

Eco-Friendly High-Speed Internet for Mountains Regions Using Li-Fi

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Abstract – Providing communication and internet access in mountainous regions is extremely challenging and costly. In this research paper, we propose the use of Li-Fi (Light Fidelity) technology to deliver high-speed internet to remote mountain villages at a lower cost. This system will function like a web spread across the mountains, helping to eliminate internet connectivity issues. Li-Fi is a technology capable of transmitting data over long distances using light. Li-Fi offers better bandwidth and much faster data transmission speeds compared to traditional wireless technologies. Moreover, this approach is environmentally friendly, causing no harm to nature, and the installation cost is significantly lower than traditional methods that require setting up communication towers.

Keywords: - Li-Fi (light fidelity), long distances using ultraviolet light, larger bandwidth for high-speed data transmission, low cost

1. INTRODUCTION In this introduction section, we will discuss the overview and fundamental principles of Li-Fi technology, as well as its potential to connect remote mountain villages to the internet. We will also highlight how Li-Fi can serve as a better alternative to traditional communication towers for internet transmission. Unlike conventional methods, Li-Fi can be utilized without causing harm to natural resources or living organisms, making it an eco-friendly and efficient solution [1][2][3][4].

1.1 Li-Fi and how it works?

Li-Fi (Light Fidelity) is an innovative wireless communication technology that utilizes light as a medium for communication (transmitting or receiving

data from sources like LEDs. Solar/LDR is used for receiving the data, working as a receiver. An electric bulb can be turned on or off, generating a binary code-like sequence where 'on' means 1 and 'off' means 0, which is exactly what is needed for machines to transfer data. This on-and-off mechanism is used for data transfer in Li-Fi. It is so fast that it cannot normally be seen, and since the speed of light is also very fast, the data transfer rate becomes extremely high as well [5][6][7].

Lifi offers a promising solution for internet connectivity in locations where traditional radio-based systems, such as Wi-Fi and mobile networks, face limitations. In hilly villages, where rugged terrain and remote locations often make it difficult and expensive to install telecommunication towers or lay fiber optic cables, Li-Fi provides a practical and efficient alternative [8].

By harnessing existing lighting infrastructure, Li-Fi can deliver high-speed internet to homes, schools, hospitals, and government offices simply through the light bulbs already in use. This approach not only reduces the need for extensive new infrastructure but also ensures that connectivity can reach places where radio signals are weak or blocked by mountains. Real-world deployments in Indian hill regions and villages have demonstrated that Li-Fi can deliver stable, gigabit-speed internet connections even in challenging environments, bridging the digital divide and supporting vital services like education, healthcare, and local administration [9][10].

Features

Li-Fi's main advantages include its exceptional speed, enhanced performance, and minimal electromagnetic interference, making it suitable for sensitive

environments and areas with congested radio spectrum. As the technology matures and integrates with next-generation networks like 5G and 6G, Li-Fi is poised to play a key role in bringing reliable, high-quality communication to hilly and rural villages, empowering communities, and enabling access to the digital world.

2. Literature review

Digital Divide in Hilly and Rural Regions

Internet access in hilly and remote regions is constrained by rugged terrain, high installation costs, and limited infrastructure support. Sharma and Verma (2022) emphasize that traditional ICT systems, such as towers and fiber cables, often cause environmental disruption in mountainous areas, while Yadav et al. (2020) highlight how poor connectivity deepens socio-economic inequality in rural India. These studies underscore the need for low-cost and eco-friendly alternatives [11][12].

Research Gap

While extensive work exists on Li-Fi's performance in urban smart city contexts, few studies directly focus on its application in hilly and rural terrains. Most research addresses technical specifications, while field-based, eco-friendly models for mountainous regions remain underexplored. This gap highlights the need for research that combines technical feasibility, environmental sustainability, and rural deployment models, as presented in this study.

