Application of Medical Implants for Public Health Monitoring and Treatment

Nidhi Mishra[1], Ghorpade Bipin Shivaji[2]

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

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ABSTRACT

The World Health Organisation (WHO) reports that diabetes affects roughly 180 million people worldwide and that cardiovascular illnesses account for nearly 30% of all fatalities worldwide. Applications involving radio frequency (RF) or microwave technology are crucial to medical diagnosis and illness prevention. The most recent developments in the field of implantable medical devices (IMDs), such as biomedical telemetry, allow biosignals to be monitored remotely via wireless communication technology. Providing correct information to the external monitoring station is the primary function of the health maintenance monitoring scheme. Because wireless communication lessens the invasiveness of electromagnetic (EM) medical equipment, it is extremely helpful in improving patient comfort during treatment. The first swallowable pills with sensing capabilities and the introduction of pacemakers in the early 1960s both demonstrated the significance of implantable medical devices (IMDs), which enable disease monitoring and therapy. Using IMDs with wireless connection has allowed for the monitoring of both system performance and patient status. IMDs have been widely employed in healthcare systems to gather real-time signals from biosensors or preprocessed physiological bio-signals for early disease identification, improving treatment quality and promoting healthy living.

1. Introduction

The development of electronic systems for medical applications is a result of the exponential growth of the healthcare sector [3]. These days, a wide range of devices are utilised in many different applications, including cochlear implants, implantable medication pumps, cardiac pacemakers, brain pacemakers for Parkinson's disease, nerve signal recorders for use with robotic prostheses, and muscle stimulators. Maximising the benefits and comfort of remote patient monitoring without physical touch or rigid schedules can be achieved by enabling wireless connectivity with these devices. One of the newest engineering applications in healthcare systems is the wireless monitoring of patients' physiological indicators utilising Radio Frequency (RF) technology. [1].

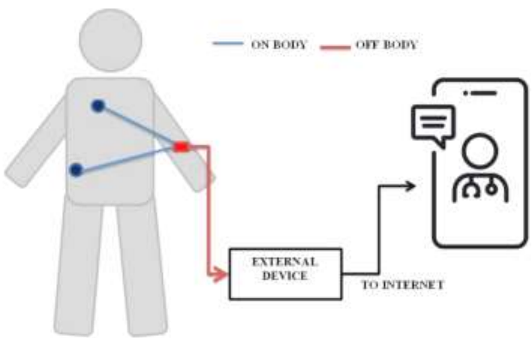

Figure 1. Body centric wireless communication

IMDs, or sensors, and body-centric monitoring systems are two categories for wireless monitoring systems. As seen in Figure 1, the body-centric wireless communication system is utilised to monitor a number of physiological data, including blood pressure, pulse rate, body temperature, sugar level, and oxygen level. Three categories of body-centric communication exist: in-body, on-body, and off-body [2]. An off-body system or device communicating with an on-body system or device is the initial kind of communication. The IMDs serve as the wireless communication link for wearable systems and on-body networks [11]. The third category includes wireless connectivity to sensor networks and medical implants [7]. Body-centric devices have sensors that can connect to external monitoring equipment or a receiver that is affixed to the body. In this instance, section 1 of the paper examines the introduction, and section 2 discusses the review of the IMD detection technique. Section 4 presents a discussion of the suggested IMD diagnostic model, while Section 5 wraps up the project. Section 3 describes how to use the CAD diagnostics system.

Performance Indication of Ad in Public Health Services

IMDs are susceptible to potentially major security vulnerabilities due to the use of wireless telemetry in them. With the addition of network connectivity and software programmability, IMDs are growing more sophisticated. Some devices have also included remote monitoring in order to enhance the quality of monitoring and make therapy modifications [15]. Since these devices were made with constrained power and storage capacities as well as small form factors, resource-intensive data and communication security was not given top consideration. Security is no longer an afterthought, though, as security attackers become increasingly sophisticated [5]. As mentioned above, there are particular security and privacy issues when IMDs use wireless communication. Attackers could jeopardise the sent data's confidentiality, which could result in patients' medical problems being disclosed against their will. Attackers may even transmit unauthorised requests to alter an IMD's parameters, thereby posing a hazard to human life [4]. The topic of computer and network security is well-established, offering security solutions for many data processing systems. However, implementing current security solutions for these devices is difficult due to the complexity of the human body, safety issues, and resource bottlenecks including low power, processing, and storage capacity. When a patient is surgically implanted into the body, a doctor enters their information into the ICD. To make sure the equipment is functioning correctly, he tests defibrillation. From now on, the doctor uses an external programmer or reader to perform wireless channel monitoring. The external device receives commands, reads data, modifies therapy settings, and may even retrieve the patient's medical history [14]. An attacker might breach patient privacy by using off-the-shelf devices, such as GNU software radio, to carry out illegal activities like eavesdropping. An attacker may use the intercepted packets to reverse engineer the device ID and other patient information [12], cause a deadly cardiac rhythm, replay commands that have been recorded, deplete the IMD battery's energy, alter or stop IMD therapies, masquerade, or launch a denial-of-service attack.

