikhat, and Yusuf Perwej. "The internet of nano things (IoNT) existing state and future Prospects." GSC Advanced Research and Reviews 5, no. 2 (2020): 131-150.

[15] Abadal, Sergi, Chong Han, Vitaly Petrov, Laura Galluccio, Ian F. Akyildiz, and Josep M. Jornet. "Electromagnetic nanonetworks beyond 6G: From wearable and implantable networks to on-chip and quantum communication." IEEE Journal on Selected Areas in Communications 42, no. 8 (2024): 2122-2142.

[16] Kawamoto, Yuichi, Hiroki Nishiyama, Nei Kato, Naoko Yoshimura, and Shinichi Yamamoto. "Internet of things (IoT): Present state and future prospects." IEICE TRANSACTIONS on Information and Systems 97, no. 10 (2014): 2568-2575.

[17] Rajendran, Revathi, and Arthi Kalidasan. "Convergence of AI, ML, and DL for Enabling Smart Intelligence: Artificial

Intelligence, Machine Learning, Deep Learning, Internet of Things." In Challenges and Opportunities for the Convergence of IoT, Big Data, and Cloud Computing, pp. 180-195. IGI Global Scientific Publishing, 2021.

[18] Shah, Sajjad Hussain, and Ilyas Yaqoob. "A survey: Internet of Things (IOT) technologies, applications and challenges." 2016 IEEE Smart Energy Grid Engineering (SEGE) (2016): 381-385.

[19] Chude-Okonkwo, Uche AK, Reza Malekian, and BT Sunil Maharaj. "Molecular communication model for targeted drug delivery in multiple disease sites with diversely expressed enzymes." IEEE transactions on nanobioscience 15, no. 3 (2016): 230-245.

[20] Maitra, Abhishek, and Madhavi Damle. "Revolutionizing plant health management with technological digital transformation to enhance disease control & fortifying plant resilience." In 2024 3rd International Conference for Innovation in Technology (INOCON), pp. 1-8. IEEE, 2024.

[21] Mucchi, Lorenzo, Sara Jayousi, Stefano Caputo, Chiara Barchielli, Marzia Paffetti, Marco Alaimo, Paolo Zoppi et al. "6G technology as enabler of psychophysical well-being & social inclusion services for citizen 4.0." In 2023 IEEE 17th International symposium on medical information and communication technology (ISMICT), pp. 1-6. IEEE, 2023.

[22] Popović, Dejana N. Jovanović. "Nanotechnology and the internet of nanothings benefits and risks." Социолошки преглед 57, no. 1 (2023): 124-146.

[23] Maksimović, Mirjana. "Transforming educational environment through green internet of things (G-IoT)." Trend 2017 23 (2017): 32-35.

[24] Kuscu, Murat, and Bige D. Unluturk. "Internet of bio-nano things: A review of applications, enabling technologies and key challenges." arXiv preprint arXiv:2112.09249 (2021).

[25] Maksimović, Mirjana. "Transforming educational environment through green internet of things (G-IoT)." Trend 2017 23 (2017): 32-35.

[26] Bakhshi, Taimur, and Sidra Zafar. "Hybrid deep learning techniques for securing bioluminescent interfaces in internet of bio nano things." Sensors 23, no. 21 (2023): 8972.

[27] Ince, Ekin, and Murat Kuscu. "Hijacking Living Cells with Surface Engineering for the Internet of Bio-Nano Things." IEEE Internet of Things Journal (2026).

[28] Akhtar, Nikhat, and Yusuf Perwej. "The internet of nano things (IoNT) existing state and future Prospects." GSC Advanced Research and Reviews 5, no. 2 (2020): 131-150.

[29] Naser, Hayder A., Alaa Thaer Lateef, Falah A. Bida, and Mohammed Zorah. "Systematic review of internet of nano things (IoNT) technology: taxonomy, architecture, open challenges, motivation and recommendations." Iraqi Journal of Natural Sciences and Nanotechnology 2 (2021): 7-19.

[30] Popović, Dejana N. Jovanović. "Nanotechnology and the internet of nanothings benefits and risks." Социолошки преглед 57, no. 1 (2023): 124-146.

[31] Mallick, Bhaskar, Zisan Ahamed, and Prashanta Kumar Mitra. "Integration of Nanobiosensors with IoT for real-time environmental monitoring and data analytics." In Plant-microbe interaction under xenobiotic exposure, pp. 661-683. Singapore: Springer Nature Singapore, 2025.

[32] Abadal, Sergi, Chong Han, Vitaly Petrov, Laura Galluccio, Ian F. Akyildiz, and Josep M. Jornet. "Electromagnetic nanonetworks beyond 6G: From wearable and implantable networks to on-chip and quantum communication." IEEE Journal on Selected Areas in Communications 42, no. 8 (2024): 2122-2142.

[33] Babar, Adil Z., and Ozgur B. Akan. "Sustainable and precision agriculture with the internet of everything (IoE)." arXiv preprint arXiv:2404.06341 (2024).

[34] Cruz Alvarado, Mainor Alberto, and Patricia Bazán. "Understanding the Internet of Nano Things: overview, trends, and challenges." E-Ciencias de la Información 9, no. 1 (2019): 152-182.

[35] Alabdulatif, Abdullah, and Navod Neranjan Thilakarathne. "Bio-inspired internet of things: current status, benefits, challenges, and future directions." Biomimetics 8, no. 4 (2023): 373.

[36] Akan, Ozgur B., Ergin Dinc, Murat Kuscu, Oktay Cetinkaya, and Bilgesu A. Bilgin. "Internet of Everything (IoE)-from molecules to the universe." IEEE Communications Magazine 61, no. 10 (2023): 122-128.

[37] Sanjalawe, Yousef, Salam Fraihat, Salam Al-E'mari, and Sharif Naser Makhadmeh. "A review of artificial intelligence-based intrusion detection in industrial internet of things." Discover Internet of Things (2026).

[38] Ibrahim, Hassan M. "Artificial Intelligence (AI) and Internet of Things (IoT) Applications in Smart Cities: Literature Review." Iraqi Journal for Computers and Informatics 52, no. 1 (2026): 35-53.