Internet of Things (IoT) Based Modern Healthcare Systems with Nano-Integrated Wearable Biosensor Devices

Rajeev Kumar Bhaskar[1], Balasubramaniam Kumaraswamy[2]

[1]*Assistant Professor, Department of CS & IT, Kalinga University, Raipur, India.*
[2]*Research Scholar, Department of CS & IT, Kalinga University, Raipur, India.*

An individual's well-being is a fundamental component of existence. The restricted technological capabilities at healthcare facilities often impose several constraints on people during medical care. The Internet of Things (IoT) is a highly captivating subject that offers many answers to these constraints. The IoT is employed in several healthcare practices, encompassing illness identification, therapy, and surveillance. Nano-integrated wearable gadgets are a component of the IoT designed to assist patients in receiving accurate medical treatment. Traditional wireless networks designed for human-centric applications encounter many challenges, such as rigorous latency requirements, limited computing capacity, and short lifespans of batteries. The emergence of 5G has introduced a range of sophisticated technologies that serve as the essential infrastructure for linking billions of devices in the future IoT, significantly transforming personal and corporate lives. This paper highlights the utilization of the IoT structure and its nano-integrated wearable gadgets and the forthcoming research obstacles associated with this field.

Keywords: Healthcare, Internet of Things, Wearable Biosensor Devices, Nanotechnology.

1. Introduction

As technology advances, there is a growing need for convenience and simplicity of use, leading to a rise in funding schemes. Numerous urban hospitals need to meet the specific medical demands of patients, resulting in patients having to seek treatment in hospitals located in other cities or overseas [4]. The Internet of Things (IoT) is gaining popularity in the healthcare industry as a promising feature to enhance existing technologies and reduce costs in all areas of healthcare [1]. Using the IoT in biomedical science is urgently required. It is necessary to deliver medical assistance to individuals by tracking, handling, identifying, and responding to data received from the system [2]. This approach significantly decreases the overall expenses associated with healthcare. IoT refers to a specific type of computer comprising networked sensors, microcontrollers, and transmitters [9]. Its purpose is to gather and transmit precise information to assist the user. It is utilized in many healthcare contexts, encompassing disease detection as a preventive measure, disease monitoring as a self-recovery pathway, and disease treatment as the curative remedy [6]. Wearable gadgets are a component of the IoT created to assist individuals in receiving accurate medical care [7]. IoT-enabled wearables are intelligent devices that can be attached to external devices, tattooed onto the skin, inserted in the body, or integrated into garments and clothes.

Biosensors are inexpensive, portable devices well-suited for rapidly detecting pathogens, proteins, and other analytes [3]. These devices were developed as a substitute for conventional testing methods, which are complex and require specialized expertise and time, leading to significant costs in their respective industries. Nano-integrated biosensors are a rapidly growing area of interdisciplinary research that has been hailed as a potential revolution in consumer, medical care, and commercial testing. The global biosensor industry currently has an annual value of 10 billion dollars. The high cost of biosensors poses a significant obstacle to their widespread adoption.

2. Biosensors in healthcare applications

While clinical science remains essential to modern medicine, the field is more reliant on technological advances in the current era. Current multidisciplinary study is conducted in several domains, such as physics, chemistry, biology, and technology.

A microfluidic biochip designed to count blood cells. The chip functions as a nanosensor supplied with a small amount of blood and utilizes microfluidic pathways to tally the blood cells electronically. When each cell traverses the electrode, electrical potentials are produced. The voltage amplitudes indicate the unique populations of several cell lines.

In a patient with severe illness, electrolytes such as sodium and potassium often fluctuate, necessitating vigilant monitoring. Implementing a method that can consistently track and provide these measurements on a screen would greatly benefit patients. Potentiometry is the method used to measure electrolytes.

Cardiovascular disease can be addressed with programmed bio-nanochips [8]. The prevalence of cardiovascular conditions is higher among the population. To identify early cardiovascular illness, it is necessary to employ more sophisticated, non-invasive equipment to identify early biochemical alterations in the body. The technology can identify many cardiac biomarkers in saliva, even before the onset of symptoms of illness.

This strategy can serve as a unique, sensitive, and cost-effective method for detecting many infectious pathogenic organisms. It can detect and identify dangerous biological weaponry. While there is variation among bacteria, they do have specific common characteristics in their genetic material.

