Internet of Bio-Nano Things for Diabetes Telemedicine System with Secured Access

Abstract - *Internet of Bio-Nano Things (IoBNT) is the network of bio-nano devices and bio-nano nodes that are ingested into the human body to sense and transmit data from the human body for further processing. IoBNT deals with various issues such as whether the designated cells would be able to interact with smart devices or not and also aid in the processing of the data collected. This requires studying in detail the IoBNT and also developing healthcare applications that can fully utilize the benefits of IoBNT - also referred to as nanomedicine. Further, with the advent of Telemedicine, it becomes imperative to combine the benefits of IoBNT and Telemedicine. The usage of IoBNT begins with the injectable design of the BNT implants that have the ability to recognize biochemical data from the bodies of humans and subsequently transmit the collected data to the wearable port outside the human body. This paper presents a study IoBNT architecture with its components. It also discusses the utilization of bio-nano devices and bio-nano nodes for collecting real-time data when ingested into the human body. In this paper, a model has been proposed for remotely monitoring Diabetes in patients through IoBNT. The proposed Diabetic Telemedicine system will sense patients' vitals via IoBNT and will transmit to internet-based nanomedicine servers where they will be accessible to different stakeholders through secured access. This proposed model promotes remote intrusive ways to investigate Diabetes through IoBNT.*

***Keywords*— Internet of Bio-Nano Things (IoBNT), biochemical data, Bio-Nano devices, Bio-Nano nodes, Diabetes, Telemedicine.**

I. INTRODUCTION

The advancements in the area of nanotechnology, biotechnology and materials science have resulted in the improvements of Internet of Things (IoT) applications. The interaction of Nano biosensors, Nano materials and Nano implants with present IoT networks has promoted the idea of Internet of Nano Things (IoNT), Internet of Ingestible Things. (IoIT), Internet of Bio-Nano Things (IoBNT) and Internet of Biodegradable Things (IoBDT). [1] In order to improvise prevailing technologies and to launch completely novel applications, there has been a growing interest in these upcoming years related to applications utilizing nanotechnology ideas and tools. The basic idea of nanotechnology is the deceptive power of things at the cellular level. The use of bio-nanotechnology considered in the current research trends as IoBNT, that encompasses IoNT by means of embedded biological substances. IoBNT is seen as a varied network of Nano bio-devices, identified as Bio-Nano Things (BNTs), linked through unconventional means like molecular communications (MC), in progressive systems, such as the internal body of humans. The goal of this upcoming networking framework is to permit direct and continuous communication with biological systems for exact measurement and control of their dynamics which will be done in real time. This strong connection amid the bio domain and cyber world with the highest unprecedented localization is assumed to unlock many opportunities to establish new programs, mainly in the area of health care, like ongoing physical health monitoring.[2] Advanced methods of treatment and diagnosis of diseases with nanotechnology guarantees to develop a new era of healthcare. Applying IoT concepts to the nanoscale grant to the efficient health monitoring which results in suitable and prompt actions.[3] Current diagnostic techniques are most of the times based on the culture of microorganisms that cause infections found insamples that are collected from patients or making use of polymerase chain reaction (PCR) which requires the use of heating as well as cooling of large samples along with the reagents to obtain enzymatic reactions in order to recognize micro-cell formation. The IoBNT architecture is different from prevailing technologies by allowing regular disease monitoring by implanting nanoscale sensors or nodes that detect interaction between contagious micro-organisms inside the human body. After that, such sensors report to a wearable port that transmitsthe collected data to health care staff. Therefore, the patient need not to go to the medical lab for testing and diseases can bediagnosed timely, and informing patients to gain medical counselling. By this, the premature death risk of patients can beminimized. [4]

The architecture of IoBNT includes following components:

- **Bio-Nano nodes** are the simplest and smallest part of the IoBNT configuration which can carry out activities like transmitting data, broadcasting, and performing basic calculations. They are responsible for all the sensing required for this setup. Their size limits their data transmitting capabilities and have an internal memory that is small in size. They are able to transfer the data collected to a nano router and these nodes are placed inside the human body itself.
- **Bio-cyber port** is a cross tool which changes the bio-chemical signals taken from internal body nanonetworks into electric signals in order to get computed by theexterior network.
- **Nano routers** are more progressive structures as compared to nano-nodes when it comes to storage and computing. They collect data from nano nodes and monitor the nano node with basic control instructions. Due to their bigger size, they have a larger computational power and act as the aggregator for all surrounding nano nodes. They send their data to the nano-micro interface.
- **Nano micro interfaces** are combination devices which

are able to connect all the data received from nano-routers and then send it across to the gateways using nano communicating techniques as well as the classical network protocol.