Author(s)	Year	Focus of Study	Key Findings	Relevance to Hilly Areas
Sharma & Verma	2022	Eco-friendly ICT in rural hilly regions	Highlighted environmental risks of traditional ICT infrastructure	Shows need for eco-friendly LiFi deployment
Yadav et al.	2020	Green communication in remote India	Identified digital divide and socio-economic gap in rural areas	Provides justification for rural LiFi networks
Haas	2018	LiFi as a paradigm-shifting 5G technology	Demonstrated gigabit capacity and secure, high-speed transmission	Proves LiFi can deliver required speeds in remote terrains
		Survey of	Discussed	Helps

Pathak et al.	2015	VLC communication systems	networking, sensing, and VLC challenges	anticipate LiFi limitations in mountainous areas
Rajagopal et al.	2012	IEEE 802.15.7 VLC standard	Defined modulation and performance parameters	Provides technical basis for LiFi design in rural setups
Alsabah et al.	2021	LiFi as "light as a service"	Showed integration with lighting infrastructure	Useful for solar/LED-based LiFi in hilly villages
Kazemi & Safari	2022	Energy-efficient rural broadband via LiFi	Proposed cost-effective green communication system	Directly applicable to low-cost hilly deployments
Hemani et al.	2023	Deployment challenges of LiFi in remote areas	Identified issues like fog and line-of-sight dependency	Matches real-world problems of mountain environments
Wangchuk (Case Study)	2020	LiFi laser experiment in Ladakh	Proved resilience of LiFi in extreme winters and hills	Practical demonstration for hilly villages

3. Methodology

In places where towers or other systems for the internet cannot be installed, such as mountain or hilly areas where traditional towers are difficult to reach, heavy optical cables, or where high power requirements cannot be met, we can use LIFI.

How can we use LIFI in the mountains so that we can provide easy internet access from one mountain to villages and towns on the other mountain?

We make a model to demonstrate the Li-Fi system, as shown in Fig. 1.

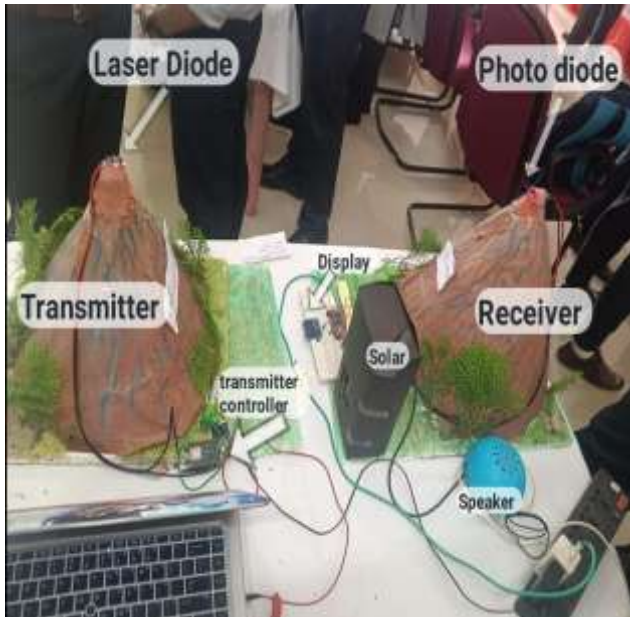


Fig 1: Experiment of sending data form of text, photo and sound using lifi

Fig 1 is a prototype of making this model, showing how Li-Fi transfers data from one mountain to another. It has two mounts, one used as a transmitter and the other as a receiver. On the transmitter mount, we tightly fixed a laser diode on top of which we can change the angle. We connected the laser diode to an ESP8266 module, which we programmed, which will convert the data into binary code (1=ON, 0=OFF) and send it to the laser diode. Here, we can code for TDM (Time Division Multiplexing) or any other networking architectures so that missing data can be detected and the data can be sent again.