A seizure is a sudden and temporary occurrence caused by abnormal and excessive or synchronized firing of neurons in the brain. Individuals who have epilepsy are more susceptible to experiencing sudden death. The pathogenesis of unanticipated death in epilepsy remains unclear to date.

Applying Microelectromechanical Sensors (MEMS) in Nephrology: MEMS, short for Microelectromechanical Systems, refers to manufacturing methods derived from the microelectronics sector [5]. MEMS is a broad term for small, modified gadgets derived from the microelectronics sector. The system can achieve high precision by incorporating both fluidic pathways and optical detectors with dimensions as small as a few nanometers.

3. Nano-integrated IoT architecture

To provide a comprehensive and flexible range of services, it is necessary to integrate various and different technologies that support healthcare services into a unified system. In an IoT-connected medical system, multiple systems can collaborate to provide healthcare services at a single location. The medical system provided by nanotechnology allows for precisely monitoring individual organs within a person's body. This medical system is employed as an intelligent medicine delivery network.

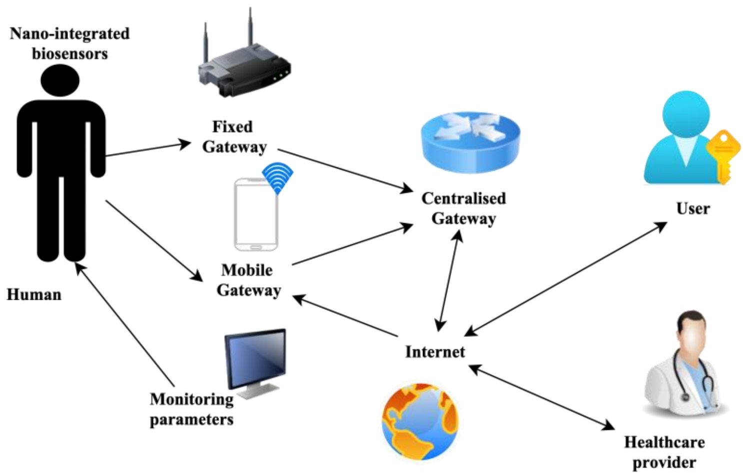

Figure 1. Architecture of the Nano-integrated IoT architecture

The nanodevices might be utilized inside the person's body or exterior surroundings. Figure 1 shows the architecture of the Nano-integrated IoT architecture. Multiple nanodevices are currently on the market that can be worn as clothing or tracked via cell phones. The structure of the Nano-integrated biosensors-based medical system consists of a collection of detectors and intelligent devices strategically placed on or inside the person's body. These devices then link to gateways that provide access to the internet. The categorization of IoT is based on the installation position of the nano-medical gadget within the body. Three prominent nanonetworks in IoT depend on that installation position.

- Off-body frameworks: Implemented from an individual's perspective, residence, motor vehicle, roadway, or medical facility. Off-body technologies can provide comprehensive surveillance services.
- On-body frameworks: Installed at a distance on the person's body. Showcase Wireless Body Area Networks and wearable devices enable the widespread personalization of health surveillance and facilitate the faster delivery of healthcare services to the patient's environment.

• Intra-body frameworks: These systems are placed in various locations within the person's body, connected or inserted in intelligent monitoring devices or interconnected nanodevices.

To establish a ubiquitous network, it is necessary to combine medical care at several levels:

• Connectivity stage: Nanotechnology-enabled systems utilize shared gateways to adapt to different settings. A Body Area Network uses a person's cell phone to identify unfavorable health circumstances. If a person operates a car connected to a cell phone, the data will be communicated through the vehicle's cell phone.
• Data stage: The information should be linked explicitly to the particular patient, independent of its arrangement, amount of detail, and context. Standardization is used to minimize the duplication and inconsistency of data. The data integrating methods are presented at this stage for subsequent analysis. The data might be stored on the patient's devices or the servers of the medical care provider.
• Service stage: It is possible to implement management services, which should be provided by different networking devices to establish more advanced services instead of creating new services from scratch.

4. Health Issues and Clinical Challenges

Intra-body biosensors are external entities that are introduced inside a person's body. There is a high probability that the person’s body have an unfavorable reaction. On-body and off-body gadgets can potentially have negative health impacts due to the radio waves utilized for communications [10].

