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Internet of Nano Things: Next Step for Future of Nanotechnology

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Abstract: The arrival of the internet of things has transformed the day to day functionality of each life's intensely. Internet of things has provided countless new opportunity to create a powerful industrialized structure and many more. Several IoT applications have been implemented and deployed in the modern years. As the research currently going on in the field of IoT. Nanotechnology has taken essential steps to get linked with Internet of Things that may perhaps take energy efficiency, medications and many various subdivisions to entire new dimension. Nanotechnology offers the latest solutions for not just a particular application, but for numerous applications such as observing of health, smart cities, military, farming, environmental monitoring and other industries. The correlation of nano scale gadgets and nano sensors with standard network and eventually with the internet terms a new networking model called as Internet of Nano Things which is also known as IoNT. The core point of this paper is to provide a brief knowledge on IoNT and overview of nanotechnology, Applications areas and issues/challenges to create awareness of internet of nano thing among researchers so that existing and upcoming challenges can be resolved and new applications related to IoNT can be found in the near future.

Keywords: Internet of Things, Internet of Nano Things, Nanotechnology, Nano sensors.

I. INTRODUCTION

In the upcoming years the evolution that is going to occur in the areas of computing will be entirely beyond the dominion of out-of-date work station. Various new technologies are forthcoming to improve and solve as many issues as they can such as security, energy sustainability, privacy and so on. In addition, the advancement of technologies, many devices are now being used to make our life's stress free in offices, business, schools, colleges, universities, homes, factories, manufacturing and many more other places where there is a need of technologies [1]. It is estimated that the number of associated gadgets not in millions, but billions of devices will be increasing at the swiftest pace in the impending years. Internet of things (IoT) is one of the most existing research areas that have open the gateway to many applications in different field. The concept of the internet of things was familiarized by Kevin Ashton in the year 1999. The term IOT includes every device is linked to the internet [2]. When we say about IoT we say that the physical object's such as mobiles, computers, laptops, smart watches and much more will be associated with the internet not just to transfer the data and information but also to control, monitor, detect, sense and much more. The idea of IoT has gained the attention of numerous researchers, industrialist, enterprise, scientist that they have done and currently making so much progress in the field of IoT and implementing countless applications such as e-health, smart automobiles, smart home, smart waste system and soon that new domains have come up in front. One of the domain name is an Internet of Nano Things (IoNT). The IoNT is increasing fast, prominently improving the mighty IoT. IoNT can be defined as the interconnectivity of microscopic devices extending from one to an insufficient hundred nanometers that can access the internet and other communication networks. The conception of Internet of Nano things was led by Ian Akyildiz and Josep Jornet [3]. It provides the know-hows for intercommunication among nano devices for gathering of data, distribution and processing with end-users. Internet of Nano things has found numerous applications in different industries such as in healthcare, manufacturing, transportation and logistics, utilities and energy, television and entertaining, trade and other services. IoNT will expose innovative opportunities of exploration in the range of Nano sensor, Nano communication and Nano gadgets [4].

In this paper the main purpose is to give awareness on Internet of Nano things, its applications, challenges and evolution of nanotechnology for young researchers, undergraduates, postgraduates, faculty members and those who want to pursue their research in the field of Nano Technology.

II. EVOLUTION OF NANOTECHNOLOGY

Thoughts and dreams of a person sometimes give rise to new science and technology. From that dream and imaginations, a new field was born which is known as Nanotechnology, a 21st century Frontline. The first ever concept of nanotechnology was presented on 29 December 1959 by Richards Feynman in his renowned speech titled" There's Plenty room at the Bottom" at the California Institute of Technology (Caltech) [5]. In this speech he described a procedure in which the researchers would have the capacity to control and manipulate the singular atoms and molecules. Almost after 15 years after Feynman's lecture, in the year 1974, the Japanese Scientist /professor of Tokyo university of Science named Norio Taniguchi coined the term Nanotechnology. He stated "Nanotechnology primarily comprises of the handling, division, merging and distortion of material by one atom or more molecules. But , the term was not used again until in the year 1981, when Eric Drexler, who published his first paper on nanotechnology did not have knowledge about the taniguchi's previous use of the term [6]. In 1980, K. Eric Drexler presented the notion of nanotechnology as deterministic, somewhat than stochastic, handling of separate atom and molecules was theoretically examined in deepness by K. Eric Drexler, who indorsed the scientific prominence of nano scale spectacles and devices through his speeches and two influential books [7]. In a time period around 50 years, nanotechnology has turned into the founding for noteworthy industrial applications and exponential enhancement. In the present day, nanotechnology is an interdisciplinary field including issues of accuracy mechanics, gadgets, applied physics, physics, chemistry, electromechanical frameworks as well as the utilization of Bioengineering and biomedicine for quality treatment or medication application. Nanotechnology has open better approaches for desired goals. For that, both engineers and scientists use dissimilar procedure and apparatuses. Moreover, Countless money has been submitted. Innovative work in nanotechnology is probably going to change the conventional practices of strategy, investigation and manufacturing for an extensive variety of engineering products. In addition, Governmental bodies, industries and universities must take steps up with regards to allot extra funds towards advancement in the area of nanotechnology.