- **Gateways** are responsible for controlling the full setup and they allow the data collected to be accessed anywhere using the internet.
- **Application definite servers** may be used in some applications for the examination, storage and instantaneous controlling of data from nano networks. [5]

In section II, the related work supporting our ideology is presented. In section III, the proposed model of IoBNT in Diabetic Telemedicine System is briefed followed by explanation of various phases of the projected model and authentication procedures for accessing the patient's data. Then, in section IV, the paper is concluded and some further work is suggested along with the benefits of using the proposed model.

II. Related Work

Many of the world's current problems can be resolved through manufacturing using nanotechnology. A more plausible assumption is that nanotechnology will affect every element of existence. Nanomedicine has several uses, including the creation of innovative imaging and diagnostic tools, stronger medications, and drug delivery systems.[6] Nanotechnology offers a wide range of uses in the medical field, including the creation of innovative diagnostic and imaging tools, stronger medications, and innovative implantable devices and drug delivery systems.[7] Nanomedicine are being used in drug delivery systems that use nanotechnology. Nano sensors are being employed in healthcare implementation of nanotechnology monitoring applications for healthcare, where they can track most conditions, including blood lipids, pressure, sugar, and temperature.[8] As part of the ecosystem for timed medication delivery, the updated nano-scale sensors are now capable of monitoring a number of physical and biological variables, including wound healing and the level of hormones present in the human body.[9] A fresh and contemporary component of IOT is the Internet of Nano Things (IoNT). Healthcare has been consistently impacted by IoNT and has undergone significant change as a result, which has helped to improve outcomes.[10] It has numerous applications in a variety of industries, including agriculture and food, environmental conservation, energy and healthcare, and these are already relying heavily on IoNT.[10] The technologies of utmost importance which are used in Nano communication networks have been recognized, along with the structure of the IoNT as well as the advantages of each component. The Internet of Nanoscale Things (IoNT) has two subfields: the Multimedia Internet of Nanoscale Things (IoMNT) and the Internet of Nanoscale Bio-Things (IoBNT). Both entails establishing connections between nanodevices and existing communication networks. The architectures of the IoNT network are influenced by the application domain and its distinctive features. The IoNT network's design is made up of four key elements (as shown in Fig. 1): -

- Nano nodes
- Nano routers
- Nano Micro Interface Devices
- Gateway

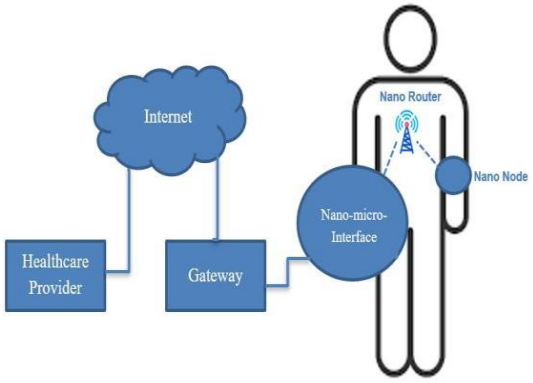

Fig.1 IoNT Architecture Components

The drug delivery systems incorporating nanotechnology are designed to offer non-invasive drug administration methods while also increasing the bioavailability and pharmacokinetics of medications. Beyond the delivery of drugs, it is crucial for a swarm of nano or microdevices to work together in unison which is implemented in the heavy industry and defense applications of the future to accomplish precise embedded sensing and actuation.[11] Liposomes, nanosuspensions, carbon nanotubes and inorganic nanoparticles are some of the specific areas of drug delivery methods using nanomaterials that are currently being developed. Realizing essential elements of the IoNT and IoBNT paradigms and enabling nanoscale communications will usher in a new era of nanomedicine. [12] A Targeted Drug Delivery (TDD) is a specific type of delivery system where the drug is only given to the site where the action or the absorption would take place and not to the target organs, cells or even the tissues.[13] An existing biological system or biochemical molecules serve as the basis for a nanodevice's design. These nanodevices can be utilized for illness detection, monitoring, and treatment, as well as analytical and imaging tools. Other than this some of the other areas of utilizations include biochemical sensors which is used in monitoring and tissue engineering which is used in tissue repair as well as reengineering.[14]. A heterogeneous network of Bio-Nano Things (BNTs), or nanoscale and biological devices, is IoBNT as previously mentioned. [7] IoBNT would be able to elevate connectivity as well as control over unconventional domains (like the human body) with unheard of spatio-temporal resolution. This would enable a new revolution of applications, particularly in the healthcare sector which involves intra-body health monitoring that is continuous in nature and on top of that theragnostic systems which involve single molecular precision.[15] The nervous system which is made up of a network at a large scale comprising of neurons connected with the help of neuro-spike and synapse communication channels, is the most sophisticated and complicated human body network.