Application of Imd System

The physiological data in the implantable medical systems depicted in Figure 2 is measured by the sensors and subsequently sent via antenna to the external devices. Compared to standard transceiver units, the interface circuits are much smaller and comprise a transceiver, power supply unit, and supporting circuits. IMDs have two alternative communication modes: radio frequency (RF) link and inductive link. Inductive links are employed in close quarters communication. In order to exchange biological data, this technology calls for the antenna housed in the external device to go closer to the implantable devices. Additionally, there's a chance that during transmission, the Bit Error Rate (BER) will rise [6]. An improved method of long-range communication with low bit error rate (BER) is offered by RF link-based IMDs. Because of their intricate designs, RF-based implantable medical devices have emerged as a promising field for research. The transmission capability of this implant determines its efficiency, which focuses on the essential component antenna.

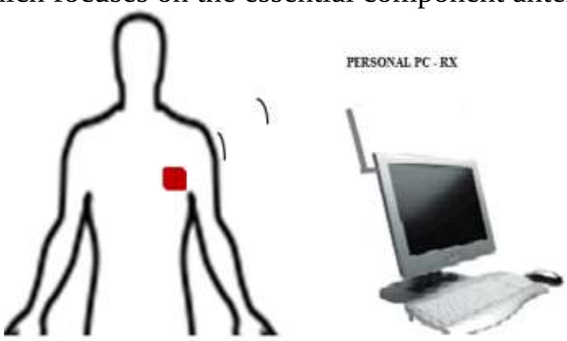

Figure 2. Implantable medical systems

The important requirements of this antenna should be:

- Compact/Small in size: The radiator should be small and lightweight because it will be inserted into the human body, allowing the bearer to feel at ease with the numerous sensors that are there.
- • Radiation Efficiency: Radiation efficiency is the measure of how well data is transferred between the sensor and an external monitoring device. When combined with other circuitry, the radiator should integrate with other additional circuits and should be properly matched.
- • Biocompatible: Because skin, muscle, and tissue are lossy and have high permittivity values, the complexity of the surrounding medium increases when the antenna is positioned inside the biological tissue layer. This biological medium's mass density (ρ), electrical conductivity (σ), and relative permittivity (εr) vary depending on frequency and temperature. Additionally, a drop in frequency causes a rise in relative permittivity, which lowers conductivity [13].

This has made the design of efficient and compact implantable antenna as a challenging task.

Proposed Imd For Public Health

Implantable Medical Devices (IMDs) are medical devices that are surgically implanted into the human body to carry out therapeutic functions such as medical condition detection, diagnosis, monitoring, treatment, and communication [8]. Due to the flexibility these devices offer patients and healthcare providers both in terms of continuous care, treatment automation, and financial savings by avoiding hospital stays they have gradually grown to be an essential component of the global healthcare industry in recent years. Figure 1.2 displays images of many IMDs that are now in demand.

