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HARNESSING VISIBLE LIGHT COMMUNICATION NETWORKS TO SUPPORT INTELLIGENT HEALTHCARE SOLUTIONS

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***Abstract*- High-performance wireless networks are anticipated to be essential to smart healthcare operations in the future. The peculiar circumstances of hospital settings, however, present a challenge to researchers since they make it impossible to implement conventional radio-frequency wireless communication networks, particularly when it comes to health issues and electromagnetic compatibility requirements. We suggest utilizing Visible Light Communication (VLC) as an alternative wireless technology to overcome these issues and improve the standard of healthcare. We have created a VLC network modeling environment as well as a real-world testbed in response to the increasing interest in VLC among researchers. The purpose of these platforms is to facilitate the development of this quickly changing technology. We use them to apply and evaluate media access control (MAC) methods with VLC in both device-to-device and device-to-infrastructure networks, with a focus on healthcare-specific scenarios.**

***Keywords*- sensing technologies), Electromagnetic Interference Restrictions, Electrocardiograms, Portability.**

1. INTRODUCTION

As smart healthcare operations and medical sensing technologies continue to advance, there is a growing need for wireless communication in hospitals. For instance, the need for real-time patient monitoring is growing rapidly in importance because it allows medical professionals to identify and act quickly when a patient's status changes. Furthermore, areas including drug distribution, precision surgery, and support in high-risk situations, like the COVID epidemic, are seeing an increase in interest in robot-assisted wireless networks. In the future, medical holography has a lot of potential for use in simulations, medical education, surgical planning, and guidance. Strong networking capabilities will be necessary for all of these future healthcare applications in order to accommodate the expanding number of medical devices that are connected and the rising demand for high data rates. As a result, it is crucial to make sure hospital networks are built to withstand this quick growth and provide the best possible treatment. The following reasons make building wireless networking systems in hospital settings and future smart healthcare applications extremely difficult:

Electromagnetic Interference Restrictions: In order to successfully manage the electromagnetic interference (EMI) that wireless communication equipment produce, hospitals are required to comply with electromagnetic compatibility (EMC) standards. This is particularly important because healthcare facilities rely on sensitive medical equipment—such as magnetic resonance imaging (MRI) machines, electrocardiograms (ECG), and electroencephalograms (EEG)—which can be significantly affected by EMI.Increasing Demands on Network Infrastructure Beyond EMC challenges, hospitals face the growing need for high-capacity, low-latency wireless networks. Real-time video conferencing is a prime example of a bandwidth-intensive application that enables doctors, specialists, and surgeons to collaborate seamlessly, regardless of location. This capability is especially vital for rural communities, where patients often depend on telemedicine for access to medical consultations and care.

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Additionally, the use of portable imaging devices—such as wireless ultrasound machines—has become more prevalent, enhancing both the efficiency and comfort of routine medical procedures. These technologies generate large volumes of data, which frequently need to be transmitted wirelessly, placing even greater demands on hospital network infrastructure. Smart Healthcare and IoT Integration

The ongoing shift toward smart healthcare is further increasing network pressure. Hospitals are increasingly deploying internet-connected medical devices and data-driven applications to enhance diagnosis, treatment, and overall patient care. As a result, next-generation hospital networks must be designed to support a high density of wireless and IoT devices.

The challenges of integrating IoT technologies are closely aligned with those of building smart healthcare environments—both require robust, scalable, and secure wireless networks capable of handling large volumes of real-time data.

Wireless Network Security Issues: The security of wireless networks creates significant issues for hospitals as well. Large amounts of private patient data, including Protected Health Information (PHI), which is subject to government laws like the Health Insurance Portability and Accountability Act (HIPAA), are transmitted across these networks. To protect patient privacy and adhere to legal and ethical requirements, it is essential to ensure the confidentiality, integrity, and availability of this data. For these networks, the Portability and Accountability Act (HIPAA) must be followed. Healthcare providers are required to protect information from any potential security threats and to maintain the confidentiality of all PHI. Furthermore, the transmission of exceedingly private patient data, like genetic information and lifestyle traits, may be crucial for future precision medical applications.