4.1 Health issues

While nanotechnology shows promise in addressing healthcare challenges like cancer detection, periodic exams, and targeted drug delivery, the implantation of gadgets emitting radiation within the human body remains a concern for researchers and healthcare providers. Several health risks associated with nanotechnology include:

Each individual's body uniquely responds to the nanodevices placed within it. The constant concern is the potential harm nanodevices and their transmitted signals pose to soft and fragile tissues and functions. Extended contact with devices composed of materials such as silicone and silver can modify the functioning of various bodily organs and cells. Nanotechnology has the potential to gradually collect within organs, obstructing blood flow and impeding the delivery of oxygenation. There is a significant likelihood that the human body will perceive nanodevices as foreign objects and produce pathogenic cells to establish a robust immune response. Frequent bodily actions have the potential to impair the body's immune system. Several scientists argue that transforming the human body into a central hub for electrical gadgets to disrupt nature could have catastrophic consequences.

4.2 Clinical Challenges

While ongoing study on biosensors persists, numerous challenges hinder their practical use. Subcutaneous biosensors experience a disruption in their detecting ability due to an immune system reaction, which can lead to the formation of connective tissue across the sensor and the human body. The development of this tissue matrix could result in a device malfunction.

Ongoing efforts are being made to decrease this inflammation by utilizing a system that combats inflammation - Titania nanotubes, Chitosan hydrogel, and drug-releasing nanomaterials. They inhibit macrophage activity and, hence, diminish fibrotic alterations.

Another crucial consideration is the need for biosensors to have a reduced weight while ensuring that the materials used in biosensors do not elicit any immune response from the bodies. Gold nanomaterials are mainly utilized for their visual and electrical characteristics, among many other metal nanomaterials. Other examples include cadmium-based quantum dots with a wide absorbance range, magnetic nanomaterials at the nanoscale, ferromagnetic substances such as iron oxide, carbon nanostructures, and various biosensors utilizing DNA and enzymes. Upon exposure to their compounds, they can undergo modifications to exhibit multiple fluorescent proteins. Determining which material is more biocompatible with the bodies remains a subject of discussion due to the need for more available evidence.

A few pertinent inquiries occur about biosensors, one of which is:

- Could a biosensor be utilized for an extended period?
- Are these biosensors biodegradable, or do the research need to remove them from the bodies separately?

The responses could be more precise. The current study is currently focused on the development of biosensors using resorbable aluminum alloy. The acceptance of these biosensors by individuals of varying socioeconomic statuses remains to be determined. The research must undertake a large-scale trial to assess the reaction of various biosensors on humans.

5. Conclusion and discussions

Due to the progress in science and technology, medical care has become more accessible and affordable. Numerous urban hospitals need more medical resources. The implementation of biosensors has alleviated these issues. The IoT in medical care has recently gained significant attention. It is seen as a promising feature to enhance existing technologies and reduce costs in all areas of medical care. The IoT has become essential in today's world as it enables the monitoring, management, detection, and response to data received from systems. This leads to a significant reduction in healthcare expenses.

These wearables can interface with devices like cell phones for interaction and computation. While wearable gadgets are becoming integrated into everyday routines, they still face challenges such as strict latency requirements, limited computational power, and short battery lifespans. 5G, the fifth-generation wireless technological advance, is seen as the next advancement in mobile connectivity. It promises significant improvements in interaction, minimal latency, and increased throughput.

Due to the progress in nanotechnology, it is proposed that these biosensors will exhibit enhanced efficiency, sensitivity, and stability, resulting in better results. The particular characteristics of nanomaterials set them apart from bulk matter and allow for their application in several fields, such as medicine, agriculture, surroundings, robotics, and more. These biosensors, which utilize nanotechnology, are expected to significantly transform biomedicine and effectively contribute to developing prosthetics for those with disabilities.

The method is expensive and outside the financial means of every individual. Nano-integrated wearable sensors continue to encounter numerous obstacles and limits, such as creating sensors suitable for everyday use, addressing technological shortcomings, acquiring data, ensuring the confidentiality of information, ensuring long-term functionality, ensuring compatibility with the human body, and maintaining an uninterrupted power source.

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