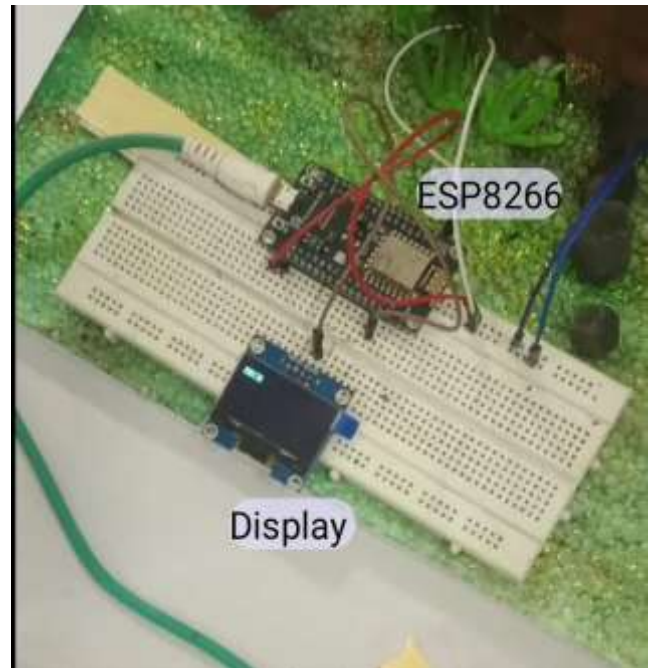


Figure 2: ESP8266 with Display

Receiver: We have installed a receiver on the mountain. The photodiode will sense the incoming laser signal and send that signal to the ESP8266 module. The ESP8266 will decode the binary signal and send it to the OLED display, which will give us the actual data. We have designed a one-way communication system here, in which data can be sent only one way. Similarly, we can transfer data in two ways. Figure 2 shows a diagram of how, using two-way communication, we can create a mesh network, which can be a good way to send low-cost, high-speed data for the entire mountainous area.

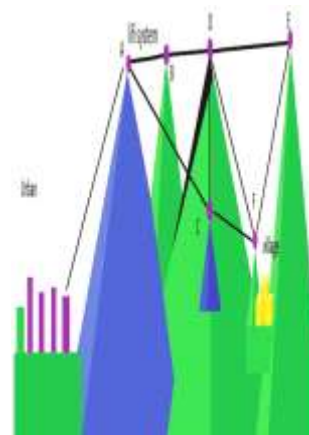


Fig 2 : Diagram of mesh connection of Li-Fi

Li-fi System: In this, we will use a laser light whose range is up to a kilometer and we will use laser diode to transmit data as well as photodiode sensor or solar panel

for receiver in a single system in which data is received from the next system, many such systems will be installed at a proper distance in the mountain hills so that one Li-Fi system is in the range of the other Li-Fi system so that the sending and receiving of data can be done easily, in this way a mesh network will be created in a mountain so that the transfer of data can be done easily in every mountain.

The urban area is the main source of internet (such as fiber optic, broadband, or a data center). Internet from the urban area is first sent to LiFi system A, located on the hill. This system receives the internet and then transmits it to other hills. From here, the connection goes to points B and D.

Intermediate Relays (B, C, D, E)

Each hill has a LiFi system installed, acting as both a transmitter and a receiver. For example: $A \rightarrow B \rightarrow D \rightarrow E$ is a direct path. $A \rightarrow C \rightarrow D$ is an alternate path. These are all connected together in a mesh network, meaning if one link goes down due to a natural disaster, data can be transferred via another route. Final Node ($F \rightarrow$ Village) The final Li-Fi system (F) is installed closest to the village. From here, the internet is either brought to the village via a LAN cable or provided to the villagers by creating a WiFi hotspot.

The overall process is:

Internet travels from the city (Urban) $\rightarrow$ Li-Fi system A on the mountain top $\rightarrow$ then through B, C, D, E, F $\rightarrow$ to the village. All LiFi systems are interconnected and share/transfer the network. This approach is designed to deliver internet at a low cost, high speed, and without harming the environment.

4. Conclusion :

This research shows that Li-Fi could be a good and lasting solution for providing internet in hilly and mountainous areas. Experiments using a laser diode and photodiode setup successfully sent data, proving that Li-Fi can work in real situations. A network of Li-Fi nodes, acting as helpers, makes the system more reliable by keeping the connection going and offering different paths for data to travel. Compared to usual methods like cell towers or fiber cables, Li-Fi has several benefits: it's cheaper to set up, offers faster internet speeds, has less effect on the environment, and can use clean energy sources. But there are still some issues to fix, like making sure the signal stays strong in bad weather and increasing how far the signal can reach. Future work should look into combining Li-Fi with radio frequency systems, improving the way data is sent, and testing the

system in real mountainous areas. In short, Li-Fi has the chance to change how people connect to the internet in remote mountainous areas.

It could offer an affordable, eco-friendly, and fast internet option, helping improve education, healthcare, and economic opportunities in places that are not well connected.

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