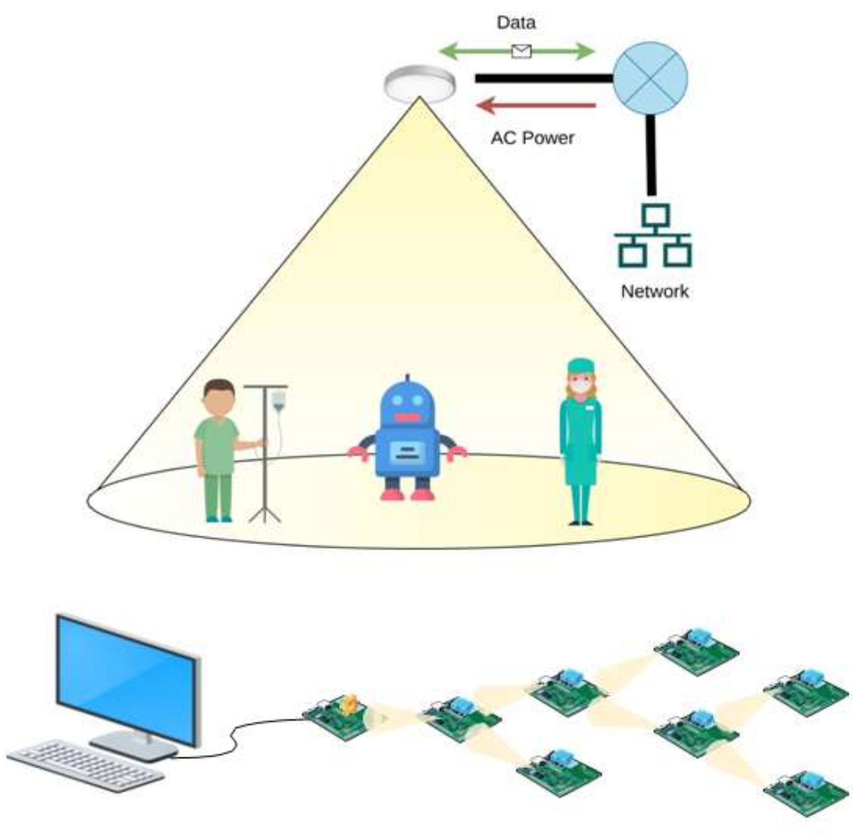

Figure 1.1. D2I network (top), D2D network (bottom)

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2. RELATED WORK

1. VLC in Healthcare Environments

Visible Light Communication (VLC) is increasingly being recognized as a viable alternative or supplement to traditional radio frequency (RF) communications in medical settings. This is largely due to its inherent advantages such as immunity to electromagnetic interference, enhanced security, and greater bandwidth capacity.

- Hospital Communication Systems: Previous research, including that by Ayyash et al. (2016) and Komine & Nakagawa (2004), has shown that VLC enables reliable, high-speed data transmission without causing electromagnetic disturbances, making it especially valuable in RF-sensitive areas like MRI rooms.
- Sensor-Based Data Transmission: VLC is also being considered for transmitting information from wearable or implantable medical devices to centralized health monitoring platforms, enabling real-time data collection without interfering with other medical equipment.

2. Smart Healthcare Monitoring with VLC

Integrating VLC with artificial intelligence and machine learning technologies opens new possibilities for intelligent healthcare monitoring systems.

- Smart Healthcare Spaces: VLC-based smart lighting solutions have been utilized to monitor patient activity, vital signs, and environmental parameters in healthcare facilities. Systems like *LiFiCare* demonstrate how VLC and machine learning can be used together for early detection of health anomalies.
- AI and Edge Computing Integration: Research by Elgala et al. (2011) and Rajagopal et al. (2012) highlights how VLC networks can facilitate fast, localized data processing through edge computing, making them suitable for AI-driven diagnostic support in wearable health devices.

3. VLC for Indoor Positioning in Medical Facilities

Accurate indoor localization is vital for optimizing hospital operations, patient tracking, and emergency response, and VLC has proven to be a promising solution in this regard.

- Precision Tracking Systems: VLC-based positioning technologies offer highly accurate location tracking, often within a few centimeters. For instance, a system developed by Shin et al. (2017) combines VLC and RF technologies to monitor the movement of patients and medical staff inside healthcare environments.

4. Enhancing Efficiency and Reducing Latency

Low-latency and energy-efficient communication are essential in healthcare, particularly for devices that are portable or battery-powered.

- Optimizing VLC Network Resources: Techniques such as dynamic bandwidth allocation, beam steering, and efficient scheduling have been proposed to meet latency and reliability requirements. Noshad et al. (2014), for example, examined VLC modulation strategies designed to meet the specific performance demands of healthcare applications.

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5. Ensuring Security and Privacy

Due to its confined transmission range and line-of-sight nature, VLC inherently offers a more secure communication channel. However, additional measures are necessary to fully safeguard sensitive health data.

Optical Security Techniques: Researchers have proposed various encryption and physical layer security techniques to further enhance the protection of patient data over VLC networks, ensuring compliance with strict privacy standards in healthcare.

3. RESULT &FUTURE OPPORTUNITIES

The simulation results demonstrate the network's resiliency and efficacy when using the suggested priority-aware TDMA protocol. Figure 3.2 shows how the average latency of a network with the conventional TDMA protocol steadily rises as the number of low-priority (Type III) users rises. This behavior is expected, as the standard protocol allocates time slots equally, without considering the priority of the transmitted data. In contrast, presents the latency trends observed in the network utilizing the **modified TDMA protocol**. Here, the average latency is distinctly influenced by the **access category** of the data. Notably, even as the network becomes saturated with low-priority traffic, users transmitting **Type I and Type II data** maintain a relatively consistent and low average latency. This confirms the protocol's ability to uphold **Quality of Service (QoS)** by prioritizing high and medium-priority transmissions over low-priority ones.