The cardiovascular system and the endocrine system are two networks that are present throughout the body but carry information at a time scale which is slower as compared to the electrochemical pulses of nervous nanonetworks. Both of these systems are made up of vessels that transport molecules that carries information in the form of blood as well as the lymph. [16] One of the biggest issues based on IoBNT technology is the issue of security and privacy during the usage of this technology, which has many sensitive applications as well as its work outside the human body. As a result, there is a greater requirement for safety to protect people and property due to the sensitivity of the information transmitted by this technology. Because IoBNT operates inside terahertz bounds, additional security measures that are compatible with this technology are required to avoid data theft and user damage. Attempts to prevent therapeutic injection techniques, data theft, and changing linkages present in nano communication levels or a BAN gateway are some of the biggest security risks. [17]

III. Proposed Model for IOBNT

The IoBNT defines Bio-Nano Things as basic structural and functional elements which interact and perform in a biological environment. It is seen that BNT would perform tasks and actions similar to those of Internet of Thingsintegrated with computer devices, including sensing, processing, and communication with other Bio-Nano things. These Bio-Nano things are created using synthetic biology andnanotechnology and are generated from biological cells. Thesebio-nano devices are based on living cells which are part of the particular sub-structure of bio-nano objects because biochemicals, molecules, or existing biological systems must be used to create them. In the proposed model, we provide system for diabetes remote monitoring. Diabetes is an amalgamation of metabolic illnesses that is characterized by high levels of sugar or glucose in the blood. The medical community refers to this persistent and common disease as diabetes mellitus. According to one of the many definitions for this condition that have been established,it has been described as "a metabolic illness with many etiologists that is defined by chronic hyperglycemia and abnormalities in the metabolism of proteins, lipids, and carbohydrates because of errors in insulin secretion and/or action." Fig. 2 shows the proposed model of Internet of Bio-Nano things for Diabetes Telemedicine System. It illustrates the interconnection process that takes place between the different parts of a network of this type. The Nano nodes are joined via Nanonetworks to enable the collection of vital data in challenging locations. Nano nodes present in the human body can collect and send signals to one another using the bio-cyber port that converts bio-chemical signals to electric signals that carry important information for the continuous monitoring of blood glucose levels. To do their tasks, these components analyse blood glucose levels, process and transmit data from the bio-cyber port to the nano router which acts as an aggregator for all nano nodes. The nano router sends all the information to the nano micro interfaces which in turn acts as an aggregator for all the nano routers. This information gets passed onto conventional-sized devices, using the gateway and convey alerts to the users about potential problems or changes in the situation. Nanomedicine, one of the branches of nanotechnology, offers the possibility of identifying and monitoring illnesses at the cellular and molecular levels. Providing diagnostic, preventative, and therapeutic tools for diseases that are difficult to control, diabetes, kidney failure, cancer and the development of HIV contagion, is the main objective in this scenario. Diabetes Telemedicine System is a communication tool between patients, internet-based servers for nanomedicine,and healthcare providers. In this system, a nano biosensor aidspatients in gathering their capillary glucose, blood pressure, and other physiological data. The sensor continuously monitors the blood glucose levels and the information is sent to the server. The model requires security since data from a body sensor contains sensitive and private information. We also implement an authentication process so that the server and sensor may establish mutual trust.

The goal of the authentication approach is to enable patients to access medical services from home. In this approach, patients' illnesses are monitored remotely and prescriptions and suggestions are given to patients based on symptom intensity, age, and location. This model has a central cloud-based telemedicine server, telemedicine service providers, andpatients (or users). Patients can easily access medical services using their internet-connected mobile devices (phones, laptops, etc.). Telemedicine service providers are doctors, medical teams, clinics, or hospitals anywhere.

3.1 Registration phase:

- *Patient registration:*

Patients can use mobile devices. Registration requires entering an ID, password, name, and address, date of birth and phone number. This data is masked for security reasons before being sent to the server. The server uses the OTP to verify the user, checks the database and registers the user if the ID received does not already exist in the server database.

- *Healthcare provider registration:*

Telemedicine service provider registration is done through a secure channel, verified and provided with an ID and password. After registration, telemedicine service providers can use the ID and password provided to log in, see patients, view data shared by patients, and communicate with patients.