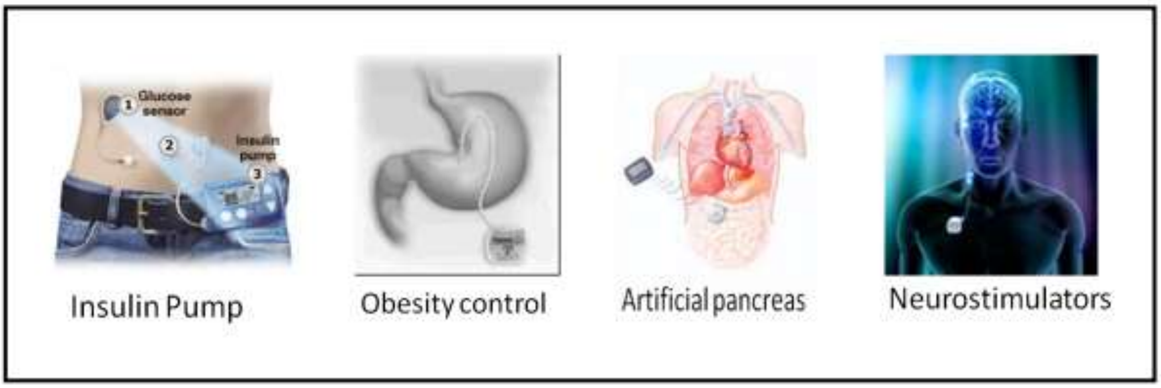

Figure 3. A range of IMDs

These devices in the current genre perform following tasks [23]:

- Sense: IMDs have the ability to gather a range of physiological data from the body, which is then utilised to diagnose a patient's illness.
- Actuate: Depending on the instruction received from an external device or the sensed data, IMDs might cause a therapeutic effect in the body.
- Information processing: IMDs have the ability to process information that has been gathered or shared.
- Communication: IMDs can communicate with external devices as well as with other IMDs in the IBN.

IMDs can be implanted either permanently or temporarily, depending on the condition. IMDs that are permanently implanted need to periodically interface with external devices in order to retrieve stored physiological and parametric data as well as for diagnostics, troubleshooting, and reprogramming. These external devices are referred to as programmers or readers. IMDs that are temporarily implanted can work independently or in concert with one another via an external controller. Because of their unusual positioning inside the body, the majority of IMDs are battery-powered, making recharging a distant possibility. Some IMDs, such as biosensors and cochlear implants, get power by inductive coupling [9]. Through inductive coupling, a patch affixed to a person's skin provides electricity to implanted biosensors. The patch is also in charge of sending data to an external base station, which then sends it to the doctor's PC, a distant station[9]. Multi-component IMDs can be peer-to-peer or hierarchically organised in a master-slave hierarchy. A multicomponent IMD's components can communicate with one another broadcast, multicast, end-to-end, or point-to-point.

Implantable Medical Device Communication

In response to an external device known as a reader/programmer, or in the event of an emergency, these devices use radiofrequency (RF)-based wireless telemetry to transmit physiometric data related to the patient and his medical state. The following goals are served by the wireless connection:

1. It gives the patient the freedom to move about while being questioned by an outside device.
2. It protects the patient against illnesses that could result from using wires.
3. It enables the external devices to query IMD status parameters and remotely monitor critical parameters for ongoing, independent care.
4. It permits external devices to access IMD for configuration, software upgrades, programme modifications, calibration, and maintenance purposes.
5. It additionally permits the in-body transfer of sensor data between two or more IMDs in order to create a loop of stimulation and actuation or for control purposes.
6. It enables medical professionals to access the IMD in an emergency so they can give the patient rapid relief.

IMD models from the past communicated in the 175 KHz band. The Medical Implant Communication Service (MICS) band, which has a frequency range of 401MHz to 406MHz, has been set aside by the Federal Communications Commission (FCC) of the United States specifically for medical devices [10]. It permits radio communication in both directions between IMDs or between IMDs and other medical equipment. Ten 300 KHz channels make up the band; two communication devices can use any one of the channels. IMDs usually involve two forms of communication: extracorporeal and in-body.

2. Conclusion and future scope

Since the initial X-ray medical trials at the end of the nineteenth century, electromagnetic has been used more and more in medicine. The most recent developments in the field of implantable medical devices (IMDs), such as biomedical telemetry, allow wireless communication technology to be used for remote biosignal monitoring. Providing correct information to the external monitoring station is the primary function of the health maintenance monitoring scheme. IMDs have been widely employed in healthcare systems to gather physiological bio-data that have been pre-processed or real-time signals from biosensors for early disease identification, which improves treatment quality and promotes healthy living. These IMDs have the capacity to communicate over an RF link or an inductive link with a peripheral observing device.

Reference

[1] Dhalluin, T., S. Fakhiri, J. Herbert, G. Bouzillé, M. Cuggia, and L. Guillon. "Automated surveillance of orthopaedic implants: a systematic review." *European Journal of Public Health* 30, no. Supplement_5 (2020): ckaa166-026.