Mobility Handling: Maintaining uninterrupted connectivity as users move around remains a significant challenge. Hybrid Communication Systems: Combining VLC with RF can harness the strengths of both to build robust systems. Managing Interference: In dense hospital environments, minimizing optical signal interference is criticality and AI Synergy: Deeper integration of VLC with AI and IoT infrastructures can pave the way for fully automated, intelligent healthcare ecosystems.

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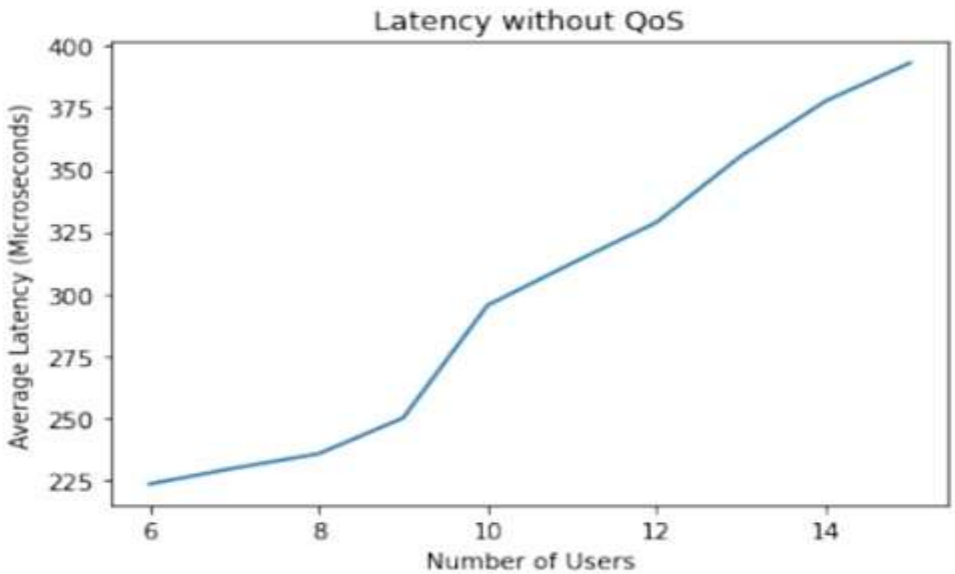
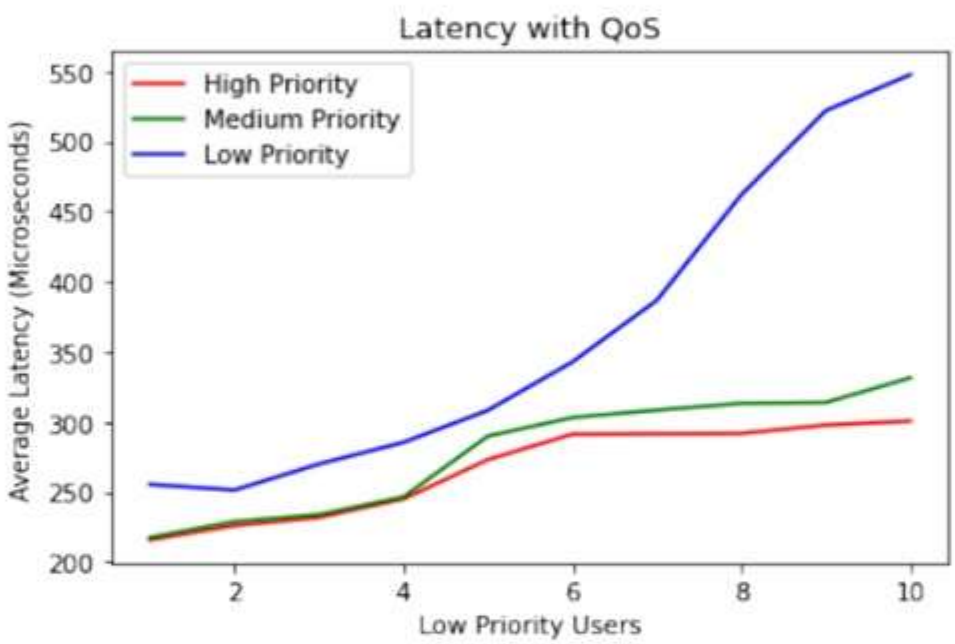


Average user latency with no QoS



Average user latency with QoS

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I. CONCLUSION

After reading various studies it can be concluded that there is no doubt that fitness scaling plays an essential role in the genetic algorithm optimization. GA's are well suited for optimization tasks even when the fitness or scaling functions which they map are fairly complicated. The comparison of various types of fitness scaling by applying complex function will be done and it will lead to enhancement in the searching which is more optimized than simple scaling functions. Also, the best suitable in given condition and parameters can be find out.

The major motive of this paper is to apply same complex function on different kind of scaling and try to get best minimum and maximum output values which are more optimized. As a result both diversity and stability of the population is maintained. By this we will also try to reduce the limitation of simple genetic algorithm which is premature convergence.

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