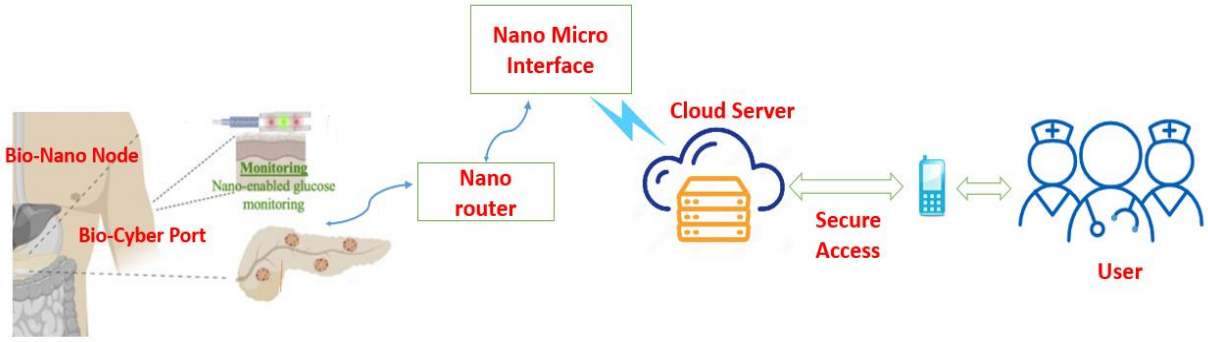

Fig.2 Internet of Bio-Nano Things for Diabetes Telemedicine System with Secured Access

Secure smart card generation for cloud server access to User

The User can be both the healthcare provider as well as the patient. The user 'U' sends a request to Cloud Server (CS) for registration and execute the following steps. Figure 3 explains the steps performed in the registration phase.

Step 1: The user Uj select its identity IUj, random number Rj and the password PUj

The user Uj completes the random identity of itself as

$$PU\ j = H\ (IUj \parallel Rj)$$

The PUj is sent to cloud server for the registration of the user Uj using secure communication link.

Step 2: The CS, after receiving PU j from user Uj, then compute a message

$$M\ i = H\ (PU\ j \parallel d),$$

Where H is the one-way hash function and d is the private key of the gateway.

Step 3: The CS generates a smart card SCj= {Mi, H (.), a, b}

and sends it to user Uj using secure communication link.

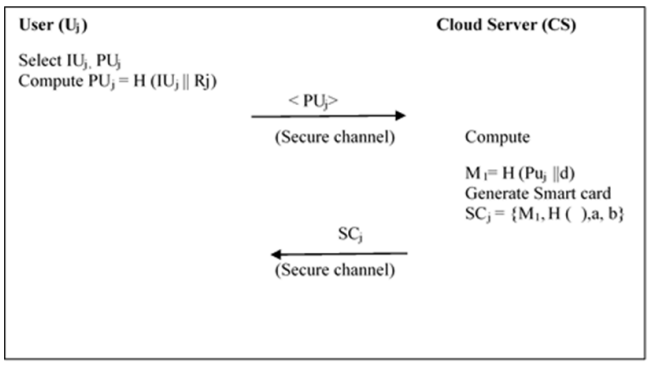

Fig.3 Smart Card Generation for User to Access Cloud Server

3.2 Login and Authentication phase:

The patient enters their ID and password, time-stamps it, and sends it to the server. The server authenticates the user using ID, password, timestamp and OTP. After the patient is successfully authenticated by the server, the patient also authenticates with the server, and upon successful mutual authentication, a session key is generated and validated for further communication. Data is shared using security protocols to ensure secure transmission and access to data. For ease of use, we do not use biometrics. Elderly patients and rural patients may not have fingerprint scanners. Upon successful login, the patient can view his or her report and share the data with the telemedicine service provider.

IV. Conclusion

Nowadays, the use of nano technology is gradually increasing in the field of healthcare and medicine. The technological advancements in the field of IoT are aiding in the increased use of this technology. The amalgamation of IoT and Bio-nano technology is known as IoBNT and it is making a significant impact on the way medicines are delivered and the way they work. Targeted Drug Delivery along with IoBNT is going to be used in the utmost quantities in the near future. In this paper, we have put forward a model of a monitoring of blood glucose levels using IoBNT. This process involves the use of IoBNT for collecting the blood glucose levels, analysing it andthen transmitting this data to outside of the body. All this procedure is made secure by adding an authentication protocol as well because the data that is being transmitted is sensitive. The authentication protocol contains two phases, namely the Registration phase and the Login and Authentication phase. With the implementation of this model the treatment for diabetes can be done in an efficient and convenient manner along with it being secure as well. In the future a model like this can even be used for maintaining the glucose levels whenever it is not in the advised range with the help of nanomedicines.

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