[2] Krogstad, Emily A., Elizabeth T. Montgomery, Millicent Atujuna, Alexandra M. Minnis, Shannon O'Rourke, Khatija Ahmed, Linda-Gail Bekker, and Ariane van der Straten. "Design of an implant for long-acting HIV pre-exposure prophylaxis: input from South African health care providers." *AIDS patient care and STDs* 33, no. 4 (2019): 157-166.

[3] S. Neelima, Manoj Govindaraj, Dr.K. Subramani, Ahmed ALkhayyat, & Dr. Chippy Mohan. (2024). Factors Influencing Data Utilization and Performance of Health Management Information Systems: A Case Study. Indian Journal of Information Sources and Services, 14(2), 146–152. https://doi.org/10.51983/ijiss-2024.14.2.21

[4] Wang, Yi, Geetha Jayan, Dinesh Patwardhan, and K. Scott Phillips. "Antimicrobial and anti-biofilm medical devices: public health and regulatory science challenges." *Antimicrobial coatings and modifications on medical devices* (2017): 37-65.

[5] Mehak, S., Himanshi., & Sanju, S. (2024). Privacy-enhancing Blockchain Solutions for the Healthcare Sector: Efficient Message Sharing and Robust Big Data Protection. Journal of Internet Services and Information Security,

14(2), 85-97.

[6] Hemapriya, D., Pavithra Viswanath, V. M. Mithra, S. Nagalakshmi, and G. Umarani. "Wearable medical devices—Design challenges and issues." In *2017 International conference on innovations in green energy and healthcare technologies (IGEHT)*, pp. 1-6. IEEE, 2017.

[7] Malathi, K., Shruthi, S.N., Madhumitha, N., Sreelakshmi, S., Sathya, U., & Sangeetha, P.M. (2024). Medical Data Integration and Interoperability through Remote Monitoring of Healthcare Devices. Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications (JoWUA), 15(2), 60-72. https://doi.org/10.58346/JOWUA.2024.I2.005

[8] Molloy, Antonia, Kirsten Beaumont, Ali Alyami, Mahmut Kirimi, Daniel Hoare, Nosrat Mirzai, Hadi Heidari, Srinjoy Mitra, Steve L. Neale, and John R. Mercer. "Challenges to the development of the next generation of self-reporting cardiovascular implantable medical devices." *IEEE Reviews in Biomedical Engineering* 15 (2021): 260-272.

[9] Bussooa, Anubhav, Steven Neale, and John R. Mercer. "Future of smart cardiovascular implants." *Sensors* 18, no. 7 (2018): 2008.

[10] Gaobotse, Goabaone, Elliot Mbunge, John Batani, and Benhildah Muchemwa. "The future of smart implants towards personalized and pervasive healthcare in Sub-Saharan Africa: Opportunities, barriers and policy recommendations." *Sensors International* 3 (2022): 100173.

[11] Allin Geo A.V., et.al Performance comparison for DSR and AODV, World Applied Sciences Journal, V-29, I-14, PP:36-41, 2014.

[12] Javan-Khoshkholgh, Amir, and Aydin Farajidavar. "Simultaneous wireless power and data transfer: Methods to design robust medical implants for gastrointestinal tract." *IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology* 6, no. 1 (2021): 3-15.

[13] Yu, Aoxi, Mingye Zhu, Congkai Chen, Yang Li, Haixia Cui, Shujuan Liu, and Qiang Zhao. "Implantable flexible sensors for health monitoring." *Advanced Healthcare Materials* 13, no. 2 (2024): 2302460.

[14] Bobir, A.O., Askariy, M., Otabek, Y.Y., Nodir, R.K., Rakhima, A., Zukhra, Z.Y., Sherzod, A.A. (2024). Utilizing Deep Learning and the Internet of Things to Monitor the Health of Aquatic Ecosystems to Conserve Biodiversity. Natural and Engineering Sciences, 9(1), 72-83.

[15] Pons-Faudoa, Fernanda P., Andrea Ballerini, Jason Sakamoto, and Alessandro Grattoni. "Advanced implantable drug delivery technologies: transforming the clinical landscape of therapeutics for chronic diseases." *Biomedical microdevices* 21 (2019): 1-22.