III. MARKET OF INTERNET OF NANO THINGS

According to various market reports, in the year 2017 the IoNT was esteemed at USD 6.24 billion and is anticipated to extend a worth of USD 22.04 billion by the year 2023, rising at a CAGR of 22.81% throughout the estimate period (2018-2023) [8].

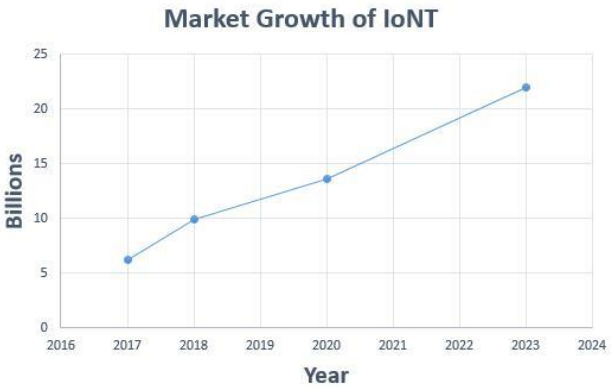

Fig. 1 Estimated Evolution of IoNT

In the previous era, the nanotechnology market has observed the rapid growth. Since the development of nanotechnology, it has provided effective and efficient solutions to a wide scope of applications in biomedical, farming, business and soldierly applications. The IoNT organization can be arranged by combining nano devices, nano sensor and additional various machineries such as Internet of Things, Sensor network, Cloud computing, Fog computing and much more etc. In the year 2017 the market of nano sensor was valued at USD 133.69 million and is expected to be USD 4,621.71 million by 2023, at compound annual growth rate (CAGR) of 79.83%, over the prediction period (2018-2023).

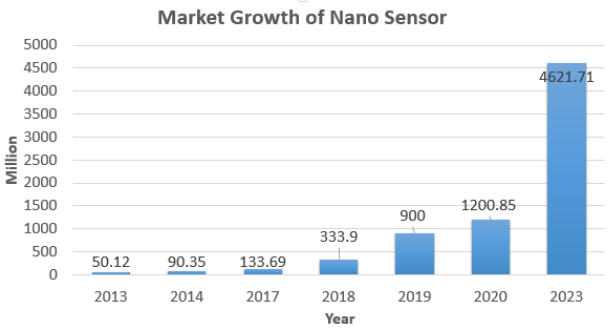

Fig. 2 Predictable Advancement of Nano Sensor

With the enormous market of Internet of nano things it is a surety that this innovative technology will construct a big impact in the innumerable fields. Following are the major player in the Internet of Nano things market

such as an e-Intel Corporation, Cisco Systems Inc., Qualcomm Incorporated, Juniper Networks and IBM Corporation in U.S., Schneider Electric and Alcatel-Lucent S.A. In France, and SAP S.E. and Siemens AG in Germany, between others. According to BCC Nanotechnology report, the worldwide market of nanotechnology products was esteemed at 22.9 billion in the year 2013 and has increased in the year 2014 about 26 billion [9]. The report expects that the market of nanotechnology is likely to grasp about 64.2 billion by the year 2019 and a CAGR of 19.8% from 2014 to 2019 [10].

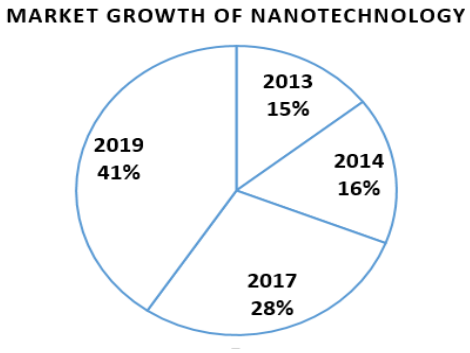

Fig. 3 Foreseeable Innovation of Nanotechnology

The inclusive market for nano material is likely to upsurge from approximately $20.6 billion in 2014 to $52.7 billion by 2019, a CAGR of 20.7% from 2014 to 2019. Overall nano tools sales are anticipated to rise from $5.3 billion in 2014 and about $11.3 billion in 2019, a CAGR of 16.2% from 2014 to 2019.

IV. NETWORK ARCHITECTURE OF INTERNET OF NANO THINGS

Internet of nano things is getting up the stride in various fields. It is estimated that the market of IoNT is to grow in the upcoming future. Nano sensor of Internet of Nano things are associated with physical objects to process, gather and share information with consumers. Nonetheless, new network architectures need to develop due to the interconnection of nano machines with existing communication methods. Following below are the four mechanisms of the IoNT architectures [11].

A. NANO NODES

Nano nodes are the nano devices like sensors or actuators which can be installed in the person's body or in any physical network space to gather the information. These kinds of nodes is considered to be the minutest and simplest nano machines due to having finite energy, low memory and limited communication competences due to which they can only transmit over very short distances and abilities to accomplish simple task. These nodes such as Bio sensor, DNA sensor and Body Sensor Network can be include inside any person's body. Furthermore, they can be adjusted in different sorts of things such as books, pens, gates and so on [12].

B. NANO ROUTER

Size of nano router is bigger than the Nano nodes and acquiring more assets. Nano routers are convenient for compiling and acquiring information that is coming from the nano sensors. Moreover, nano router also plays a vital part in monitoring nano nodes by interaction control instructions.

C. NANO-MICRO INTERFACE DEVICES

These nano-micro interface gadgets used to gather and route the data coming from different nano routers to transport it to the micro scale area and vice versa. Nano-Micro Interface devices are also hypothetical to be hybrid devices. These hybrid devices capable to convey in the nano scale using nano communication methods and also with long-established communication network with conventional network protocols [13].

D. GATEWAY

Gateways are micro scales gadgets that permit the distant control of the whole system. These devices can obtain and forward the data inside the network

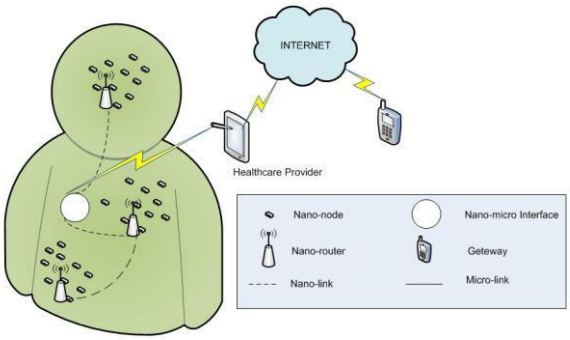

Fig. 4 Architecture of internet of nano things

V. INTERNET OF NANO THINGS APPLICATIONS

There is no doubt that IoNT will make a gigantic impact

on the nanotechnology businesses. Internet of Nano things has countless applications such as Oil and Gas, Armed, Farming, Smart Cities, Healthcare and many more etc. In this section, we have described only the major applications of IoNT which can improve the nanotechnology benefits in many fields [14].

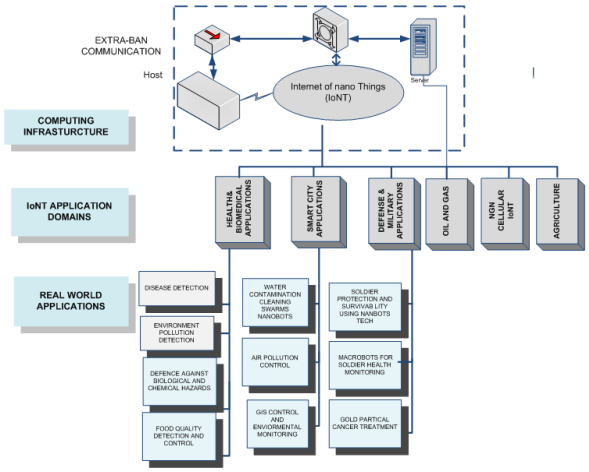

Fig. 5 Classification and Applications of IoNT

A. OIL AND GAS

By using the nano sensor we can increase the repossession rate of the oil. Nano sensor can travel through the holes of the rock and benefit us to discover the oil bounded to the rocks. However, there is a cross well imaging and seismic tool which has more impact to this area, but the firmness provided by them is very low. In Internet of Nano things, nano sensor cooperates and interconnect with each other by molecular communication. Furthermore, the collection of information can be transported in actual time using the neighboring gateway. Due to which the oil position can be efficiently plotted without needing an exact magnetic source and receiver.

B. AGRICULTURE

Farming has always been providing the food for humans and animal directly or indirectly. Due to increasing of world population, it has become the necessity for improving the quality of food that is produced by Farmers. With the assistance of IoNT, we can improve the productivity of agriculture and can develop numerous accuracy farming applications. For example, Nano sensors and nano based intelligent distribution schemes could assist in the effective usage of agricultural natural resources such as water, vitamin and biochemical through precision farming. Furthermore, there are many kinds of nano particles that have proven its efficiency in management of pests. Controlling of the fungus on plants can be done by usage of nano particles. Moreover, Nano sensor can be spread into the field to monitor and identify the sign of plant virus so that data can be collected and transmitted to agriculturalists to check the status of the plant. In momentary, IoNT can facilitate precision agribusiness that uses the facilities of satellite communication, geographic information systems (GIS), and remote detecting to increase the productivity and competence of the agriculture.

C. SMART CITIES

Implementation of a smart city provides an interaction and communication with the home appliances, monitoring sensors, observation cameras, actuators, buses, cars and others. The roadmap for the smart urban be contingent on topographical surroundings and persons routines. The communication technologies can be used by anyone, regardless of their financial situations. Execution of smart cities has previously been done with the assist of Internet of Things. Furthermore, with the aid of internet of Nano things. We can use nano sensor to monitor and recognize the location of litter discovered in the air in high absorption and trigger nano sensors to clean up that exact position. Moreover, with the assist of the innumerable amount of nano sensors, we can use to collect an enormous quantity of information in real time to improve the quality of life and offer new facilities and applications [15].

D. ENVIRONMENTAL MONITORING

In numerous metropolitan urban communities around the globe the air contamination is the key component that must not would be disregarded in city urban making arrangements for the well-being and security of a native's life. In the event that this factor would not control or observed speedily, it can cause ascend in death rate or sicknesses. One of late occasion in the Lahore city which would cause an entire city covert by a Dark condense haze was likewise caused by an increment in air contamination rate in the city. Hence, in this area, the two kinds of condition sensor are being utilized:

- Analytical sensor (GC,UV)
- Gas Sensors (solid state gas sensor)

The practical example of Environmental Gas sensors is 'solid state gas sensor' which are commonly used due to

its rigidity and easy process control, mass production and continuous measurement. This Air pollution Monitoring system can be developed by using GIS based server and client communication system which can correspond with different locations and zones across the city. Inside each zone a site is nano sensor node is located which determine its zone air quality and subsequent reporting and assessment to the server via GIS based system [16].

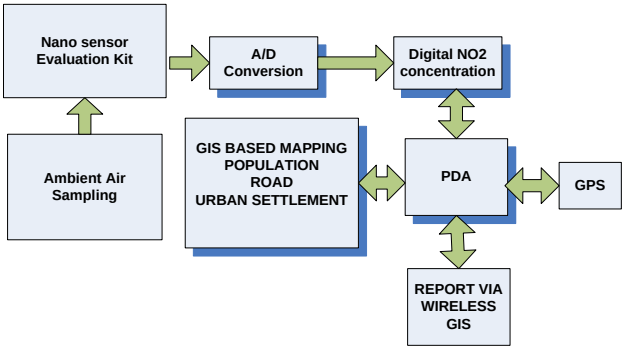

Fig. 6 Environmental Control using IoNT

E. MILITARY/AEROSPACE

After bridging several decades, low-weight, elite polymeric materials and composites like carbon nano fibers, nano-Al2O3, nano-TiO2, poly (methyl metha crylate), polyethylene, poly (vinyl alcohol) etc have now reformed propelled business in military/aerospace developments. Polymers keep on supplanting heavier metals and metallic amalgams and new advancements run from biomaterials and electro-optical gadgets to interchange vitality sources and nanotechnology. Having said that, the Fundamentals of engineering and sciences are likewise empowering to build erodes opposition, compound specialist obstruction, more durable glues, and self-fixing novelties for military aerospace and weapon industry. For light weight individual reinforcement and vehicle insurance, thicker multilayered anti ballistics materials are being created incorporating multifunctional defensive coatings with multilayer structures. Presently, the research is being focused in low volume and light mass nano fibers based defensive polymer thin films, also include some highly robust, anti-reflective, passive Nano sensors chemical coatings that are precisely developed with controlled linear as well as nonlinear immersing properties. Whereas, work on evaluating the ballistic execution of multilayered composites polymer will be started soon [17].

In addition, the Scientists and Researchers offer a remarkable interdisciplinary research concentrated on giving polymeric materials-based resolution for lightweight Army smart uniforms frameworks with expanded usefulness & ballistic defense security. Moreover, for aerospace domain RCS (Radar cross section) avoidance based anti-electromagnetic nano composites polymer coating provides improvised stealth and enhanced unwavering quality in the aerial battlefield.

F. MEDICAL AND HEALTH CARE

By the evolution of Nano medicines, drugs will make their own particular manner through the body and assault unequivocally the ailing cells on achieving their goal. In the field of Nano MEDs, a multi-disciplinary activity is required for growing new innovations for regenerative drug and treating human sicknesses that include mechanical malfunction, for example, cancer. There was a research states that each cell consists of organelles structured within a cell that performs specific functions. When these small nano scale motors are powered with a high ultrasonic wave, they begin to crash into the organelle the Nano motors can act as a bleeder, to essentially homogenize the cell's content or they can act as battering ramps to actually puncture the cell's memory. That being said, this revolution will mean that these nano bots will be able to go into the membrane of a virus or disease and annihilate it from the inside out. This research also shows that the nano bots can assemble in a straight line when powered they can spin cells in a fast rotating spin and assemble the cells in a roll as well [18].

In this regard, Scientists have also been learning about magnetic fields and using magnetism theory to move these things.

Similarly, for stimulating sampling and monitoring immunity, it’s promising both using nanotechnology. To accomplish these novel facts micro needle patch biopsies approaches to sample local immune cells from local tissue sites single-cell. Nano well micro engraves technology to analyze in detail the functional status of recovering live immune cell this will be done with use of nano bot’s technology.

Other Nano structured bio matters for treatment of hemorrhagic shock is based on creating a hemo static gel that is now structured and will stop blood flow and reduce subsequent leading cause of death for the soldiers after penetrating injury on the field [19].

. G. FOOD PACKAGING

About intelligent packaging the exploration in nanotechnology field has risen steeply over the previous period and there are several corporations which are focusing in the creation of new forms of nano sized substance. However, one industry which is flow to catch on to this is the food industry and this is not surprising as the public reference for natural food products has historically inhibited the implementation of emerging food technologies and indisputably the most active area of food nano science investigation and expansion is wrapping. After introducing nanomaterial compounds like SiO2, TiO2 and KMnO4 the food packaging sealing can be enhanced greatly. Another way is to make nanostructured packing's a nano material can be functional on to the packaged surface or can be unified as a lambda nano composite layer. The main advantage of this is the reduction in material usage and simpler film conversion processes metal oxide-based coatings can be used on both biodegradable and non-biodegradable polymers, exhibiting antimicrobial and barrier properties to it. Under the intelligent packaging systems, innovative methods like intelligent acts such as oxygen indicators, time, temperature, humidity indicators, freshness indicator, etc., are used the indicator or sensor interacts with the internal factors that is food components or external environmental factors and a response is generated. Nano sensors can be utilized for identifying and report the food condition, quality and verification of reports like travel papers. To maintain smooth operation a message to the operator is sent to alarm the food storage and environments indicators to avoid item expiry [20].

H. HIGH SPEED DATA TRANSFER/CELLULAR

In telecommunication domain, IoNT incorporated electromagnetic wave nature properties for Pico and Femto cells based networking over Terahertz band (0.1THz – 10THz), for correspondence among sensors. Due to matters of fact that, THz based frequencies have higher capacity and transmission rate available, it can exchange rapid information and can be made conceivable by incorporating Nano gadgets in the cutting edge cell systems and military related applications [21].

I. GENERALIZED APPLICATIONS

In a large portion of the ventures, nano proximity sensor identification tags are utilized to identify and record the parts information. They require vicinity of the source to transmit its identification. Nano sensors are making the detecting bit of the control circle more successful in mechanical machines. By Nano sensors application, any Management Information system (MIS) database can be updated in real-time manner covering all information regarding the item over which it is applied [22]. Any unexpected action will activate an alert about the creation line administrator's close to home gadget. With IoNT wherever bringing considerations enthusiastically will be simple. Machines or gadgets present anyplace can be directed with a nerve action produced in mind making another type of Man-Machine thinking paradigm, Man to machine telepathy [23].

VI. SECURITY OF IONT

The Internet of Nano Things is spreading fast and greatly enhancing the might of internet of thing. Every technology security is the most problematic issues [24]. In the Internet of Nano thing the security plays a significant role in providing secure and accurate communication environment amongst nano devices in nano networks. Nano networks contain of nano devices that interconnect with each other to exchange information [25]. Various Attackers can exploit the vulnerabilities and weakness in the nano network so that they can perform malicious actions. This is due to the current security methods and tool are not suitable for the nano device that are present in the nano network and the nano devices works on terahertz band physical layer. It is compulsory to develop different security solutions in order to protect the infrastructure of IoNT [26]. Following are the suggested solution for protecting the IoNT infrastructure [27]: -

- Checking the data integrity by using checksum algorithms
- Using of encryption algorithms to encrypt the information when transferring among nano devices
- Use of hiding algorithms to conceal the critical data from unauthorized users.

Moreover, healthcare is the one of the essential sources of IoNT data. All the medical information related to the patience should be protected from unauthorized use so that peoples' lives could not be in danger. It is necessary to ensure that the sensitive data coming from the patience, personal health monitoring device should be handled carefully [28].

VII. CHALLENGES/ISSUES

Internet of Nano Things is considered as the utmost scaled down nano sensor systems having the enormous ability to be adopted in actual time application in different numerous fields. Scientist and researcher all around the world have started to shrink microns and millimeter sensor in size of nanometer scales. The main purpose of turning hand size technologies small enough so that they can circulate within human bodies to detect sickness accurately and urgently and also to combination directly with manufacture materials. Likewise, IoNT has numerous advantages in many areas such as medical, energy, farming, manufacturing and many more. However, every technology come with disadvantages. Internet of nano things also has some problems and objections that need to be resolved so that IoNT can get interaction with the business sector, education sector and many other sectors without any difficulties. The major challenges that need to be checked by working agency on nano have to face because of this transition from macro to nano are unavoidable. The combination of all electronic pieces into a solo nano device for the usage of recognition and communication of the signal is the major obstacle. In addition, security and privacy have always been one of the biggest challenges and unsettled concerns not in IoNT but as well in every technology. However, these nano gadgets can be toxic which can be leading to even greater problems [29].

Furthermore, besides working on different applications and expansion of nanotechnology based IoNT devices, new security and secrecy instruments needs to be talked with regard to the information being gathered by nano sensor. In addition to security, the IoNT also requires overcoming of several practical hindrance, such as obtaining reliable high-speed radio communication networks.

VIII. CONCLUSION

Nanotechnology is an evolving science with extensive applications and potential benefits. The nanotechnology predicts a world in which innovative products are designed at the microscopic and molecular level; deliver accurate, cost effective method for sturdy renewable energy sources and keeping the atmosphere clean. Various researchers, scientists and engineers all round the world in the field of nanotechnology are discovering new techniques to use nanotechnology for the benefit of the world. Nanotechnology has several applications with medicines, electronics, food, solar cells, batteries, chemical sensors, Environment and many more. Moreover, the most momentous benefit of nanotechnology is expected in medical and healthcare sectors where it can show frequent advantages. The expansion of nano machines with communication capabilities and interconnection with nano scale device will allow the idea of Internet of Nano Things. In the upcoming future the expansion of nano machines, nanotechnologies, nano devices, nano sensors, IoT and IoNT will have a huge impact in nearly all the fields of science and engineering which will be helpful for the entire world. In this paper, we explained the depth review with regards of IoNT and overview of Nanotechnology. In addition, we also enlightened the major application and challenges of IoNT.

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